Particle Physics at the dawn of LHC13 from the experimental side

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What’s the dawn for the experimentalist?

The hardest hour in the night shift: the point where you start to collapse
where your best wish is to be in your bed or any bed or just to have the
possibility to sleep putting your head in your arms and just sleeping sleeping.
And this is often just the time where the major catastrophy in the shift happens;
And you are there with a reduced crew of people, in the same state you are
and having not to panic but solve the problem…s…

BREF
…..The worst hour…

Similarly the “dawn” in the opening of a new period as so-called “LHC 13 TeV era”…
Is the time where:
The machine is in the commissioning of this new regime => trying to overcome the issues which appear at this stage;
The time where the experiments are experiencing all the upgrades and repairs.
⇒ Cautious and tedious calibrations, comparing MC with real data and trying to understan all the discrepancies….

BREF
… the worst, toughest and tedious period….before getting everything working as expected
And hopefully later on…much later on???
The miracle of the discovery…and/or important breakthroughs

Outline

Particle Physics at the dawn of LHC13 era from an experimentalist viewpoint:

- The machine: LHC setting up & early performances **at 13 TeV** i.e. in 2015 & perspectives plus remaining challenges
- The instruments: 3 **upgraded** experiments for exploring the Unknown
  - ATLAS:
  - CMS
  - LHCb
- The **Physics objectives**, where we stand and the perspectives
- What IF Discovery(ies) and/or NOTHING at 13-14 TeV ???

  => **NEW MACHINES**
- Why **NEW PHYSICS implies NEW HIGH TECH** developments

N.B. The audience is assumed to know about the main results from LHC 2010-2012

The dawn of LHC13 era for the LHC

LHC Performance in Run 2 and Be

Slide from Mike Lamont for the LHC team (LP

LHC - 2015

- Target energy: 6.5 TeV
  - looking good after a major effort
- Bunch spacing: 25 ns
  - strongly favored by experiments – pile-up
- Beta* in ATLAS and CMS: 80 to 40 cm

$$\mathcal{L} \propto \frac{1}{\beta^*}$$

Energy

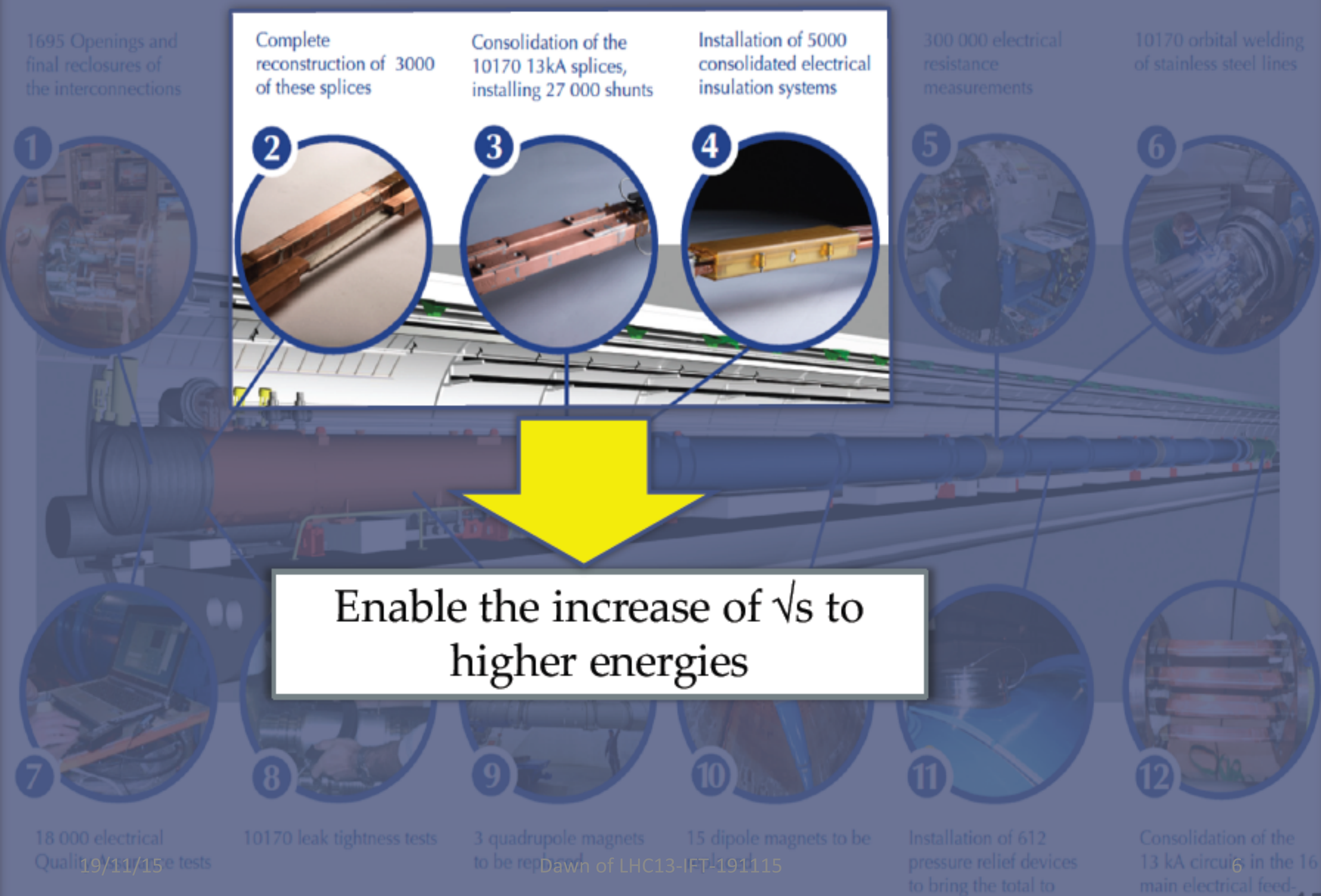
- Lower quench margins
- Lower tolerance to beam loss
- Hardware closer to maximum (beam dumps, power converters etc.)

25 ns

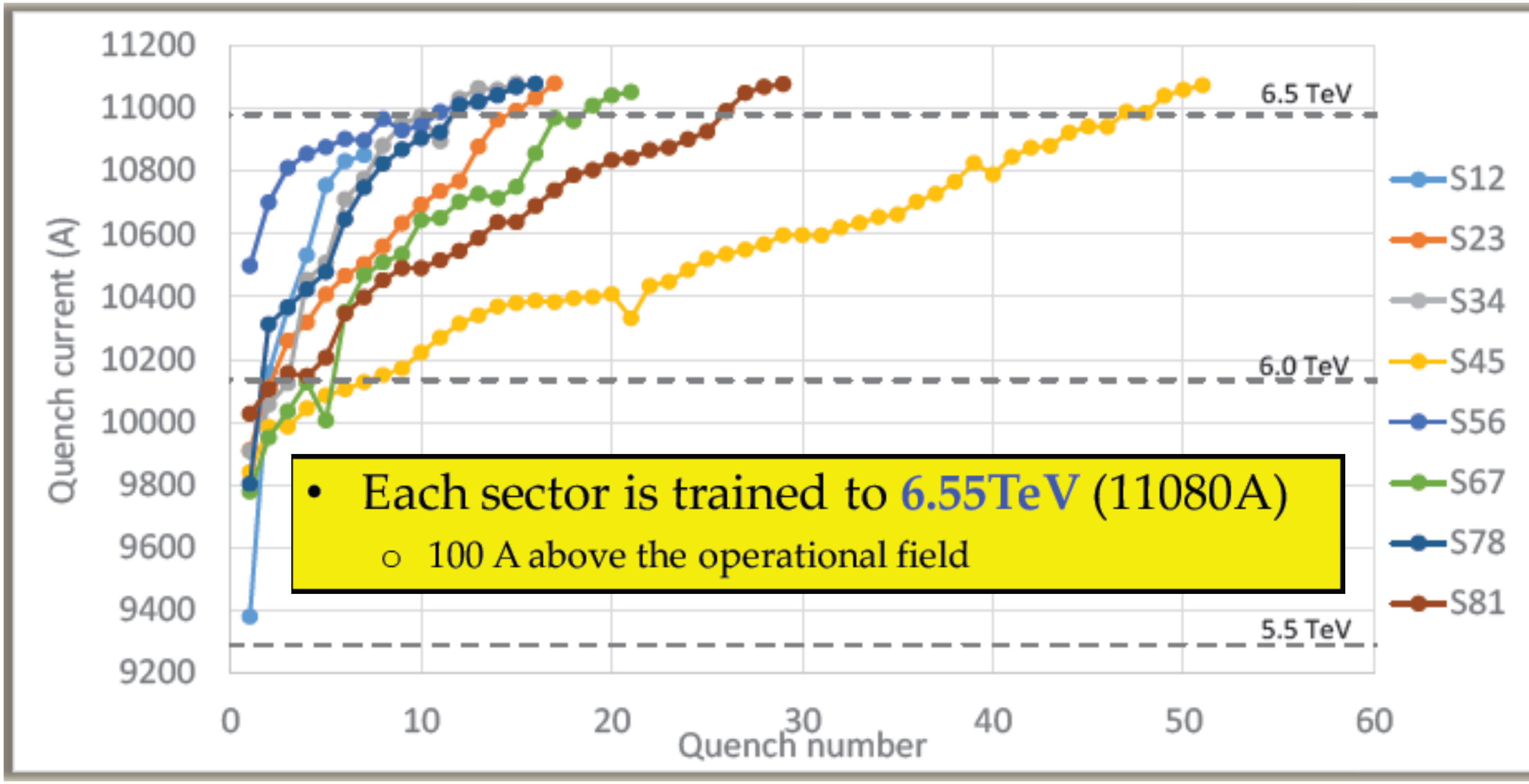
- Electron-cloud
- UFOs
- More long range collisions
- Larger crossing angle, higher beta*
- Higher total beam current
- Higher intensity per injection

(Slide from Mike Lamont's talk at Lepton-Photon 2015)

The main 2013-14 LHC consolidations



Key elements:1232 Dipoles to be trained



Dipoles bend the beam around the 27 km. ring. The momentum of the beam is very high and these magnets have to produce a very strong magnetic field (8 Tesla)

To reach the high B-field required, high currents are needed. To avoid excessive resistive losses, the magnets are superconducting.

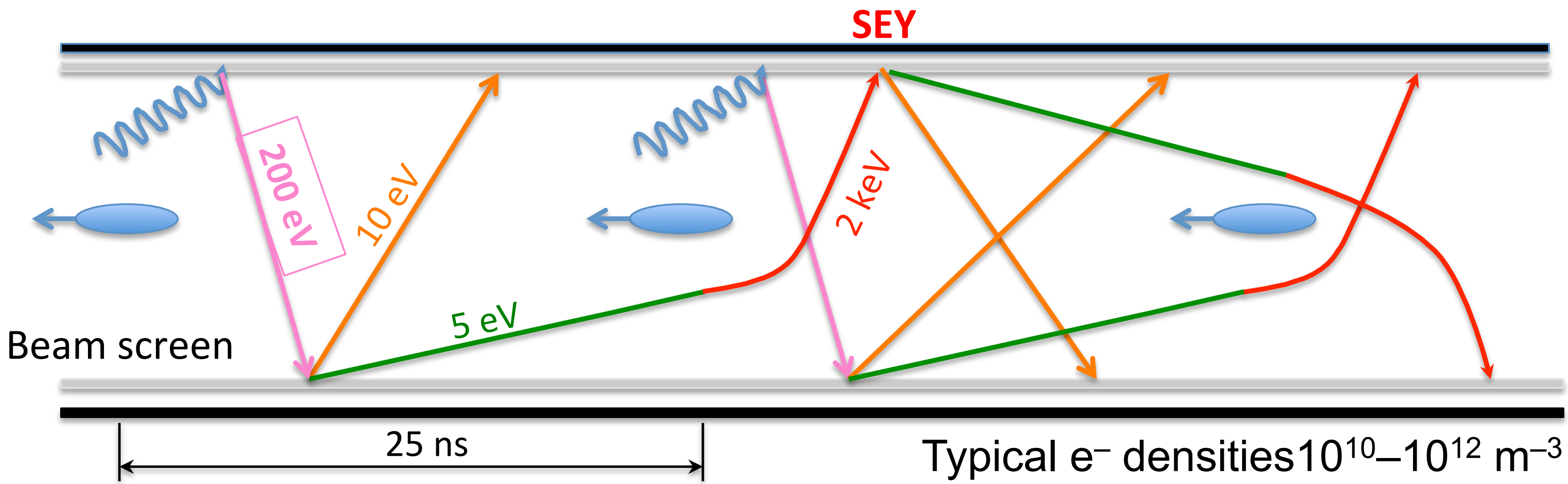
A huge cryogenics system is required to produce the liquid He needed to keep the magnets cold

Electron cloud

- Electron clouds are the result of an avalanche-like process, when electrons from gas ionization or photoemission are accelerated in the electromagnetic field of the beam and hit the beam chamber walls with energies of few hundreds of eV, producing more electrons.
- The electron impacts on the wall cause molecule desorption as well as heat load for the cryogenic system in cold regions.
- High electron densities in the beam chamber lead to oscillations and blow up of the particle bunches due to the electromagnetic interaction between electrons and protons.

Giovanni Rumolo

25 ns & electron cloud



Possible consequences:

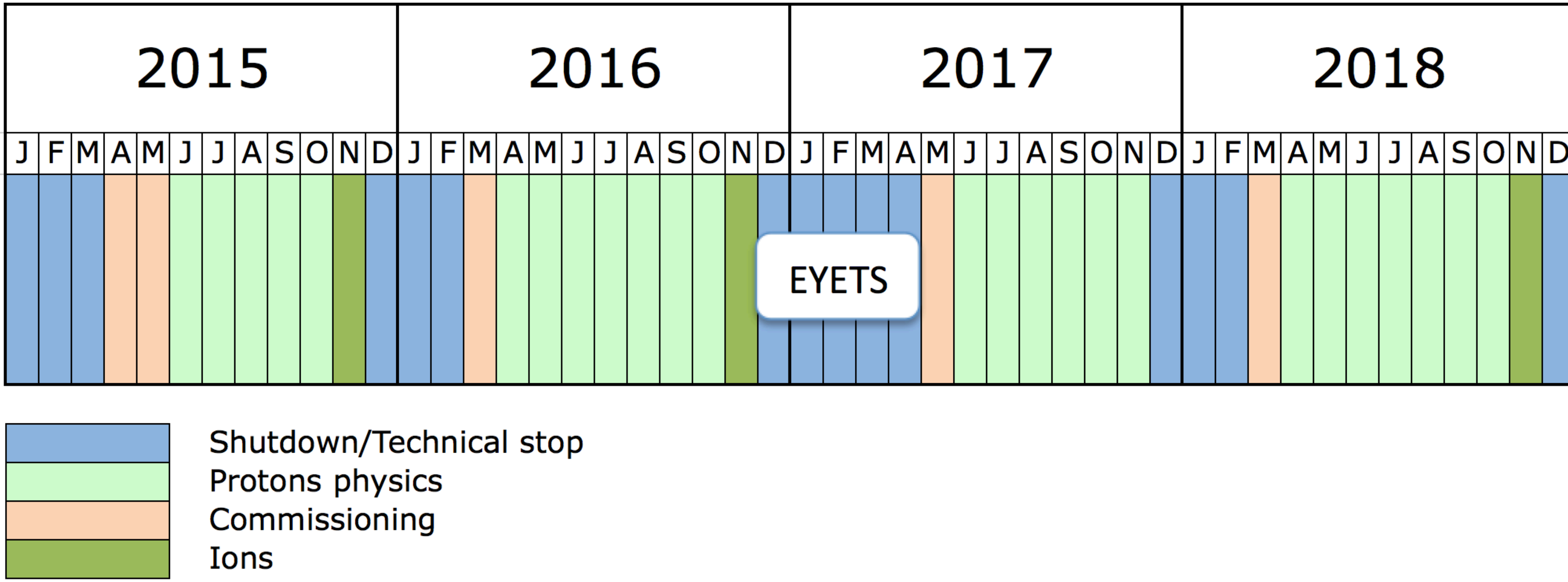
- instabilities, emittance growth, desorption – bad vacuum
- excessive energy deposition in the cold sectors

Electron bombardment of a surface has been proven to reduce drastically the **secondary electron yield (SEY)** of a material. This technique, known as **scrubbing**, provides a mean to suppress electron cloud build-up.

Mike Lamont's slide

Electron cloud significantly worse with 25 ns

Run 2



- EYETS – Extended Year End Technical Stop – 19 weeks – CMS pixel upgrade
- Start LS2 at the end of 2018

Mike Lamont's slide

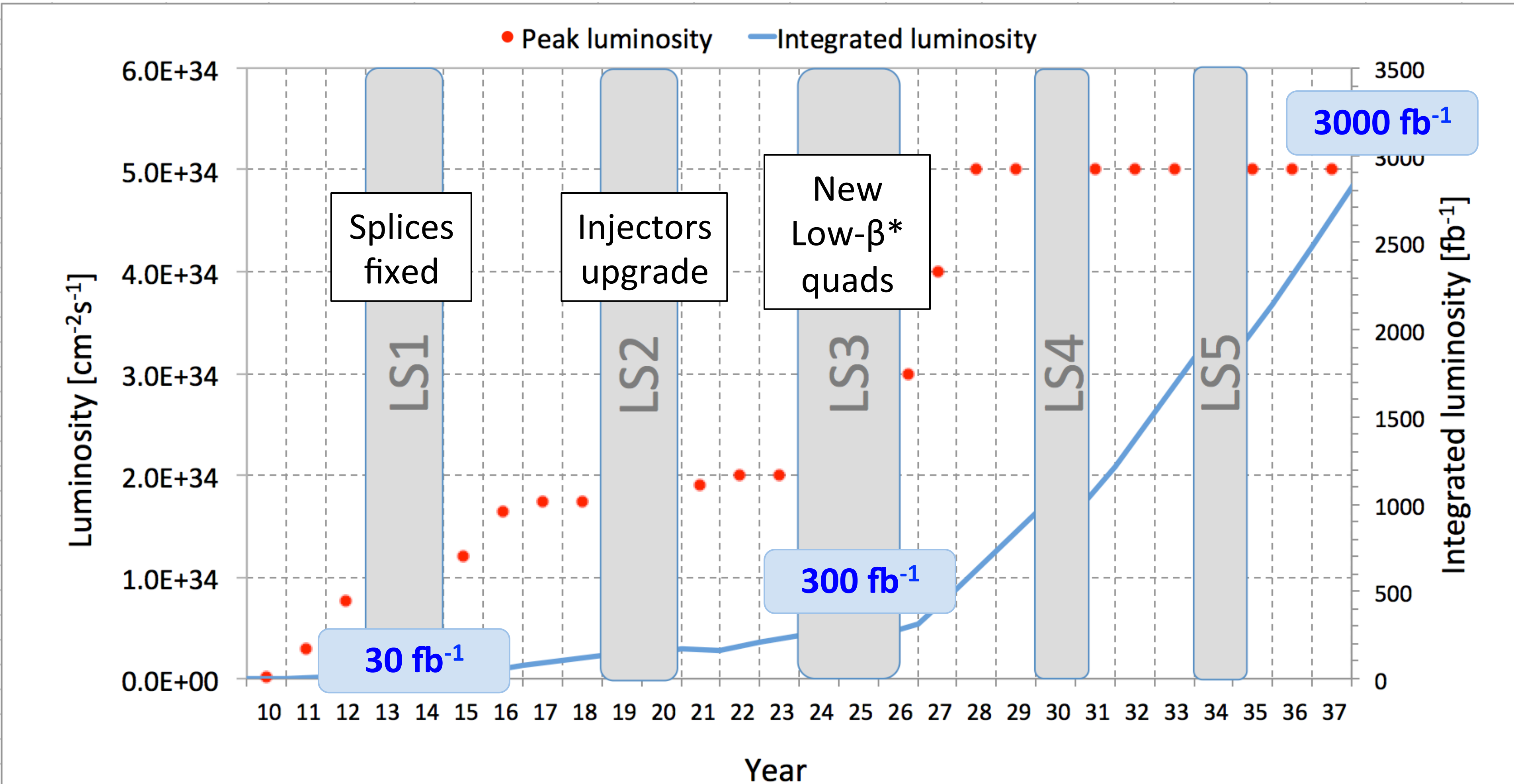
Run 2 performance

Mike Lamont's slide (LP2015)

- Start 2016 in production mode
  - 6.5 TeV, machine scrubbed for 25 ns operation
  - Beta* = 40 cm in ATLAS and CMS
  - New injection protection absorbers
  - Peak lumi limited to 1.7e34 by inner triplets
  - Reasonable availability assumed – usual caveats apply – really need to gain experience with 25 ns operation

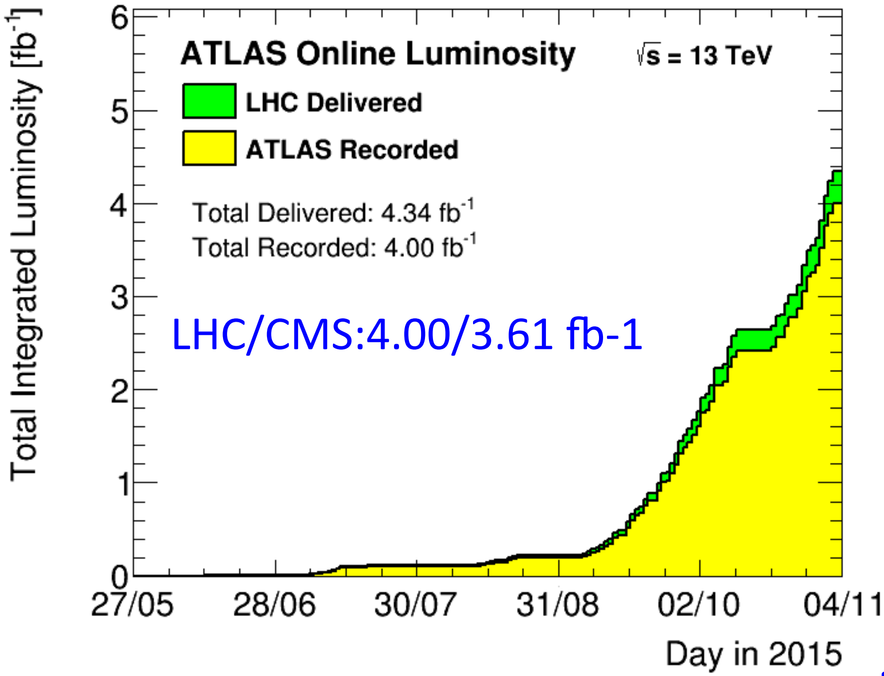
	Peak lumi E34 $cm^{-2}s^{-1}$	Days proton physics	Approx. int lumi [fb^{-1}]
2015	~0.5	65	3
2016	1.2	160	30
2017	1.5	160	36
2018	1.5	160	36

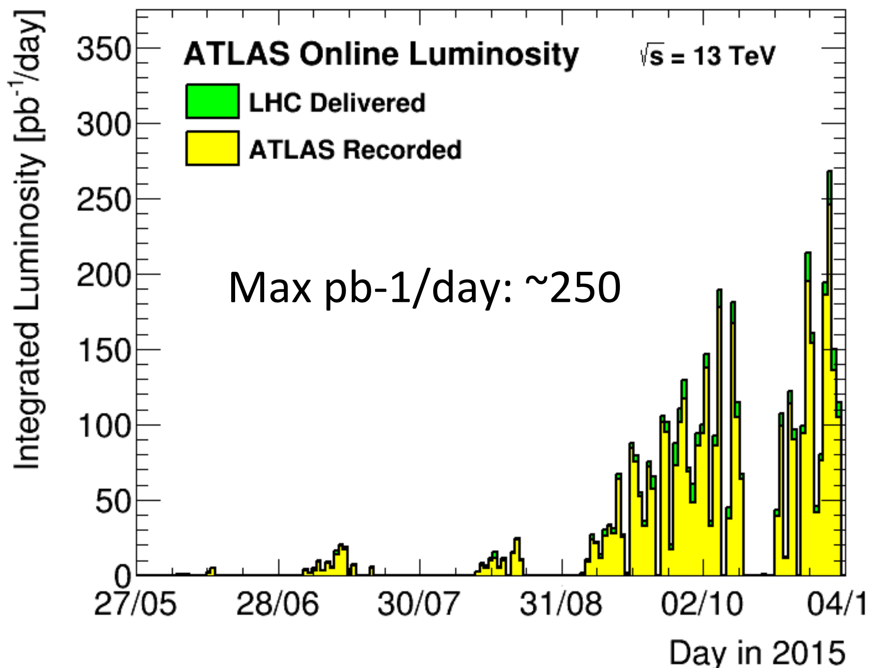
And beyond



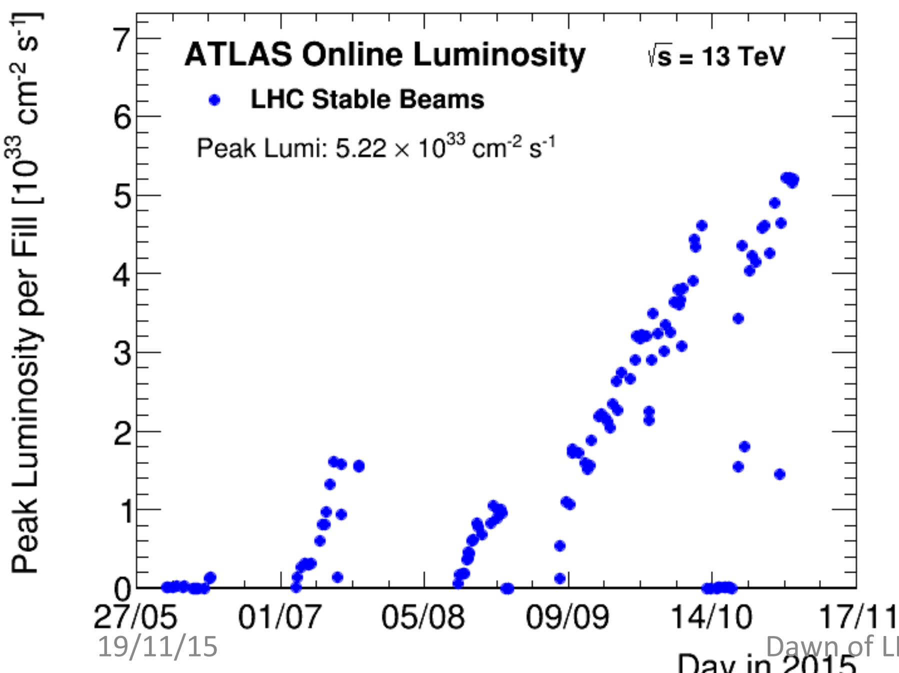
LHC is highest-E, highest-L operational collider → full exploitation ($\sqrt{s}$ ~ 14 TeV, 3000 fb^{-1}) is mandatory:

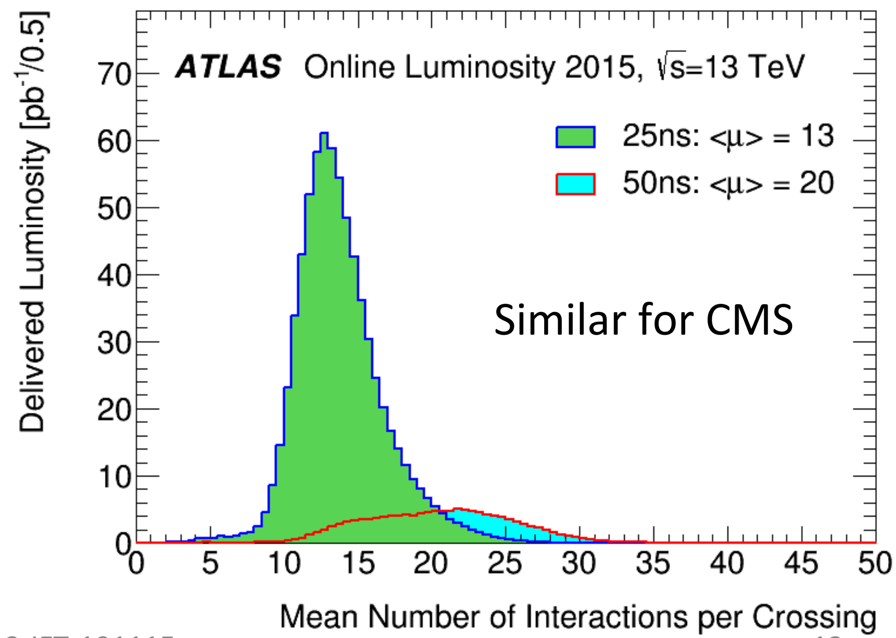
FG EPS 15





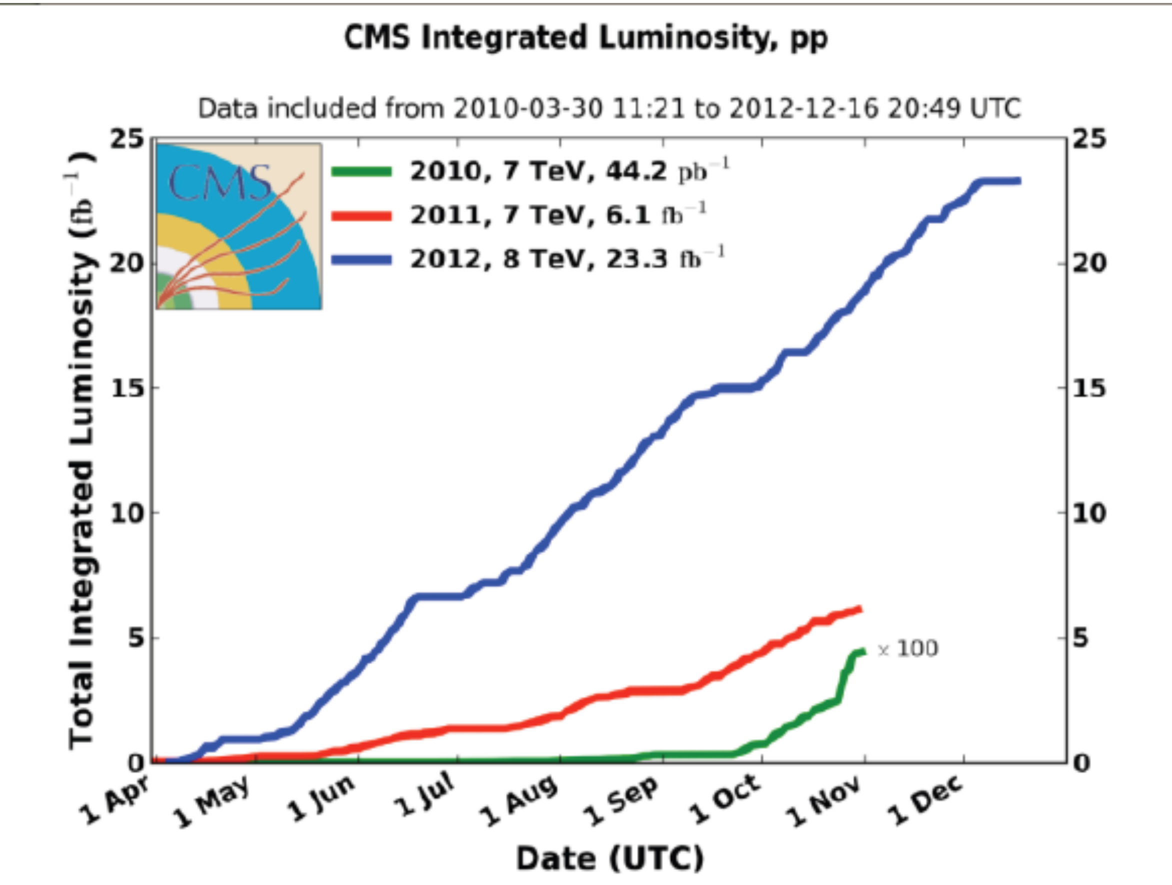
2015 LHC BEAM PERFORMANCES





Remind: LHC 2010-2012 Run!

Here we are by analogy in 2015



2010: **0.04 fb^{-1}**

$\sqrt{s}$ = 7 TeV

commissioning

2011: **6.1 fb^{-1}**

$\sqrt{s}$ = 7 TeV

… exploring limits

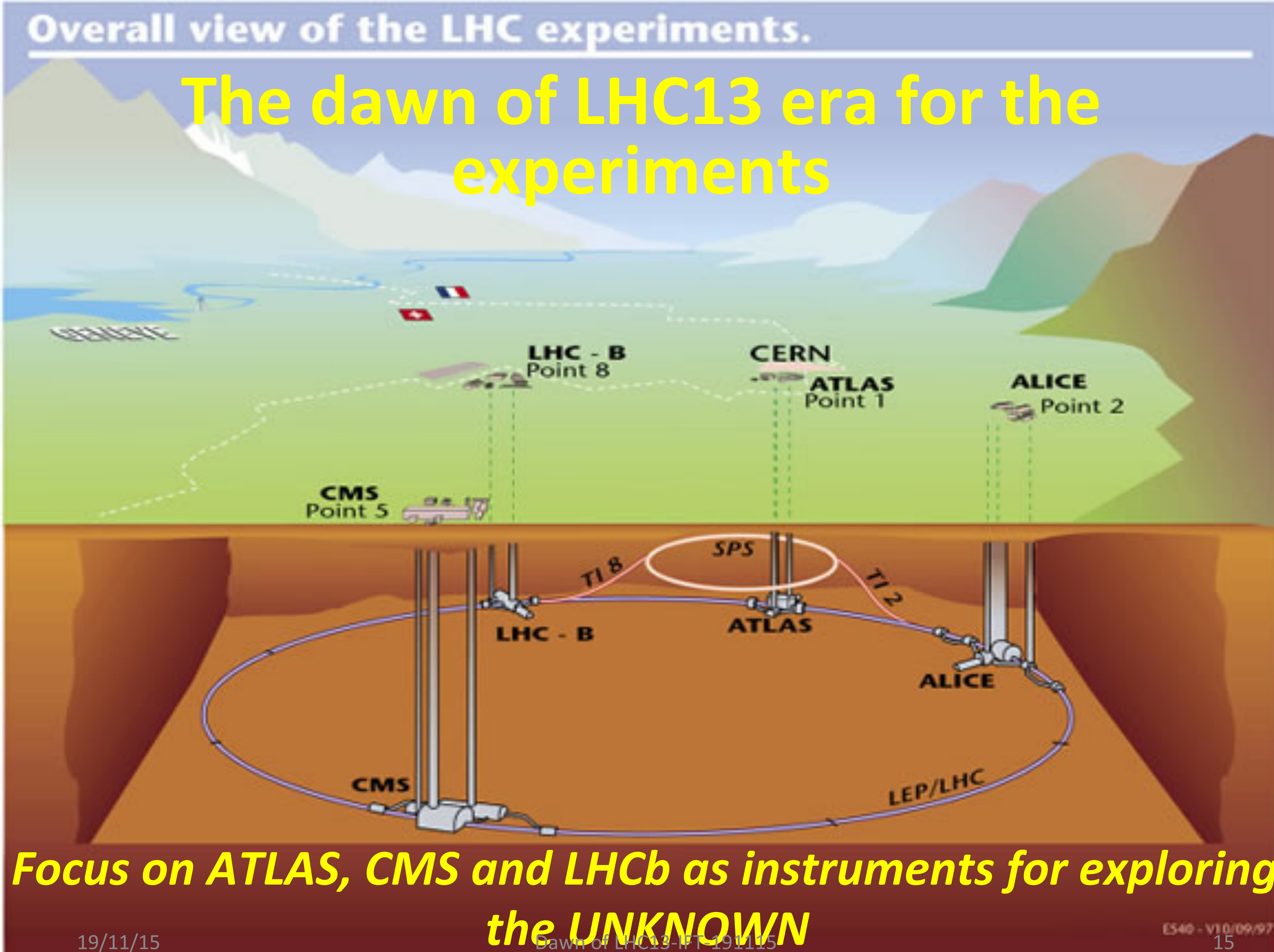
2012: **23.3 fb^{-1}**

$\sqrt{s}$ = 8 TeV

… production

Peak luminosity: **~280 pb^{-1}/day**

The dawn of LHC13 era for the experiments



Focus on ATLAS, CMS and LHCb as instruments for exploring the UNKNOWN

Exploring UNKNOWN territory needs improved tools

- Unknown territory why and what it means?

In previous Run: main goal = find HIGGS with strong indications of a light Higgs (LEP and Tevatron). Now no more guidelines…Thus

- Ways to look for BSM are:
  - Deviations from SM predictions
  - Search for New particles (events) production

- Both ways request improving the instruments/detectors:

New/improved detectors, FE signal processing, Triggering, realtime processing (DAQ), Data Analysis => keyword**:** **UPGRADES**

Based on:

=> ***continuous upgrade*** (LEP & Tevatron legacy)

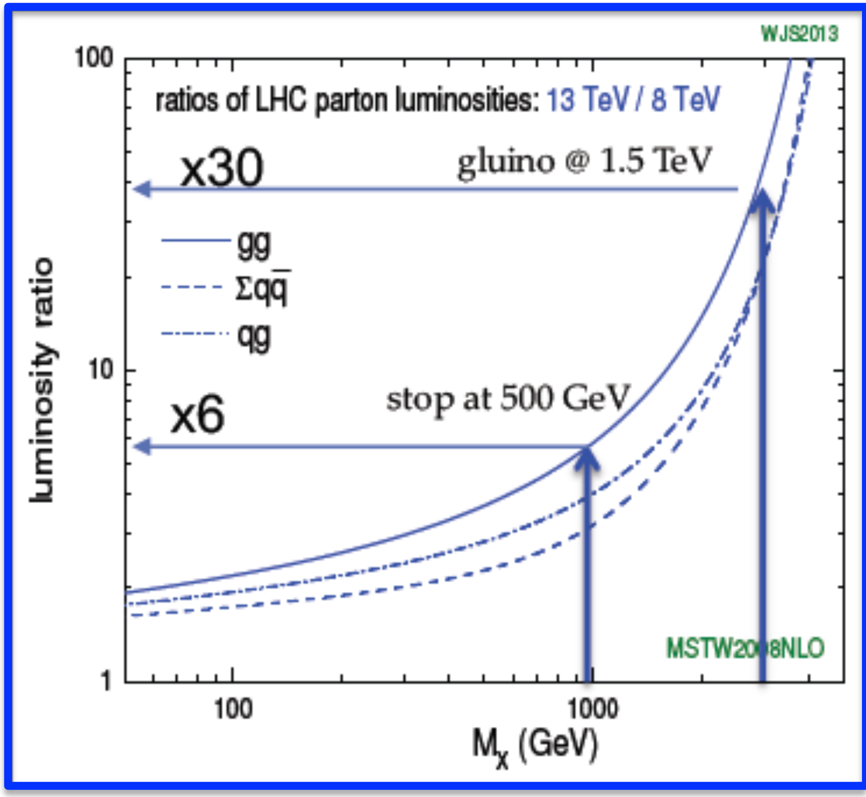
During LS1, ATLAS, CMS and LHCb have undertaken first upgrades

⇒ ***the experience from the 2010-2012 Run***, for example on handling large PU…

goal: the increase of PHYSICS POTENTIAL

What’s new in this starting Run Period

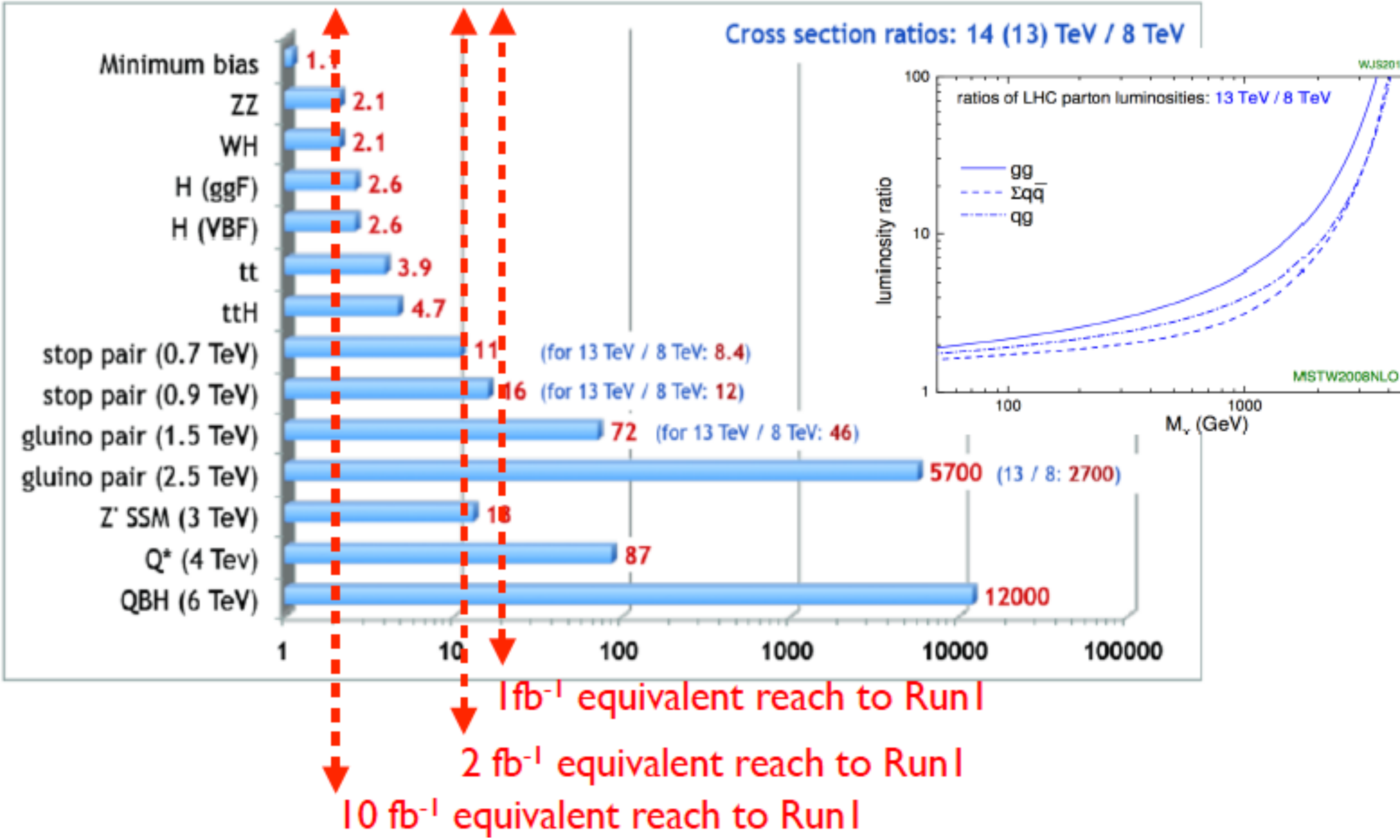
- **LHC is getting to design parameters**
  - Energy cm up to 14 TeV
  - 25 ns BX
  - Collecting 100 fb-1 by end 2018
- **Dramatic increase in Physics potential**
  - Massive new objects, W’/Z’, SUSY etc..
  - Observe rare processes, ttH, HH, LFV…
  - Precision studies: Top, Higgs. B Physics…



Continuous and major efforts across the Machine and Experiments for exploiting at best the Full Physics Potential

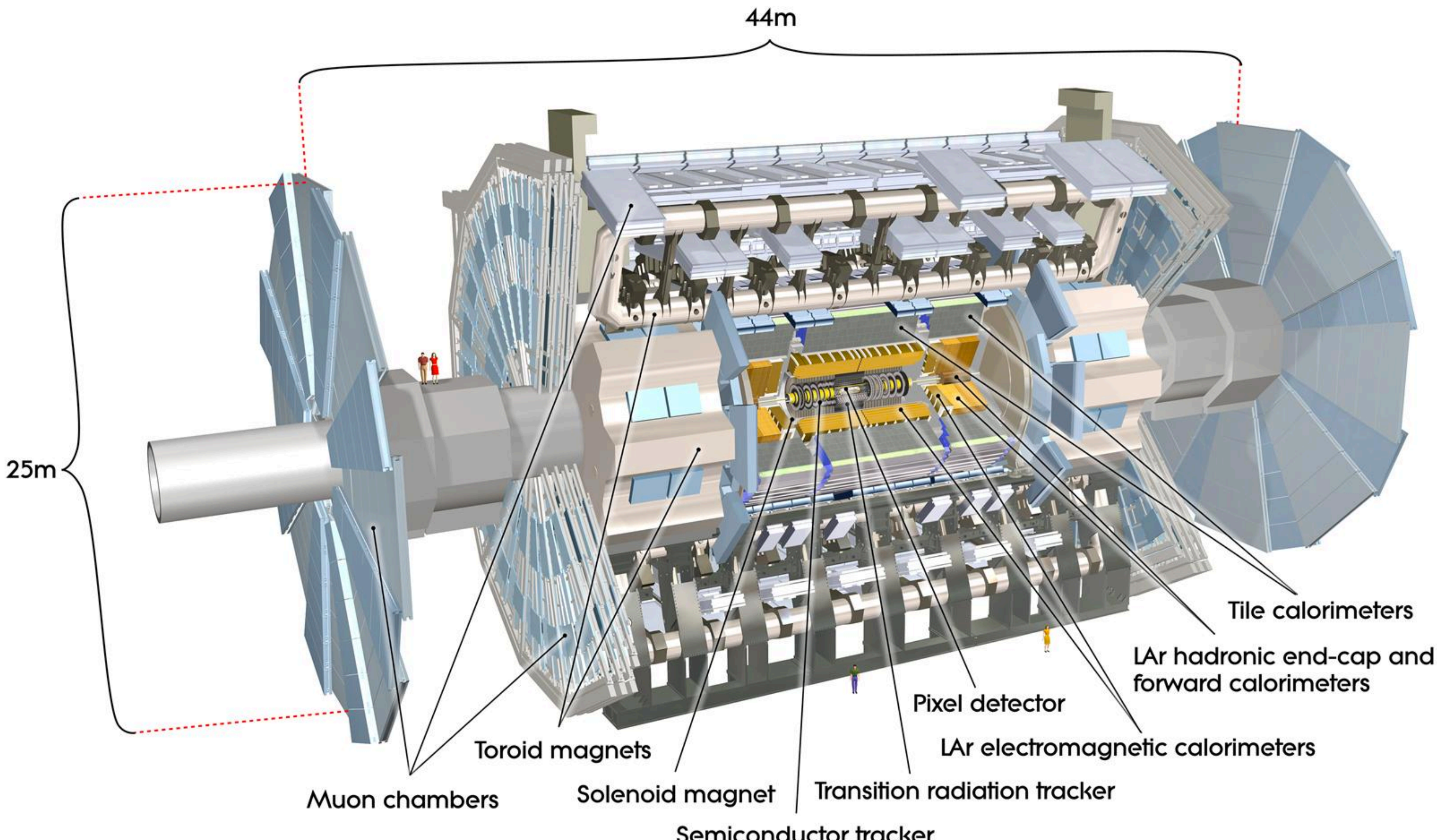
(see some examples for the experiments in next slides)

Increased Energy => Increased Physics Reach



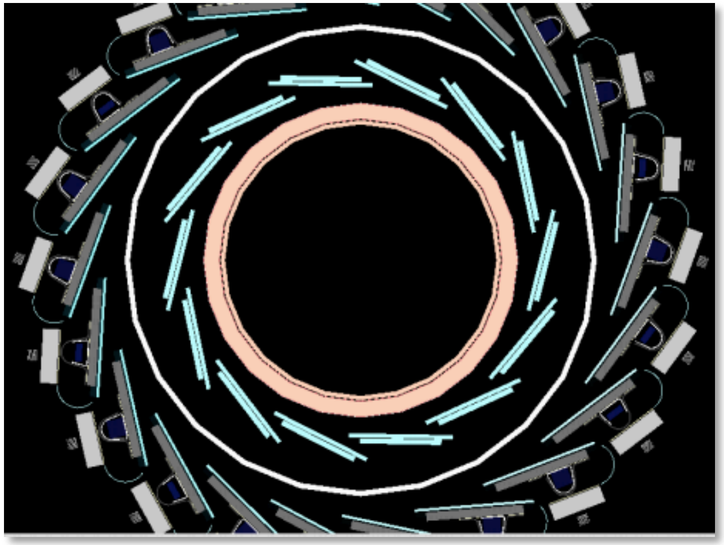
CAVEAT: The Backgrounds, especially Physics backgrounds increases as well!!!
The gain is obvious for high mass objects of course.

ATLAS EXPERIMENT

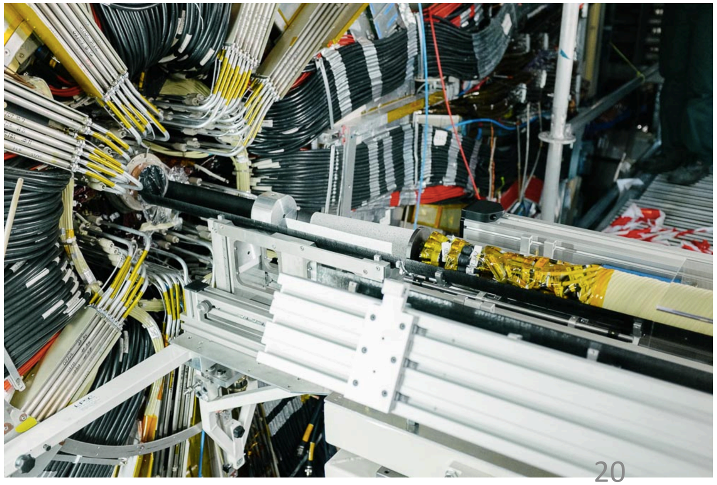


Upgrades to ATLAS during LS1

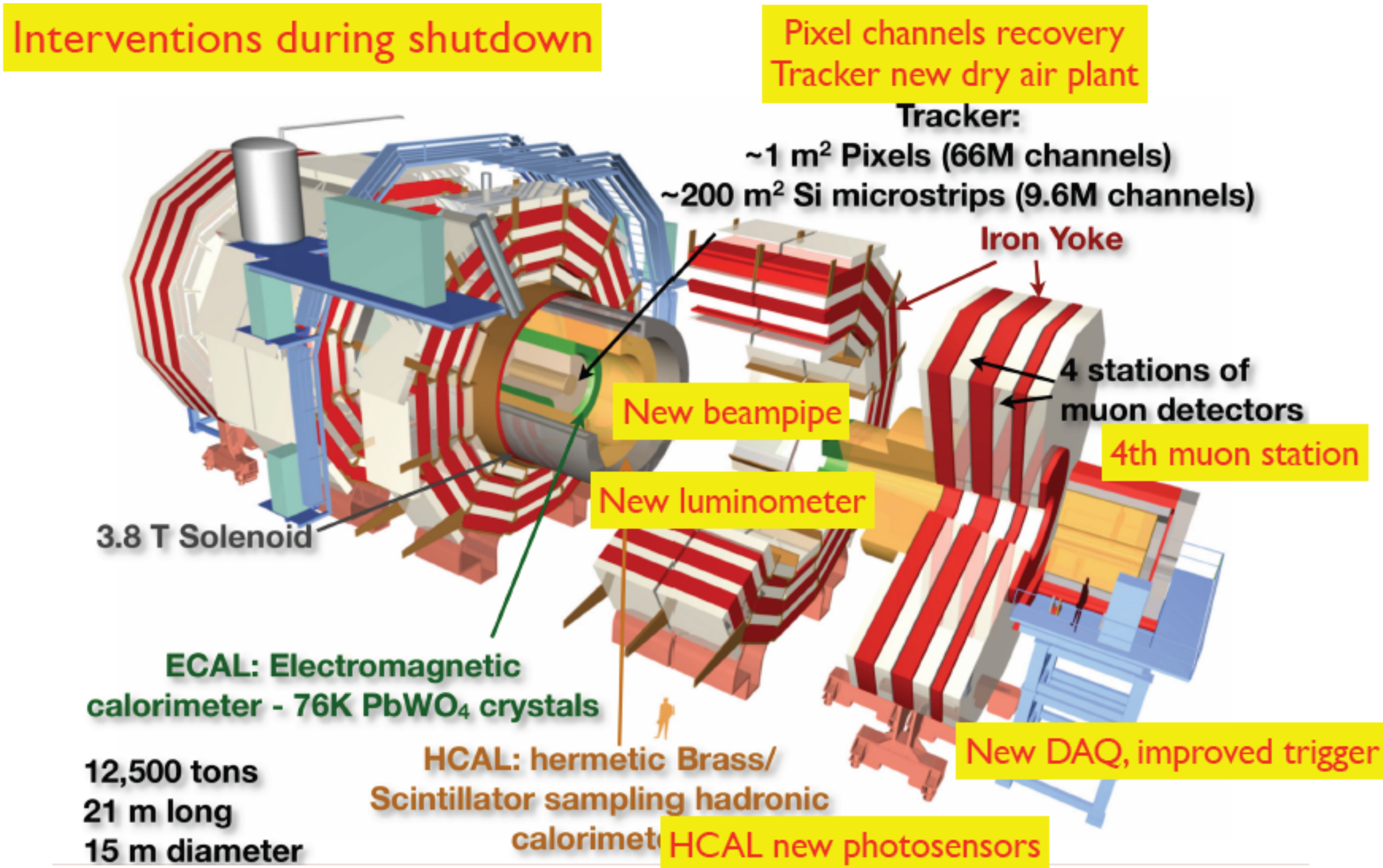
- Infrastructure:
  - New beampipe, improvements to magnet & cryogenic system
- Detector consolidation
  - Muon chambers completion (|η|=1.1-1.3) and repairs, improved readout of various systems (L1 rate 100 kHz), repair of pixel modules and calorimeter electronics, new pixel services, new luminosity detectors, new MBTS detector
- **4th silicon pixel detector layer (IBL)**
  - **Innermost Pixel detector layer at R=3.3 cm from beam**
- **Trigger improvements**
  - **New Topological L1 trigger, new central trigger processor**, coincidence between Tile and muons, restructuring of high-level trigger**, new Fast TracK Trigger (FTK)**, improved L1 calorimeter trigger
- Software
  - Many improvements to simulation, reconstruction, grid and analysis software



IBL Insertion: May 2014



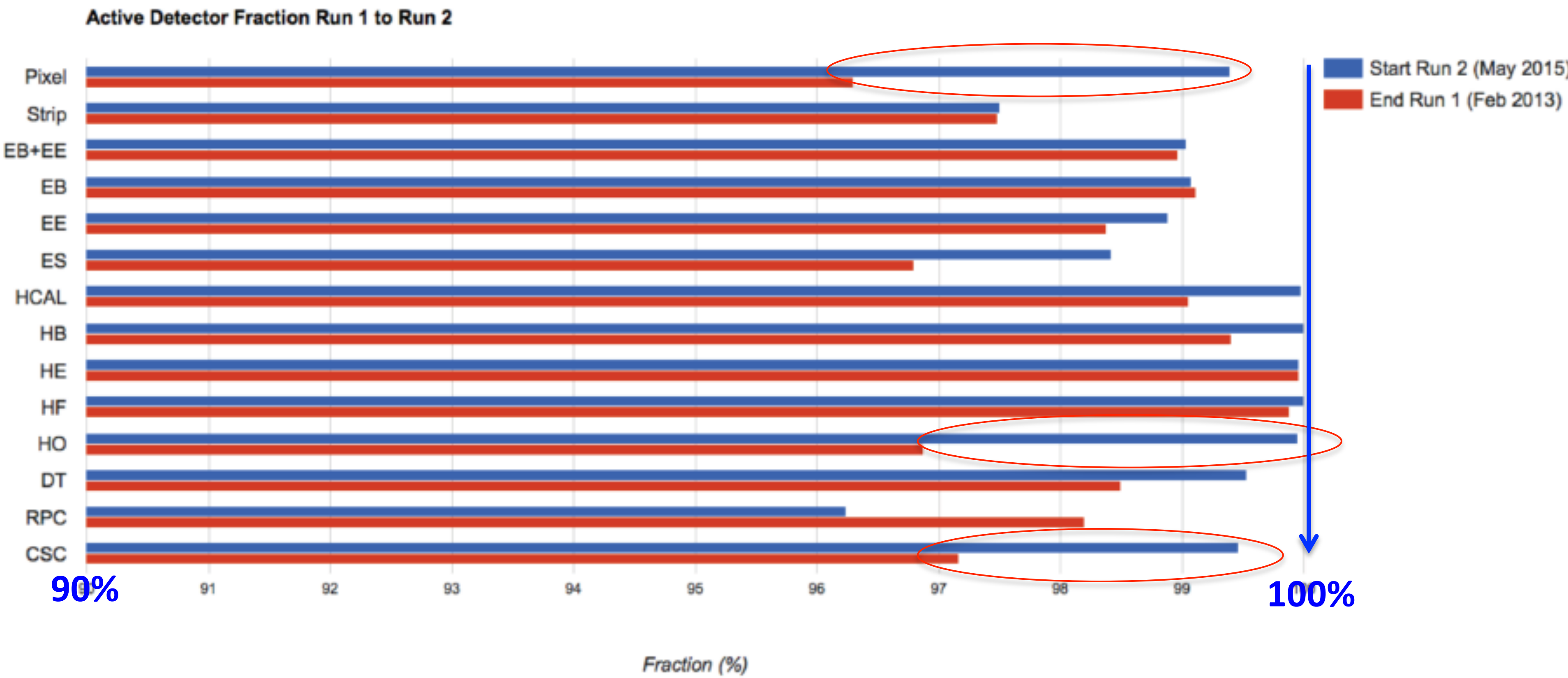
Compact Muon Solenoid EXPERIMENT



REPAIRS DURING THE LONG SHUTDOWN March 2013 -> April 2015

Several recovery campaigns have re-established an almost perfect status.

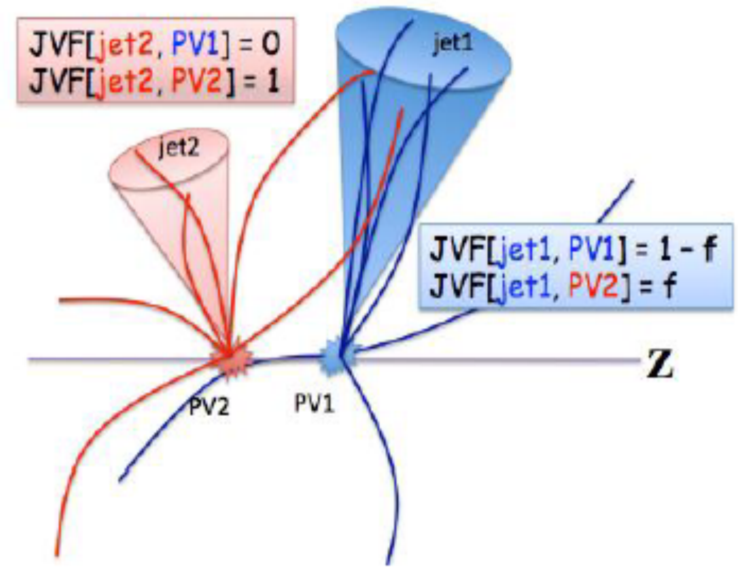
➡Please note that the scale starts at 90%!



Pile-up effects

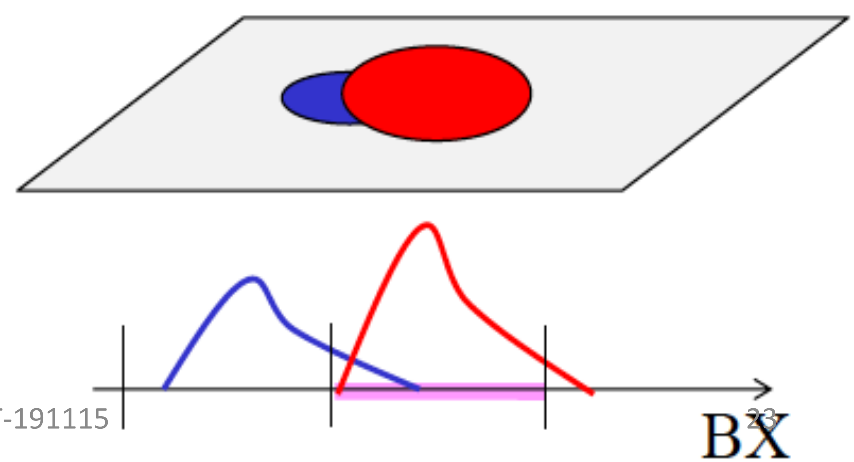
In-time pile-up

- The pile-up happens from several pp interactions per bunch crossing due to high luminosity.
- Mis-association of the tracks from other collisions makes worse for the jet energy measurement.

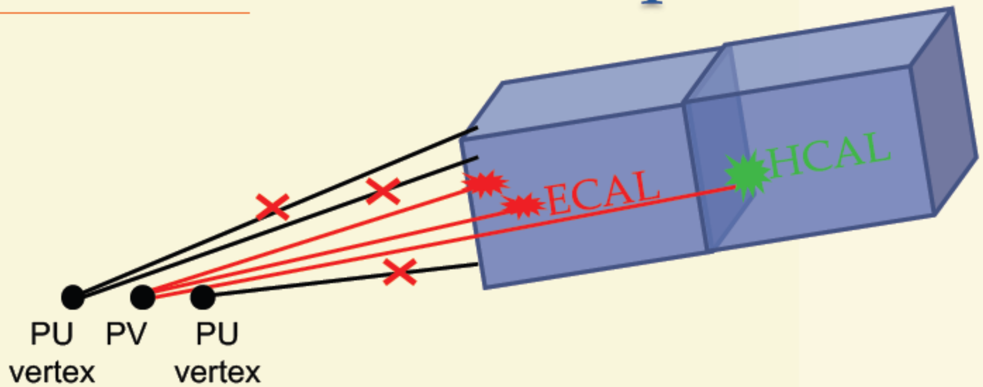


Out-of-time pile-up

- Effects from particles of the previous bunch crossings due to slow or uncorrected detector response.

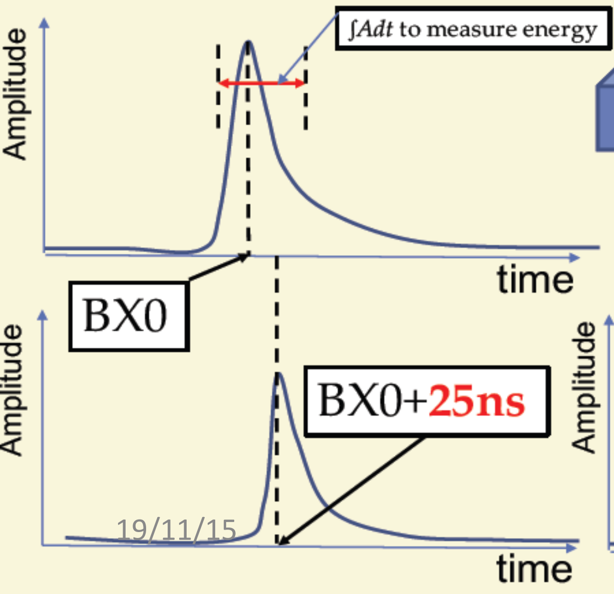


In Time Pileup

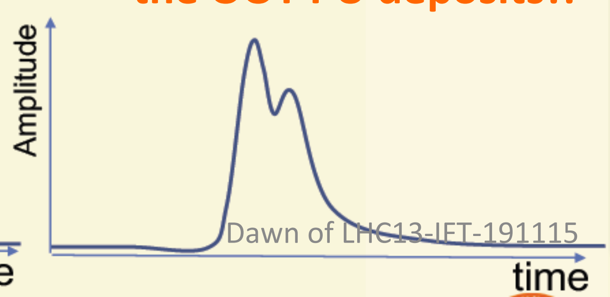


- We want to measure energies of particles produced in the **primary collision (PV)**
- Energies from PU collisions **can be subtracted** by taking out the charged tracks that come from **PU vertex**

Out of Time Pileup



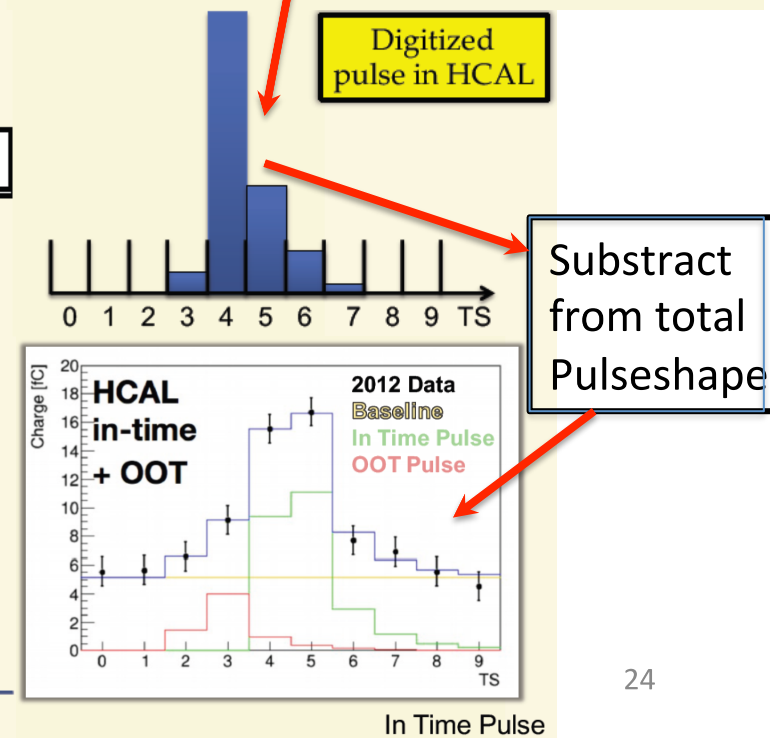
NO tracks to substract the OOT PU deposits!!



PILEUP MITIGATION

- Both ECAL and HCAL do a faster version at HLT
  - Roughly **50% reduction** in pileup background rate at same threshold with no loss in performance

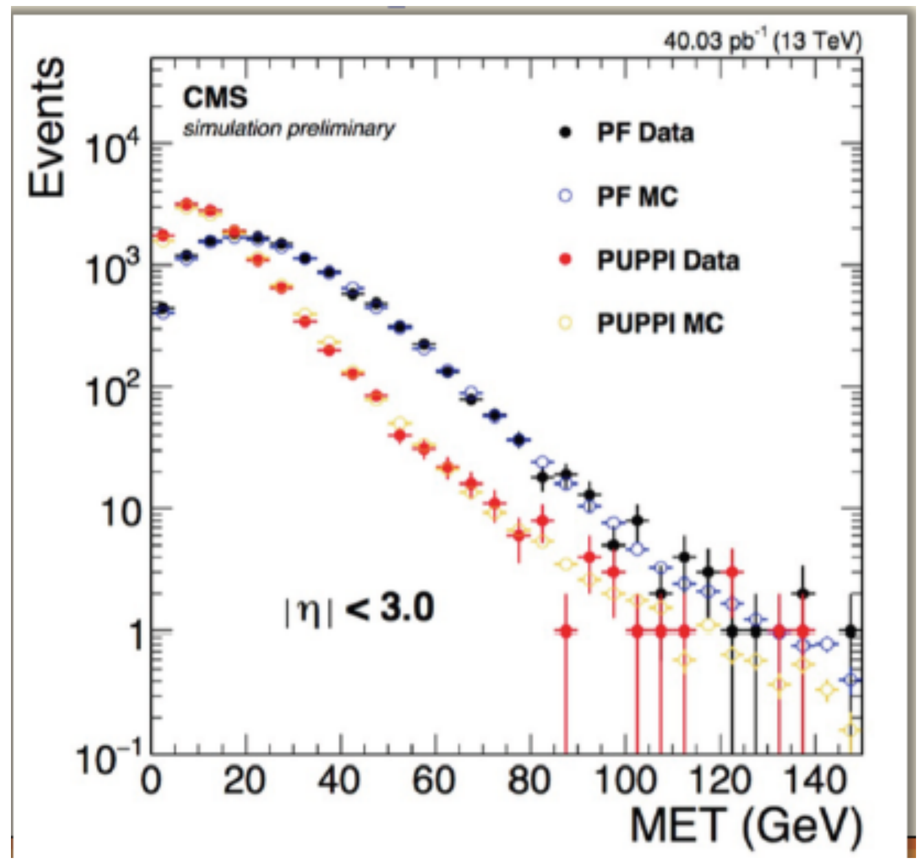
Fit measured data for the known pulse shape from past test beams



PUPPI: Pile Up Per Particle Identification

Discriminates particle from hard scattering from PU => Improves

- JET Energy determination
- Missing Transverse Energy
- Electron Isolation
- Tau-ID



This is how OOT is currently handled by software (HLT). For Run II (HL-LHC) hardware solutions are investigated by including timing in calorimeters FE ASIC (TDC) => able to get rid at L1 trigger level.

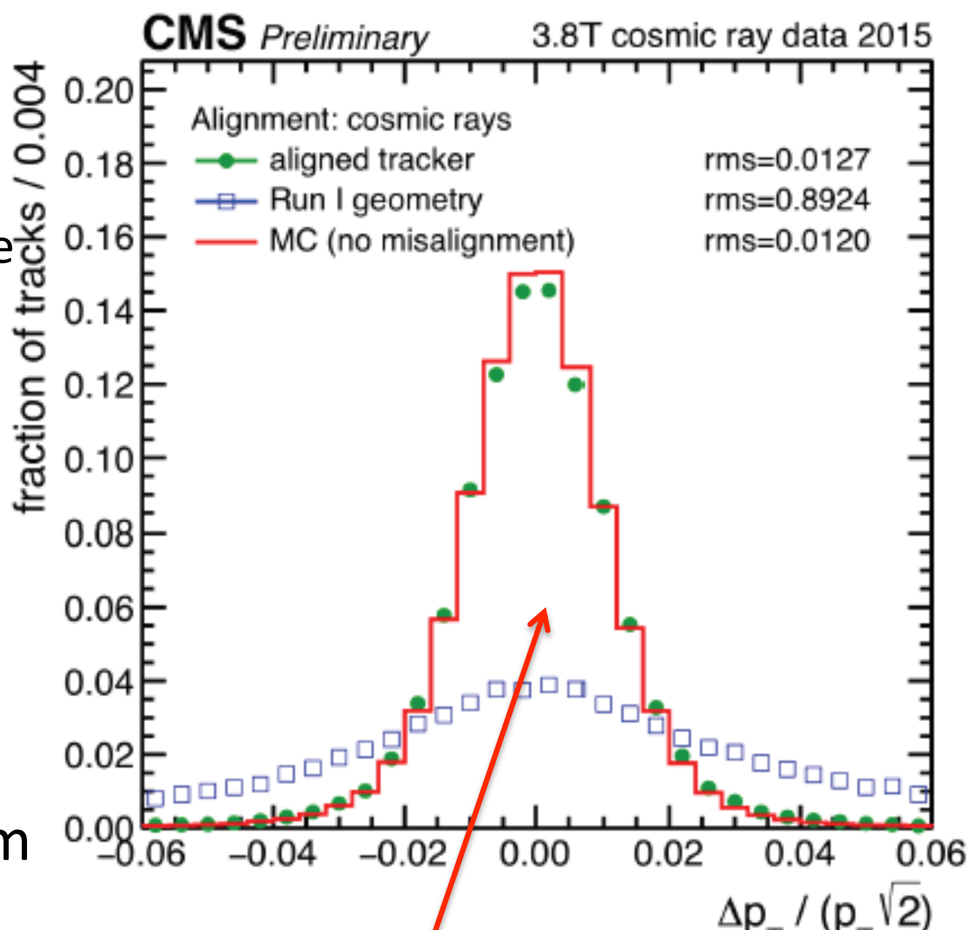
Alignment

The Pixel detector is re-centered from
-1.3 cm because of new beampipe
(1st layer now at 3.4 mm)

Long & crucial alignment campaign of the overall tracker system
(200 m^2 of Silicon strips)
plus Pixels) with
-> Cosmics
-> Primary beams delivered by the LHC
20 Millions collisions track

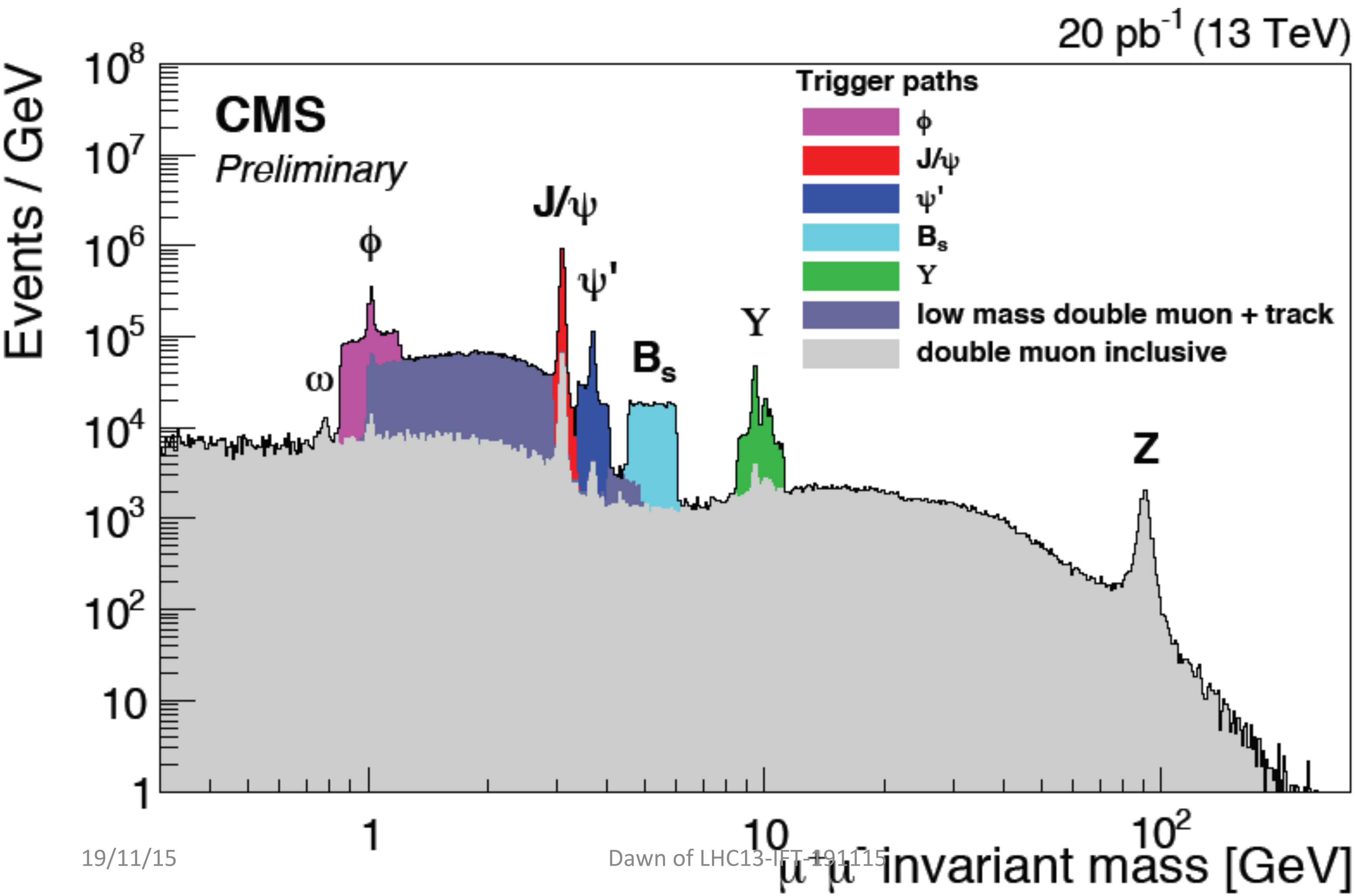
RMS of median residuals after Alignment ranging from 3 to 10 μm

CMS-DP-2015-029/CDS:2041841

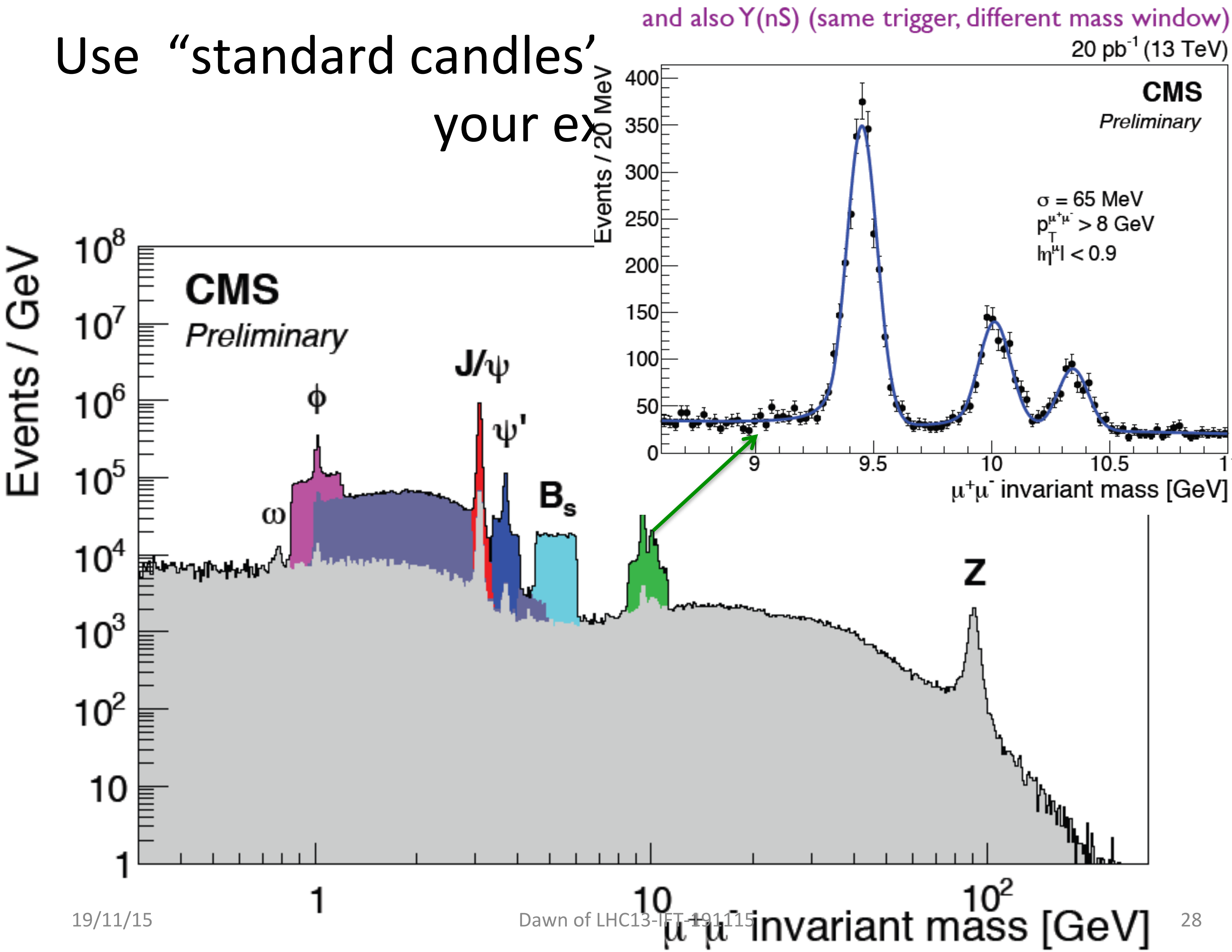


Reaching almost "asymptotic performances"

Use "standard candles" to test the functioning of your experiment

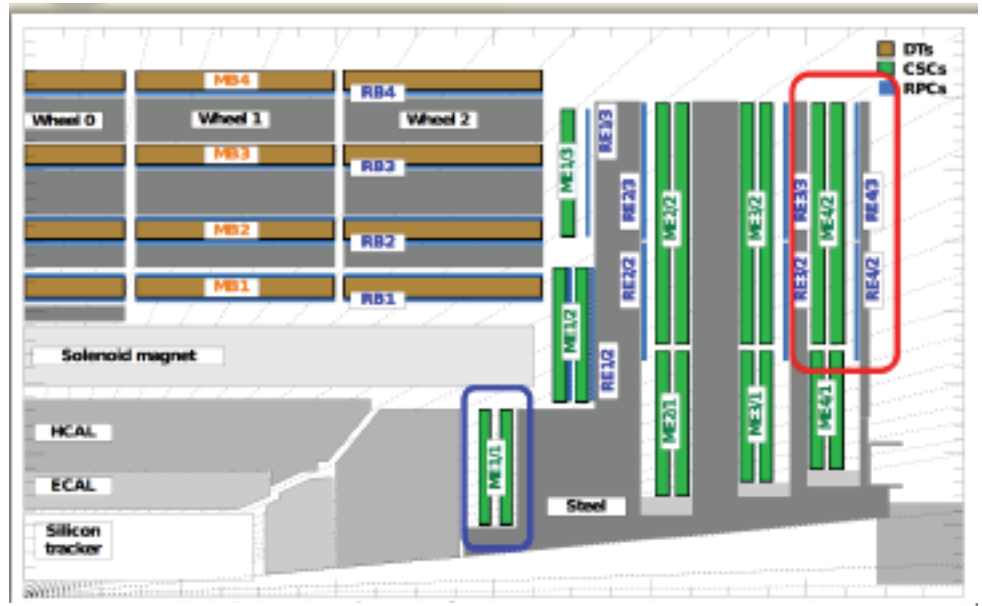


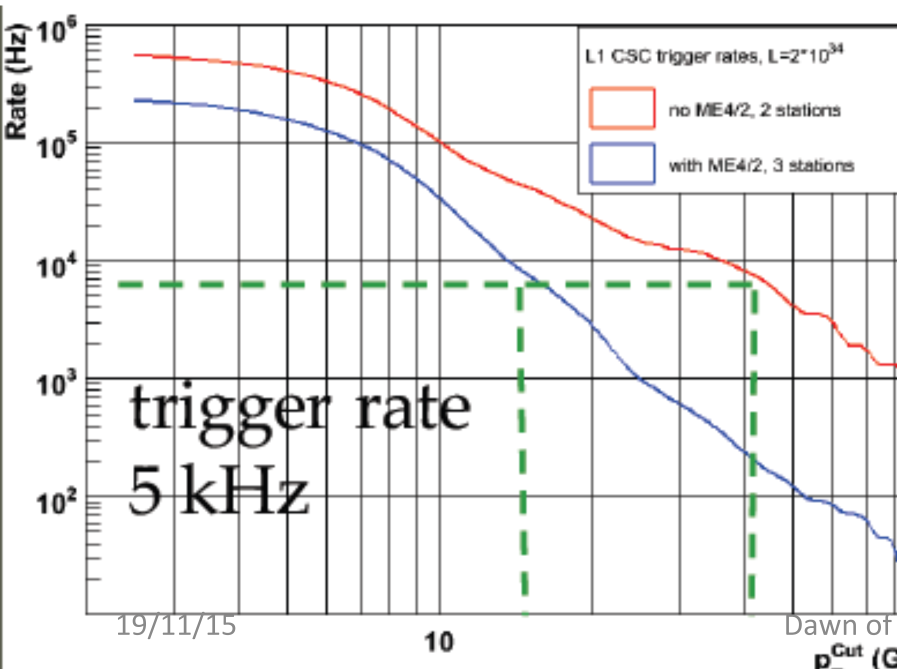
Use "standard candles' your ex

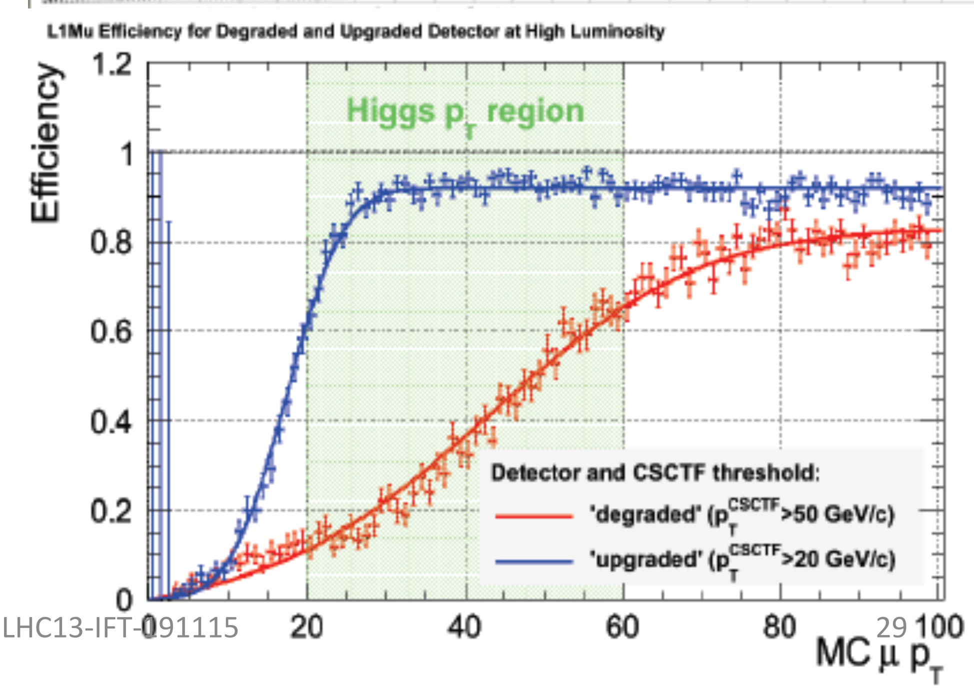


Muon & trigger LS1 improvements

- ME1/1 chambers: new digital boards & trigger cards
- ME4/2: 72(144) new CSC (RPC) chambers
- Maintain trigger rates at a lower Pt Threshold



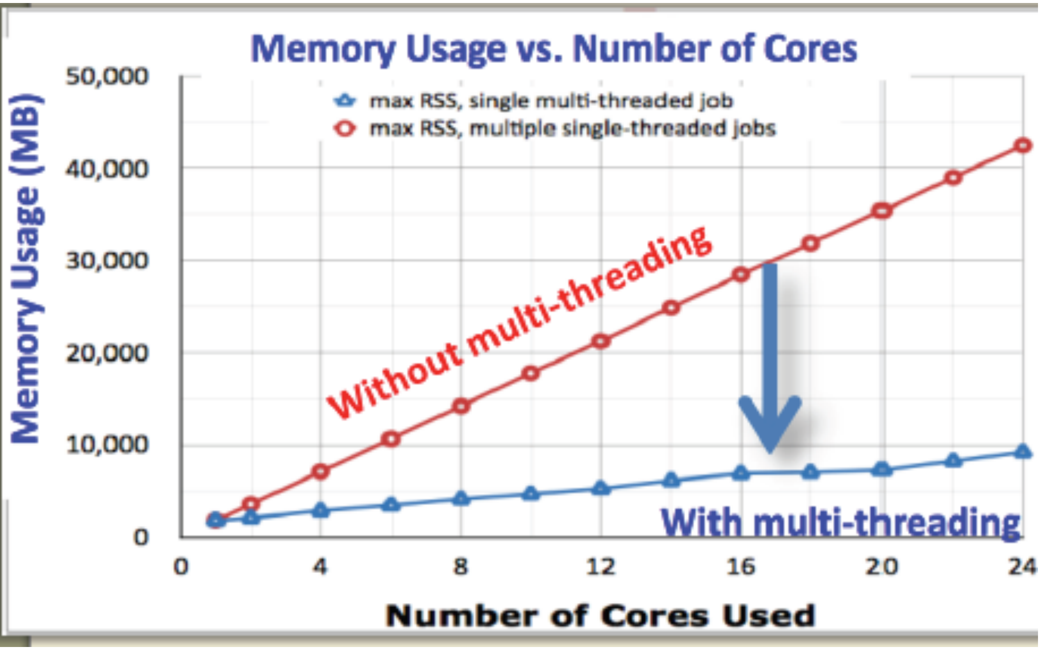


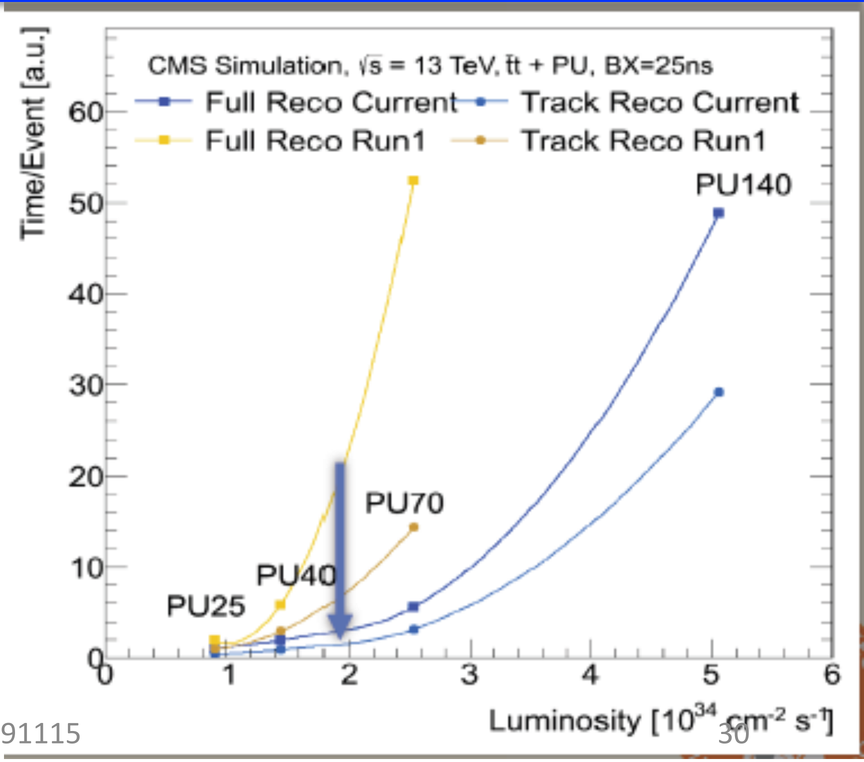


Software & Computing

Significant overhaul during shutdown

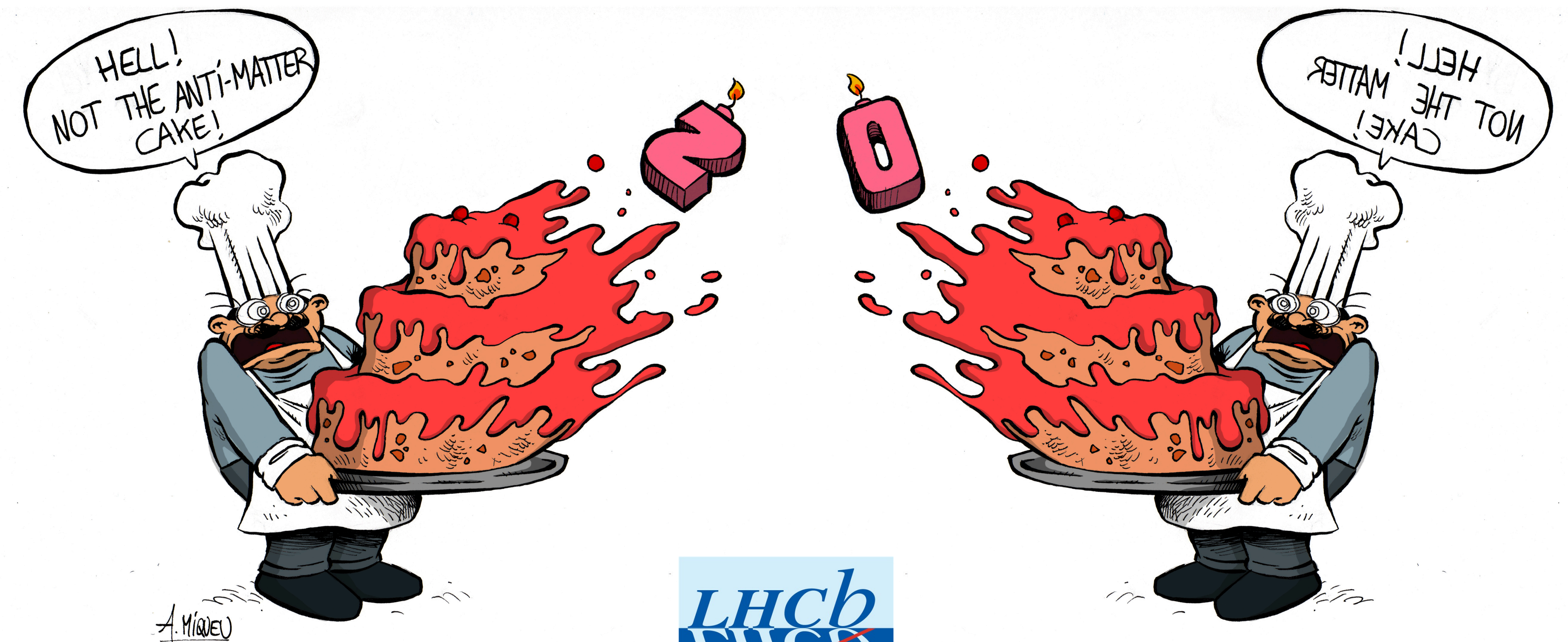
- Multithreading in simulation/reconstruction: **x4 improvement**
- Improve **reconstruction time** at high PU
- **Any Data, Anywhere, Anytime (AAA)**
- New data format (miniAOD): reduce analysis time **by x10**





HEAVY FLAVOUR SECTOR: another way to LOOK for NEW PHYSICS ?!?

From Giga (10^{12}) in 1 fb-1 to 0.01-0.1 TERA events in 50 fb-1



LHCb is a HIGH PRECISION EXPERIMENT designed to:

- ✓ *Measure the CP-VIOLATION in the b- and c-sector*
- ✓ *Perform INDIRECT SEARCH for NEW PHYSICS*

LHCb: FORWARD SPECTROMETER

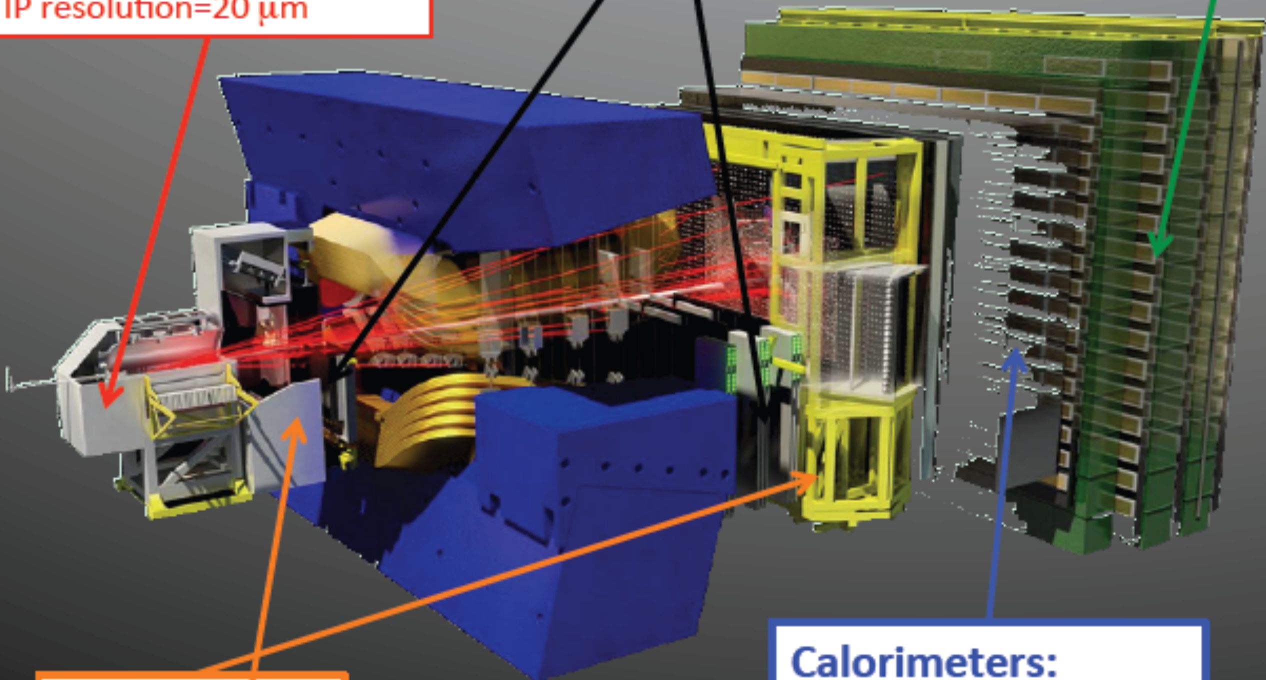
exploiting the large production of Beauty-pairs in $2<\eta<5$

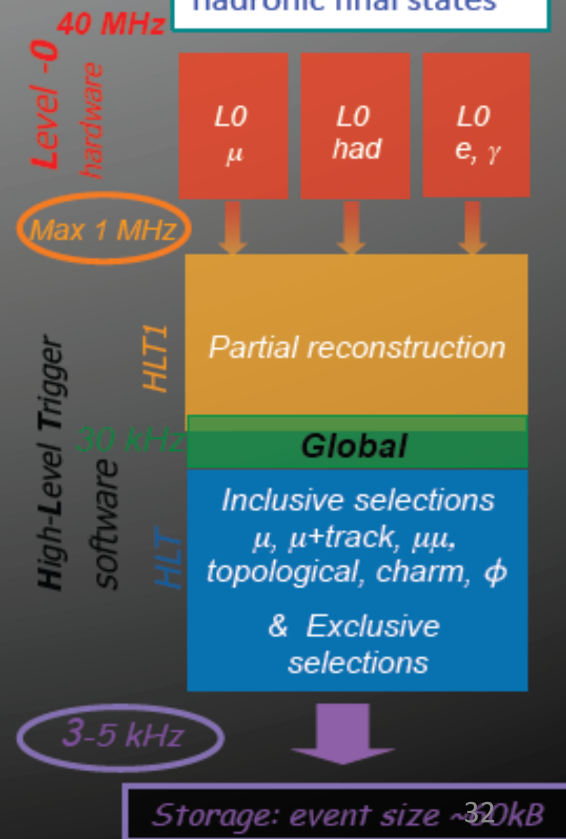
Tracking System (TT,IT,OT):
Excellent momentum resolution:
$\Delta p/p$= 0.4-0.6% from 5 to 100 GeV/c

VErtex LOcator:
Separate secondary from primary vertex:
IP resolution=20 μm

Muon System:
μ identification efficiency > 97% with <2.5% π mis-ID

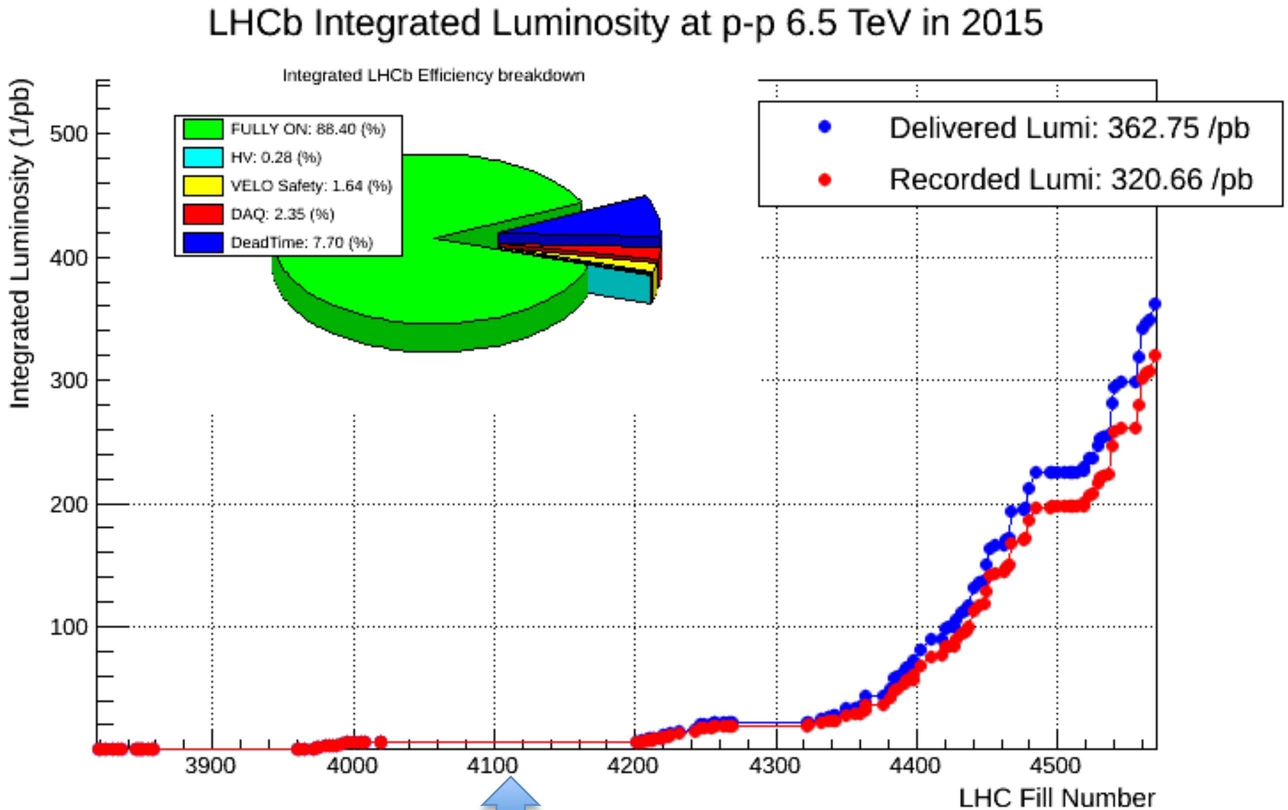
Trigger System:
multi-stage selection of leptonic and hadronic final states



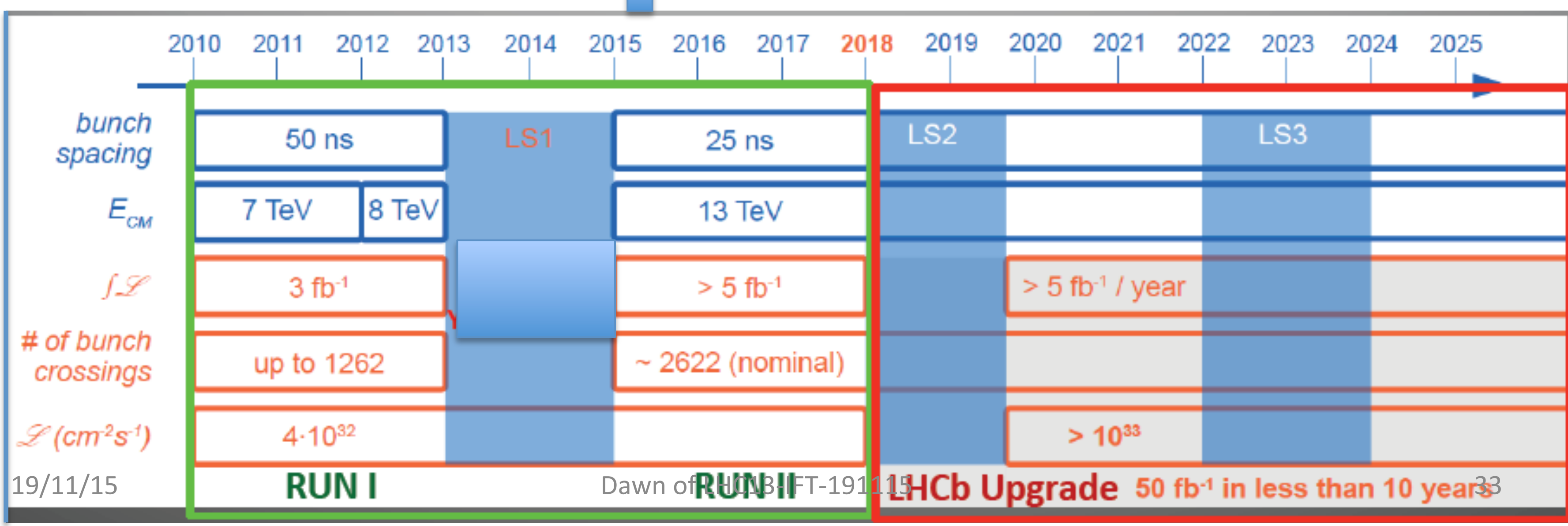


RICH System:
K/p/π separation

Calorimeters:
Energy measurement, e/γ identification. π^0 mass resolution ≈ 10 GeV/c^2

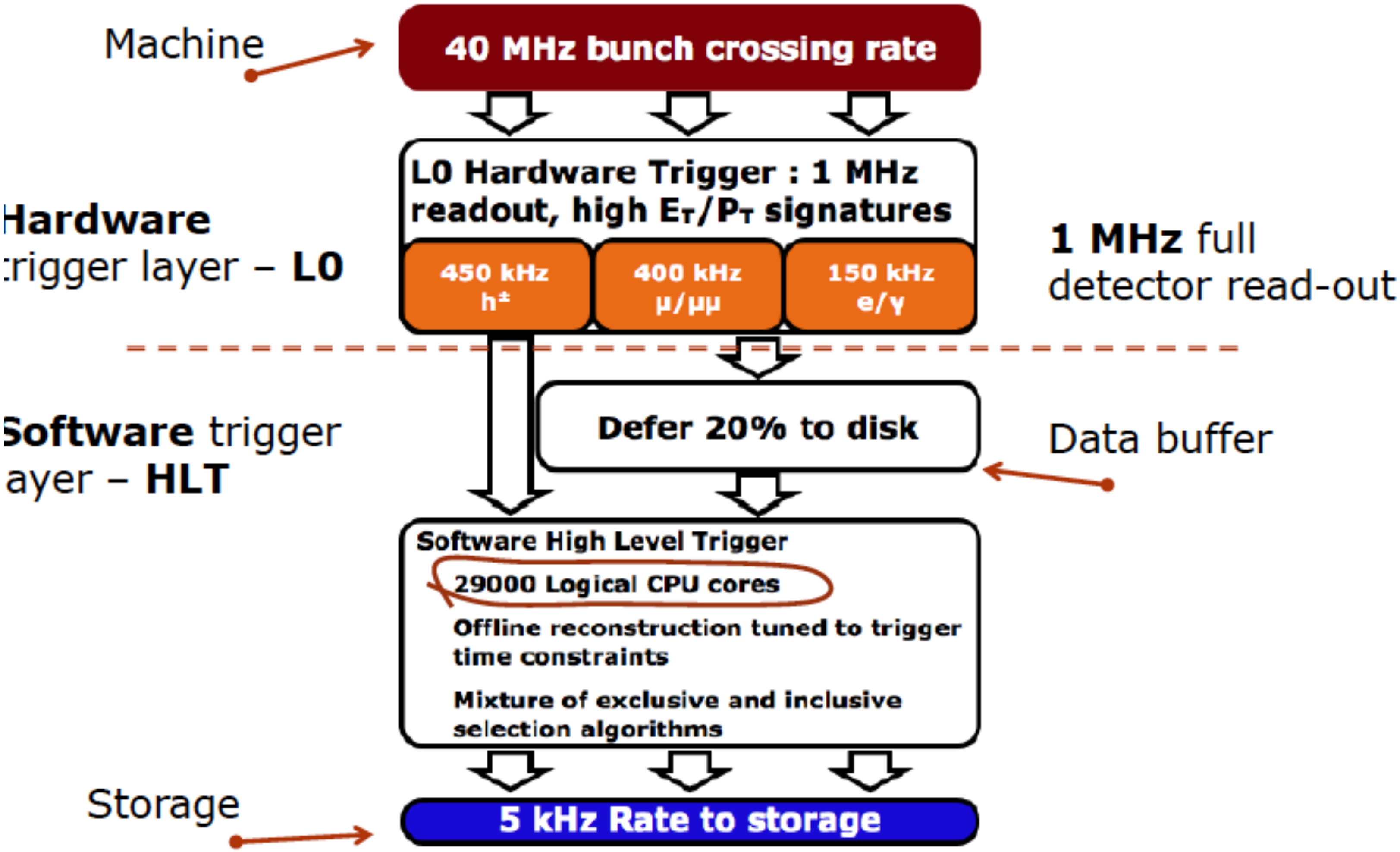


LHCb Integrated Luminosity at p-p 6.5 TeV in 2015
Integrated LHCb Efficiency breakdown
FULLY ON: 88.40 (%)
HV: 0.28 (%)
VELO Safety: 1.64 (%)
DAQ: 2.35 (%)
DeadTime: 7.70 (%)
Delivered Lumi: 362.75 /pb
Recorded Lumi: 320.66 /pb
Integrated Luminosity (1/pb)
100
200
300
400
500
3900
4000
4100
4200
4300
4400
4500
LHC Fill Number

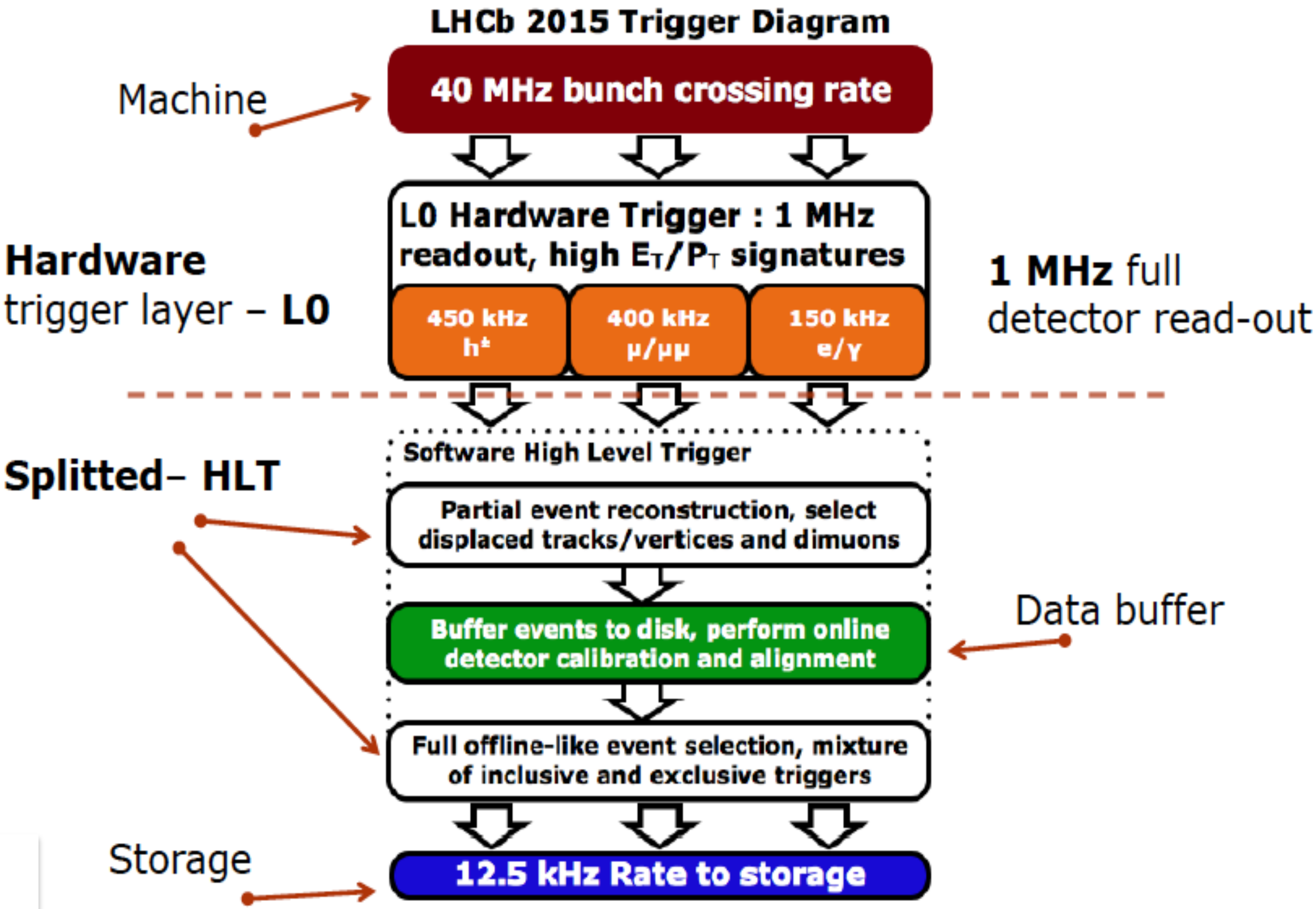


2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
bunch spacing
50 ns
LS1
25 ns
LS2
LS3
E_{CM}
7 TeV
8 TeV
13 TeV
$\int\mathscr{L}$
3 fb^{-1}
> 5 fb^{-1}
> 5 fb^{-1} / year
# of bunch crossings
up to 1262
~ 2622 (nominal)
$\mathscr{L}$ (cm^{-2}s^{-1})
$4\cdot10^{32}$
> 10^{33}
RUN I
RUN II
LHCb Upgrade
50 fb^{-1} in less than 10 years

❑ **RUN I** (already heavily revised comparing to the original specs)



❑ **RUN II** (major revision of the trigger system)



No need for further calibration off-line (all at HLT)

-> No offline reconstruction at all! The whole reconstruction is carried out in the online Event Filter

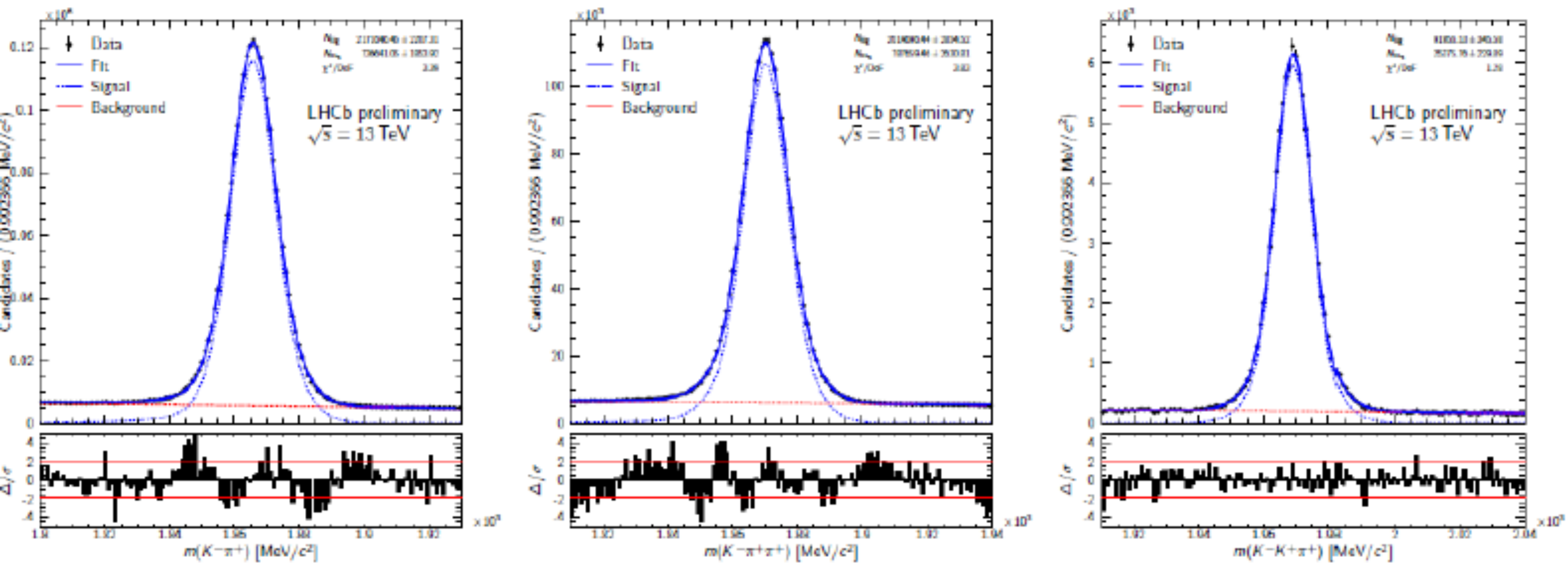
-> Allows writing-out data drectly on micro-DST format (in the "**TURBO**" stream no raw data, just the tracks of the candidate heavy hadron!)

The early hints of Physics at the dawn of LHC13

I) Exploring further the Heavy Flavour Realm at LHC13: or entering in the VERY VERY HIGH precision measurements regime

VERY VERY FIRST LHCb RESULTS

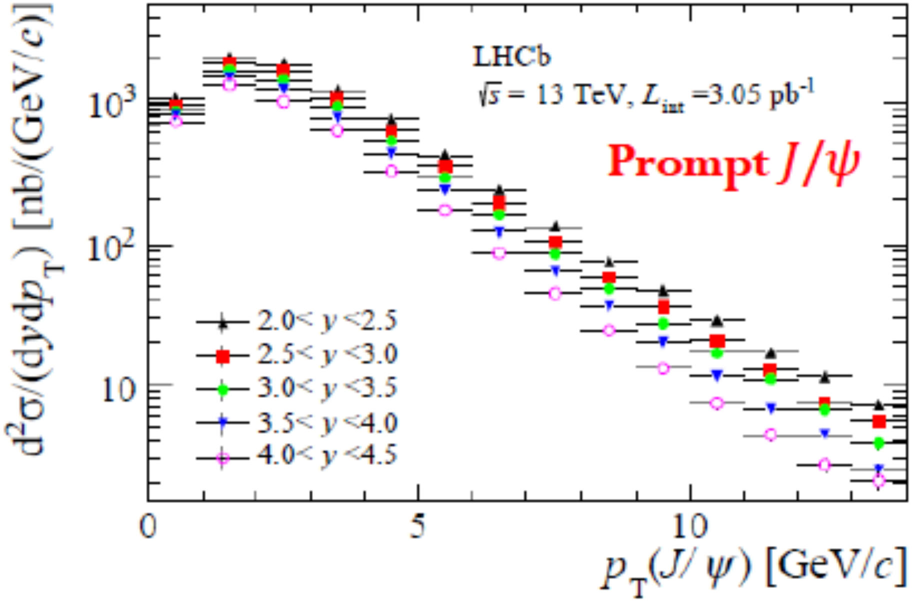
- **The TURBO** stream has been commissioning this year and is performing superbly
- Below plots obtained directly after the HLT

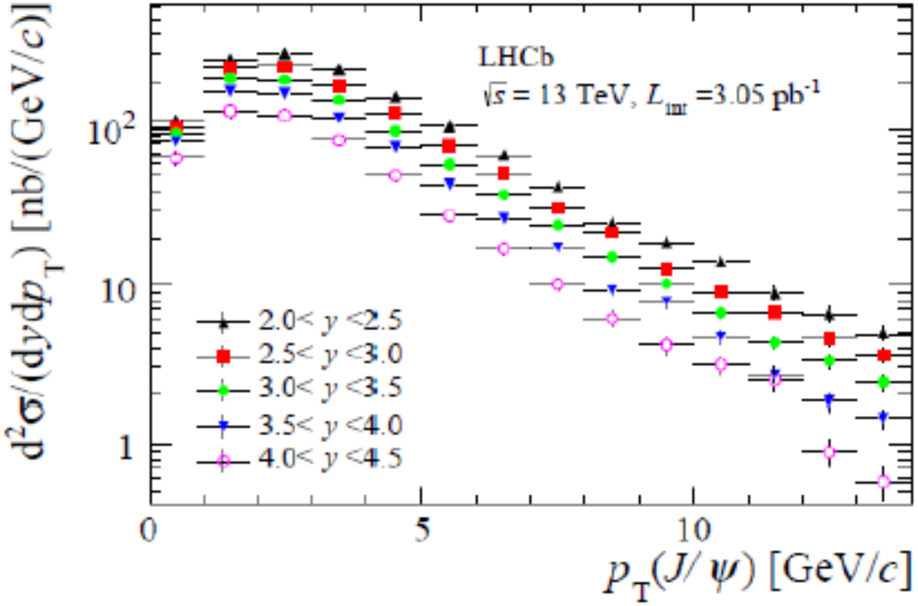


$D^0 \to K^- \pi^+$ $D^+ \to K^- \pi^+ \pi^+$ $D_s^+ \to K^- K^+ \pi^+$

- Background almost non existent – tribute for the excellent LHCb tracking performance – off-line tracking quality in the HLT
- The number of events is much higher than that in RUN I

❑ J/ψ cross-section measurement (prompt and secondary)





$$\sigma^{J/\psi}_{prompt} = 15.30 \pm 0.03\,(stat) \pm 0.86\,(sys)\,\mu b$$

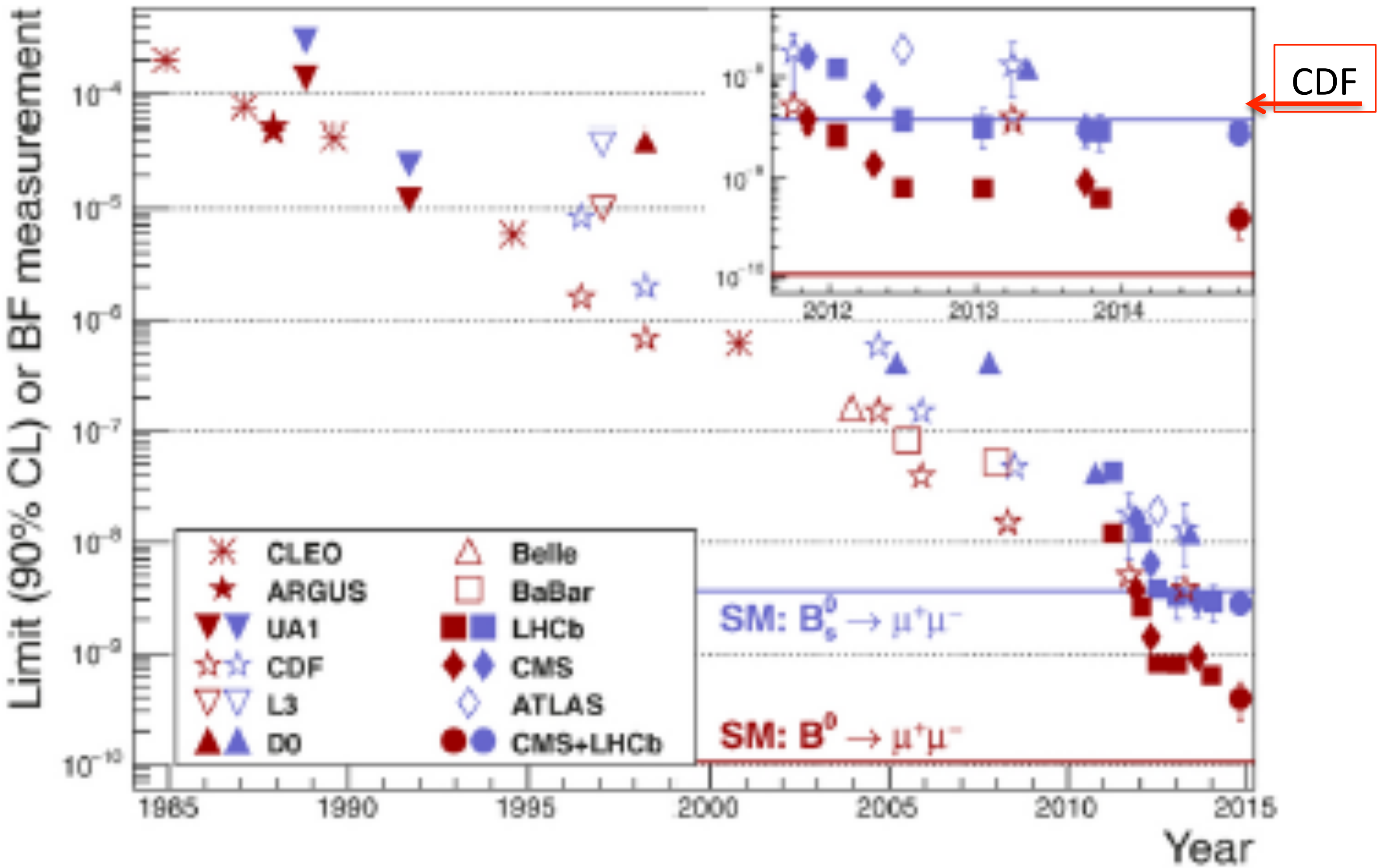
$$\sigma^{J/\psi}_{from-B} = 2.34 \pm 0.01\,(stat) \pm 0.13\,(sys)\,\mu b$$

$$\sigma^{b\bar{b}} = 515.0 \pm 2.0\,(stat) \pm 53.0\,(sys)\,\mu b$$

=> LHCb is back on stage

Bs decay into 2 muons discovery & beyond

Intensively searched for over 30 years!

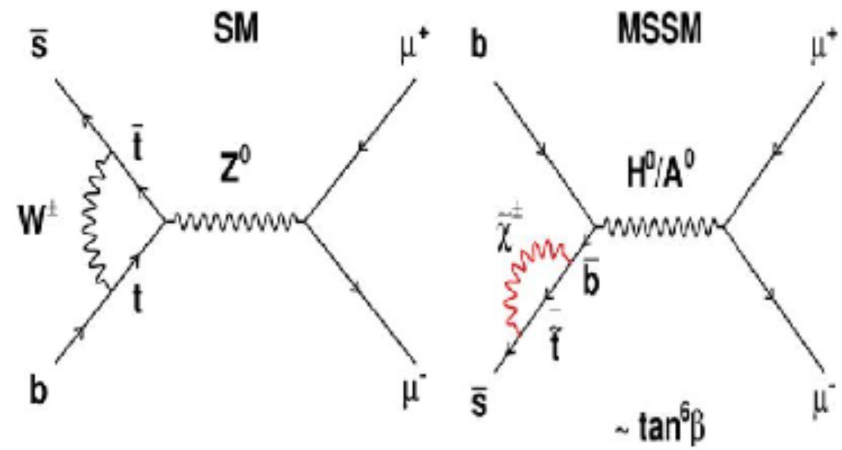


An important discovery at LHC 2010-2012 by CMS and LHCb

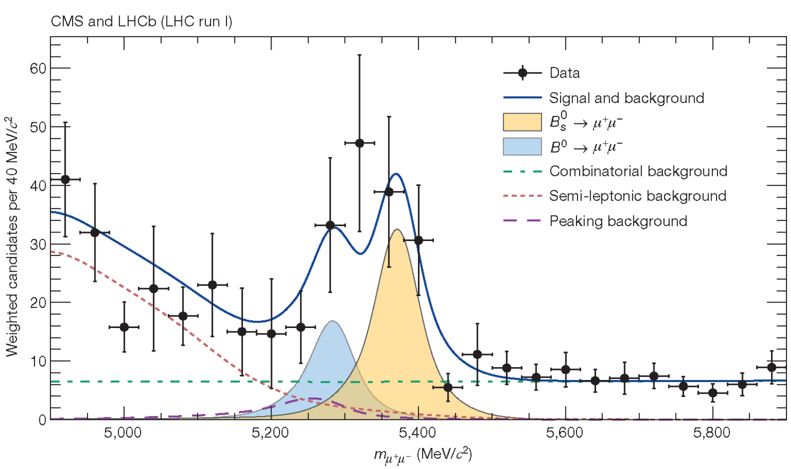
For long time we were dreaming to find NP

Very rare in Standard Model due to
- absence of tree-level FCNC
- helicity suppression
- CKM suppression

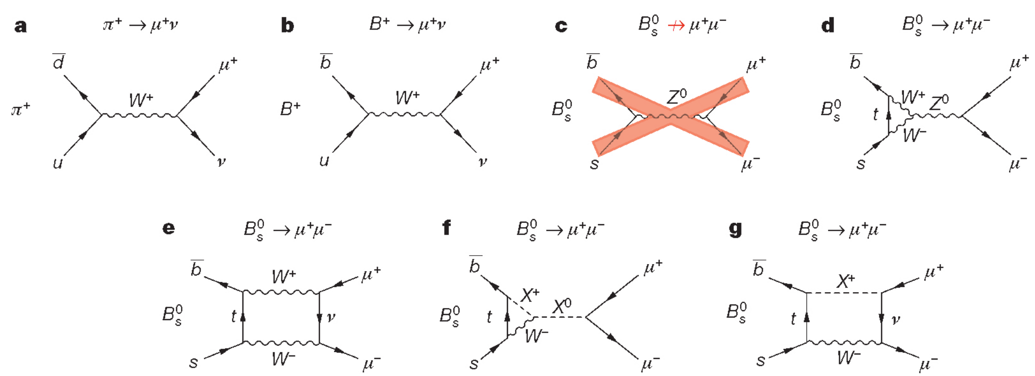
… all features which are not necessarily reproduced in extended models



$$B(B_s \to \mu^+\mu^-)^{SM} = (3.66 \pm 0.23) \times 10^{-9} \qquad B(B_s \to \mu^+\mu^-)^{MSSM} \sim \tan^6\beta / M^4_{A0}$$

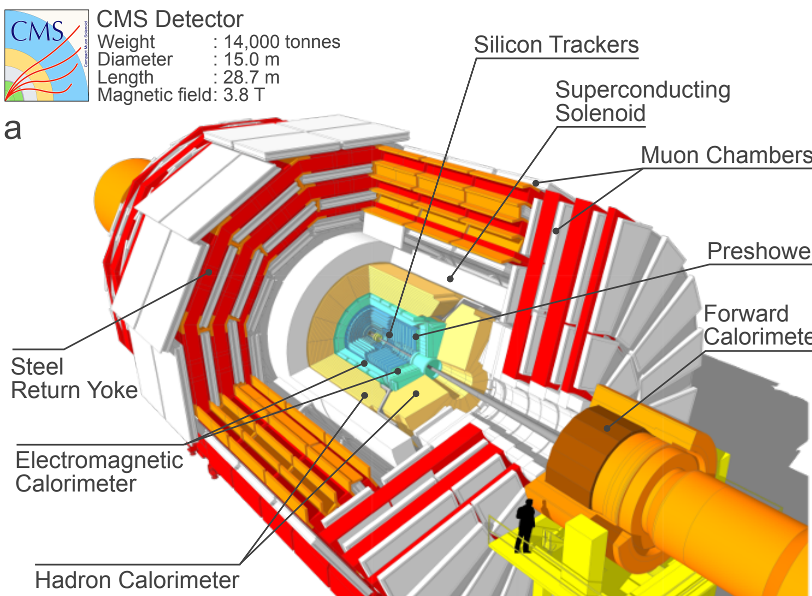


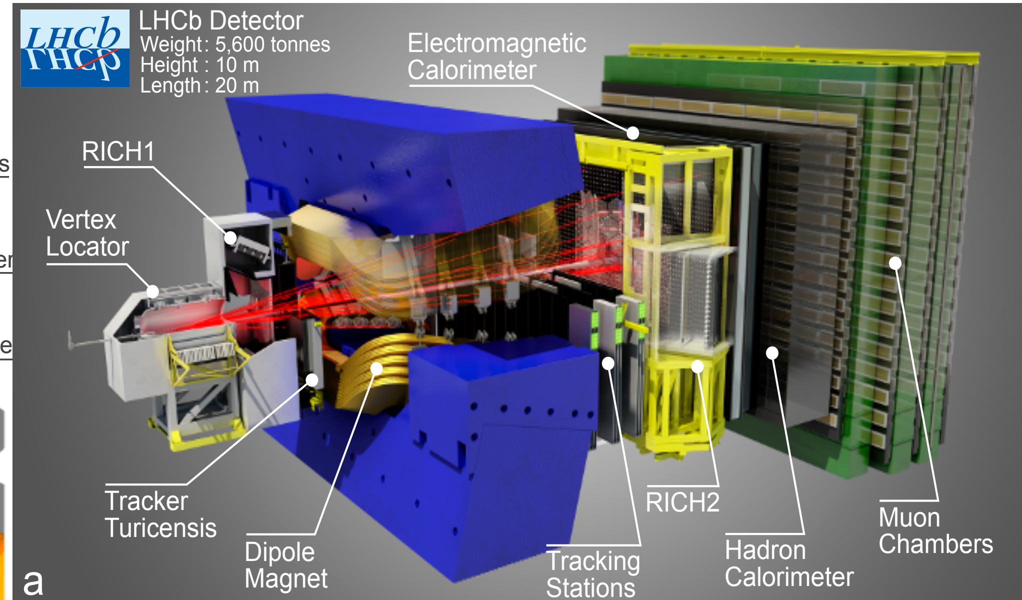
Weighted distribution of dimuon invariant mass, $m_{\mu+\mu-}$, for all categories.

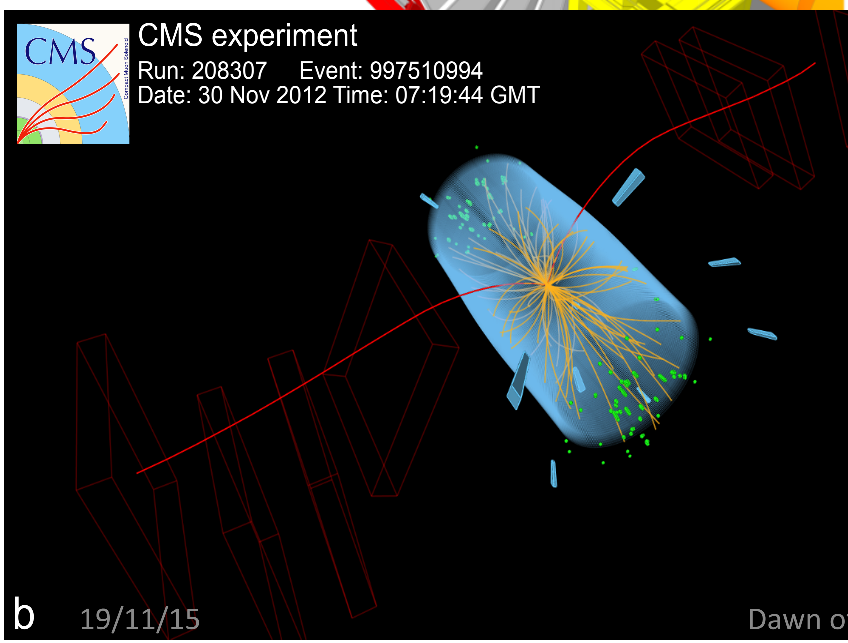


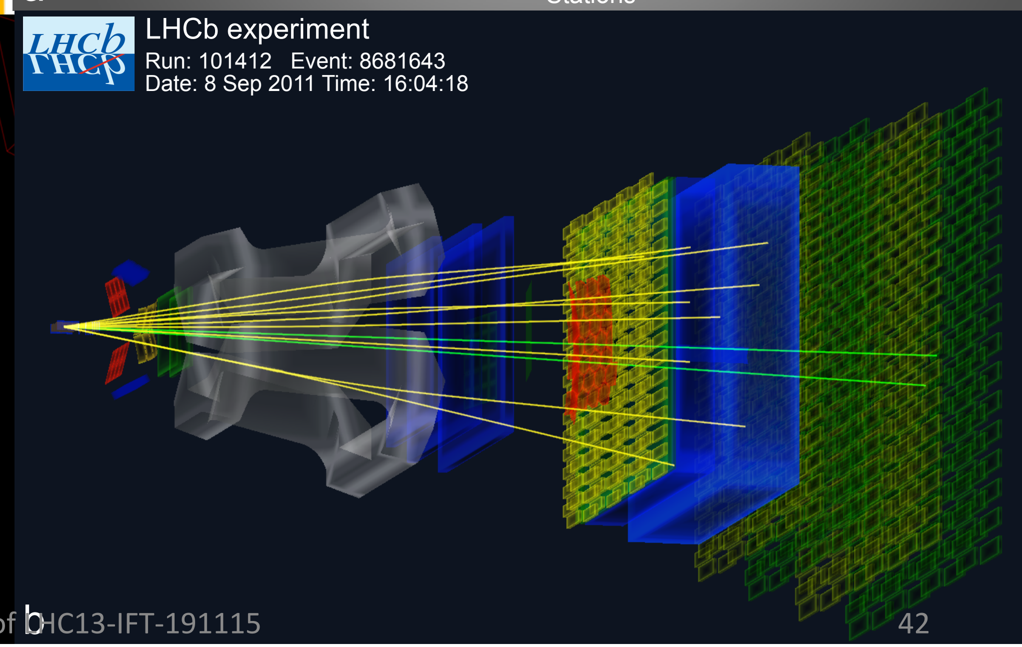
Feynman diagrams related to the $B^0_s \to \mu^+\mu^-$ decay

The Bs➔μμ events seen in CMS and in LHCb

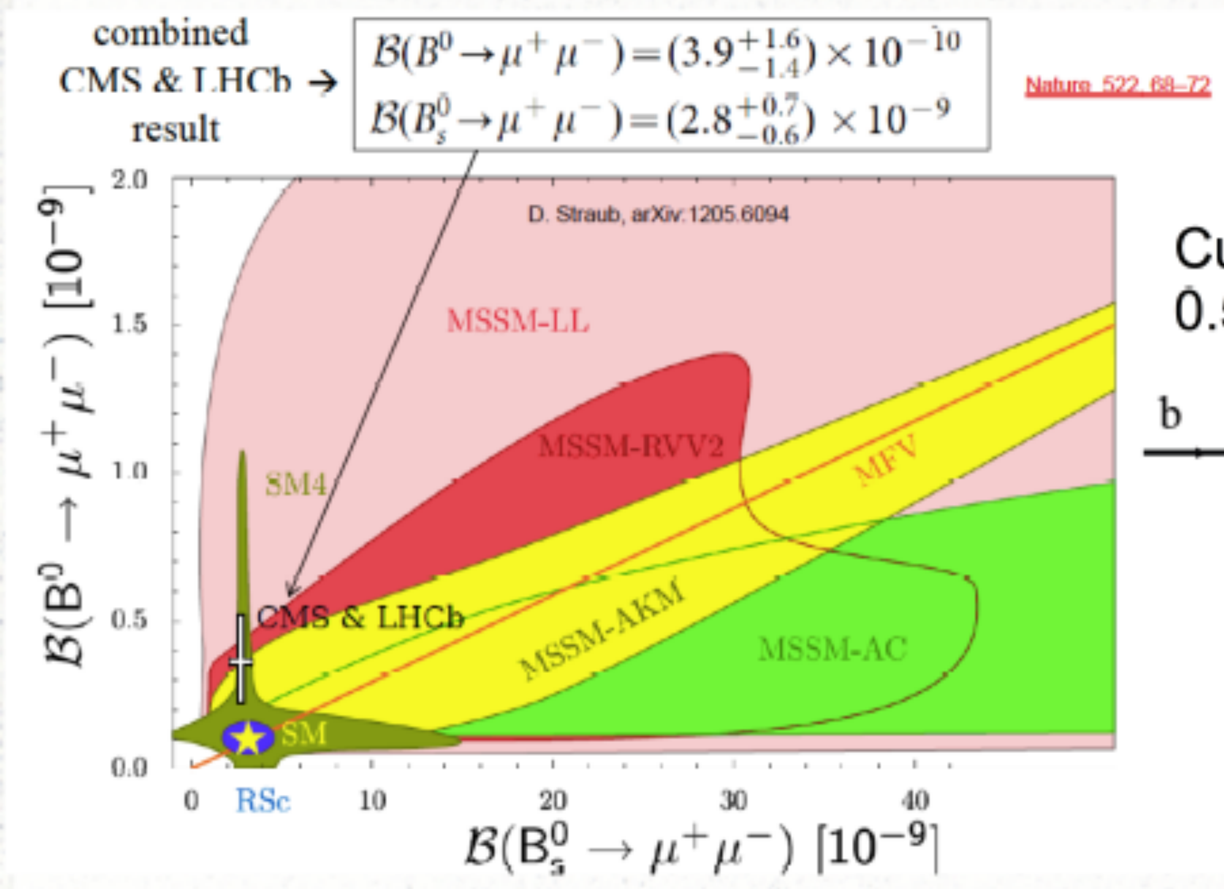




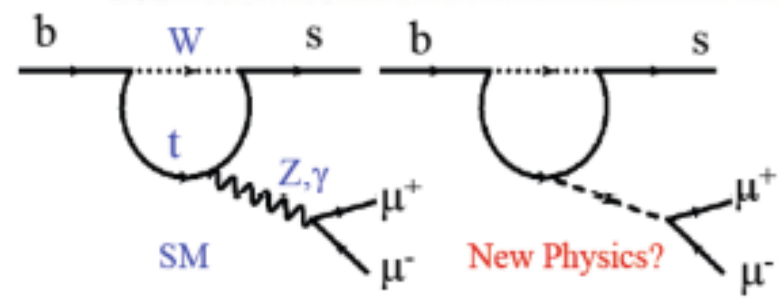




Is this the end of the story??



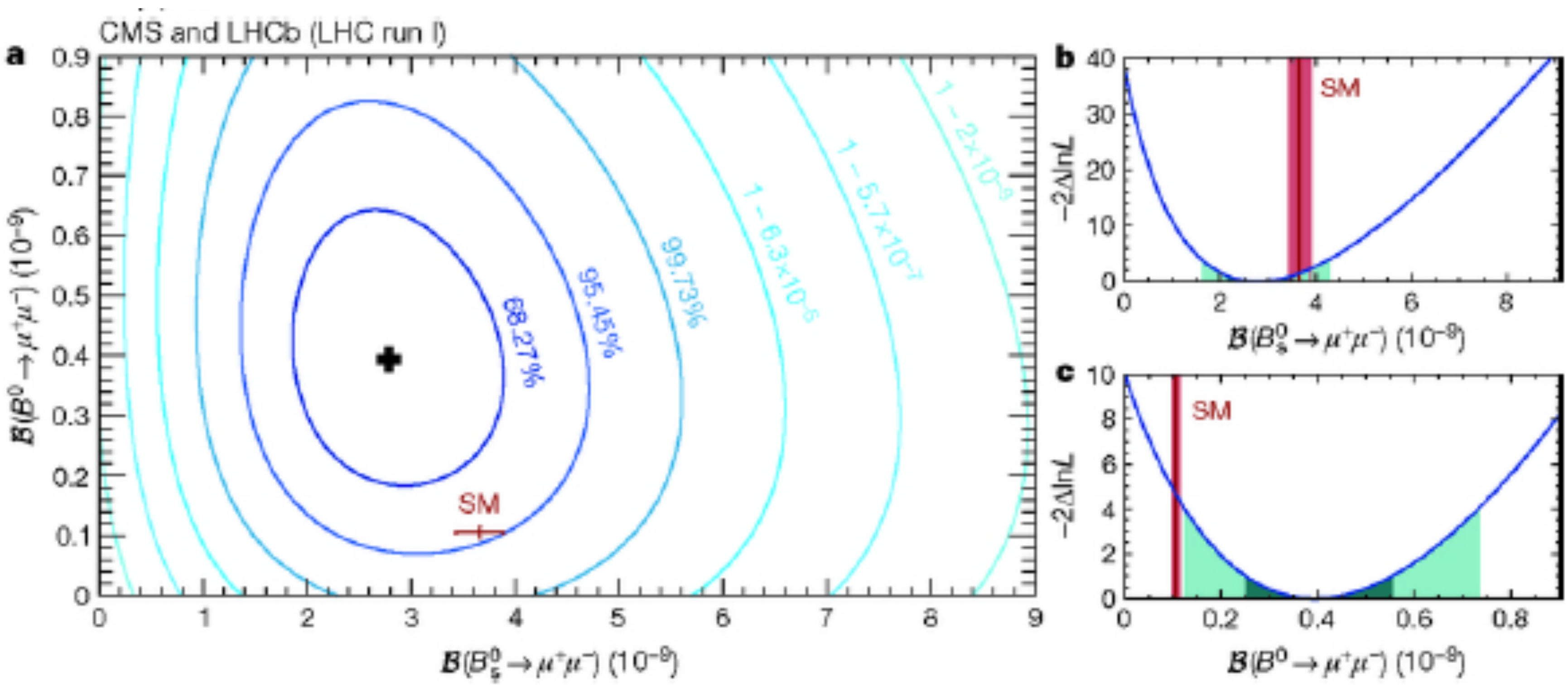
Currently probe NP masses 0.5-1 TeV - as Higgs coupling



- Expect LHCb 5x better resolution on BR(Bd)/BR(Bs) at end of Run 3 (σ = 0.4 , still far from current σ(th) = 0.05)
- Extremely important probe, and will stay so for a long time in future
- Possible NP at tree level probed at even higher scales (0(100 TeV))

=> Moving towards HIGH PRECISION ERA for Bs to dimuon decay

Is this the end of the story??



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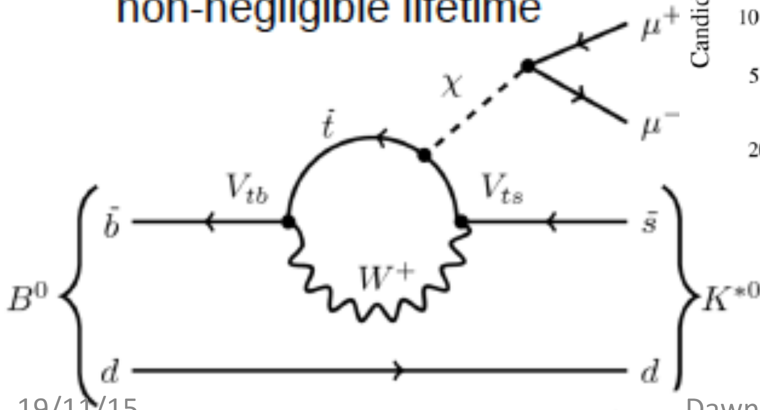
=> Moving towards HIGH PRECISION ERA for Bs to dimuon decay

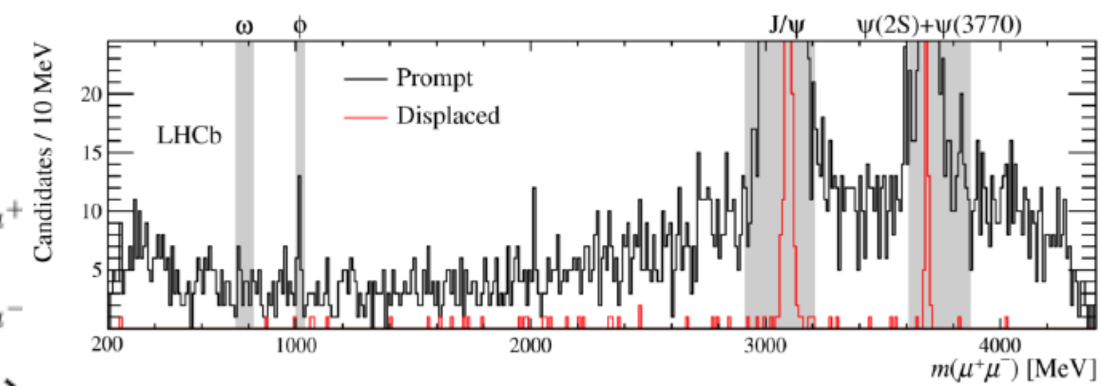
Full angular analysis of $B^0 \to K^{*0}\mu^+\mu^-$

LHCb-CONF-2015-002

- $B^0 \to K^{*0}\mu^+\mu^-$ provides superb laboratory to search for new physics in $b \to s l^+ l^-$ FCNC processes
  - rates, angular distributions and asymmetries sensitive to NP
  - experimentally clean signature
  - many kinematic variables … with clean theoretical predictions

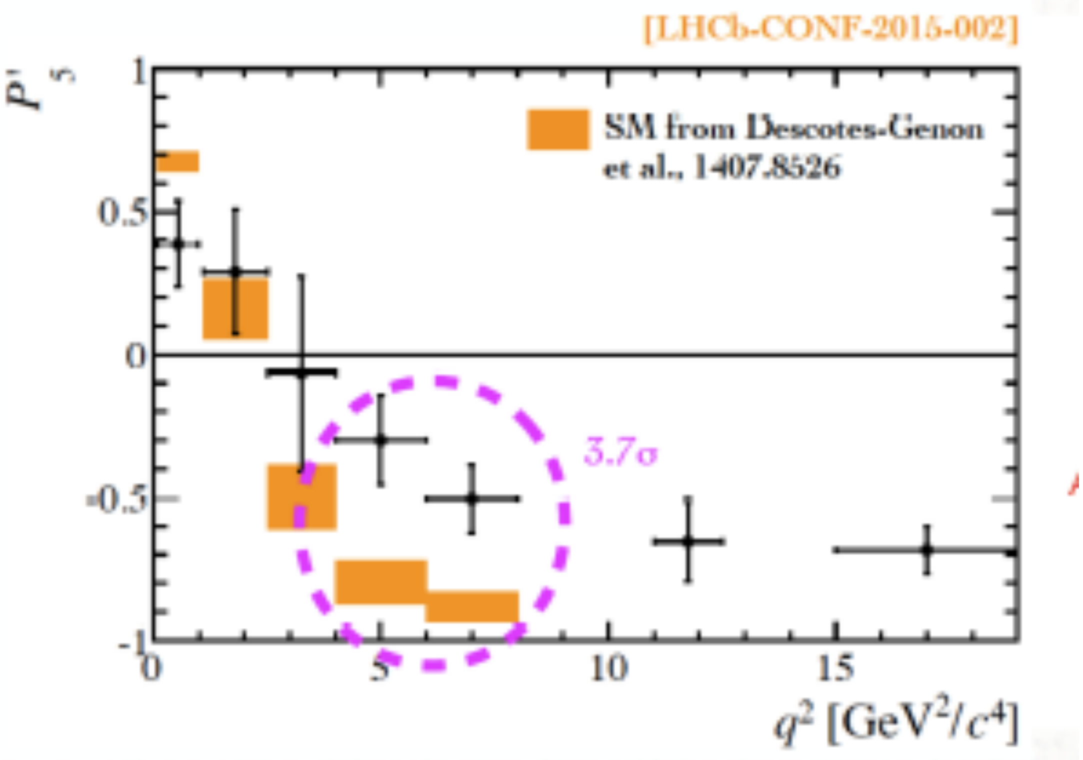
Search for narrow μμ peak in $B \to K^{*0}\mu\mu$ decays corresponding to χ with either negligible or non-negligible lifetime





No significant peak away from known resonances

Existing deviations: $B \to K^*\mu\mu$



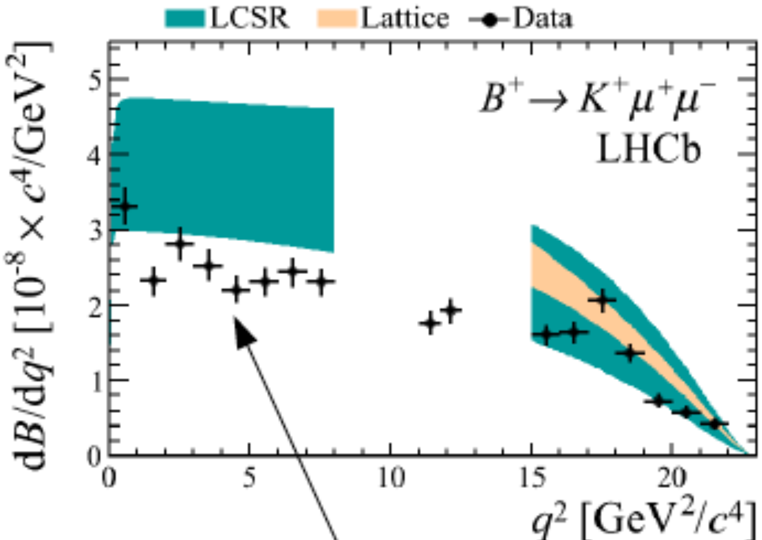
Study of this decay as a function of different angular distribution, here P'5.

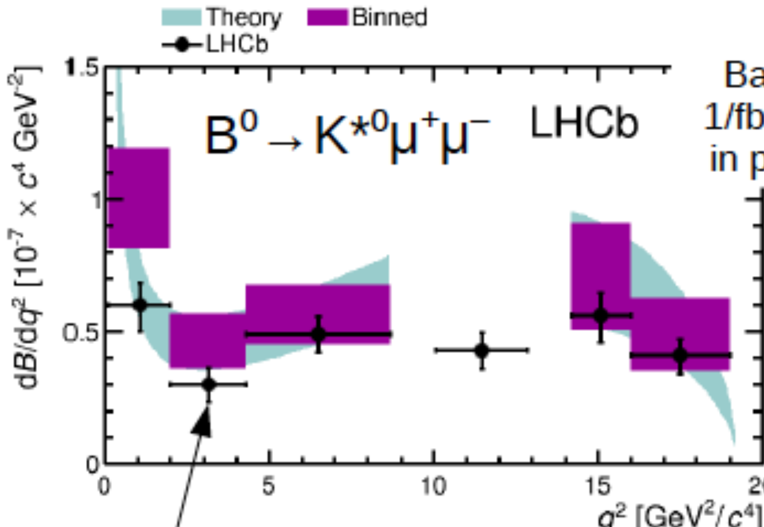
Plotted as a function of q2 = mass(muon pair)

=> **local deviation wrt to SM calculation at 3.7σ** level in the q2 region from **4.3 to 8.68 Gev2/c4**.

More data is not only more stat, but will also allow exploring further variables & channels => learn more about Physics.

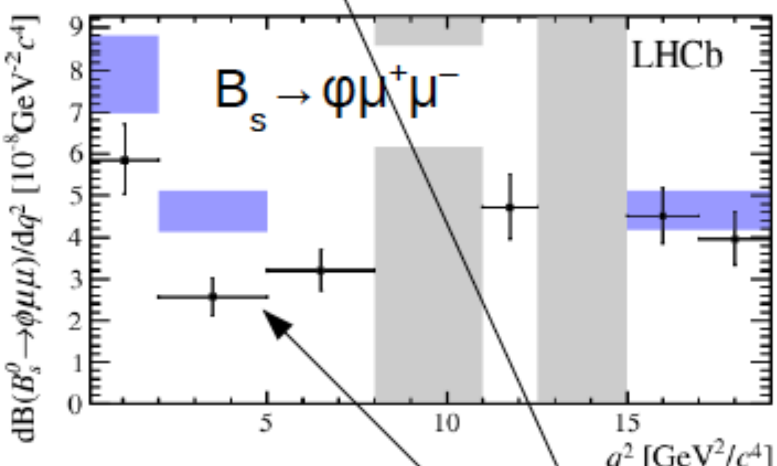
$b \rightarrow s\mu^+\mu^-$ branching fractions

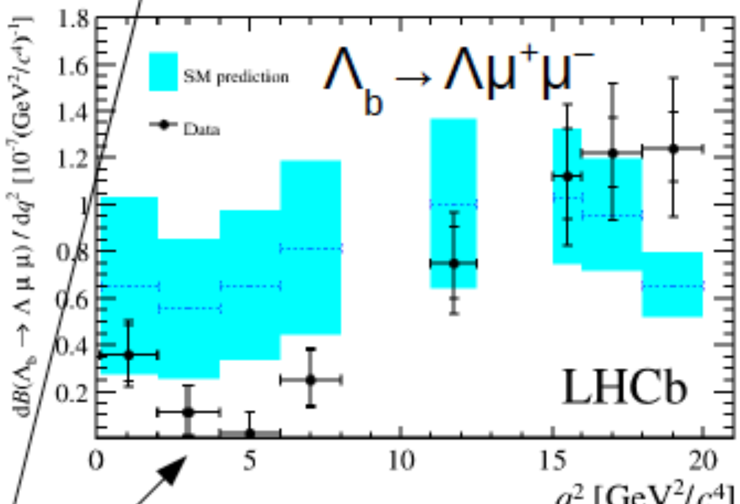




Based on 1/fb; update in progress

Several 3σ hints of BSM





Trend to be below SM prediction at low q^2?

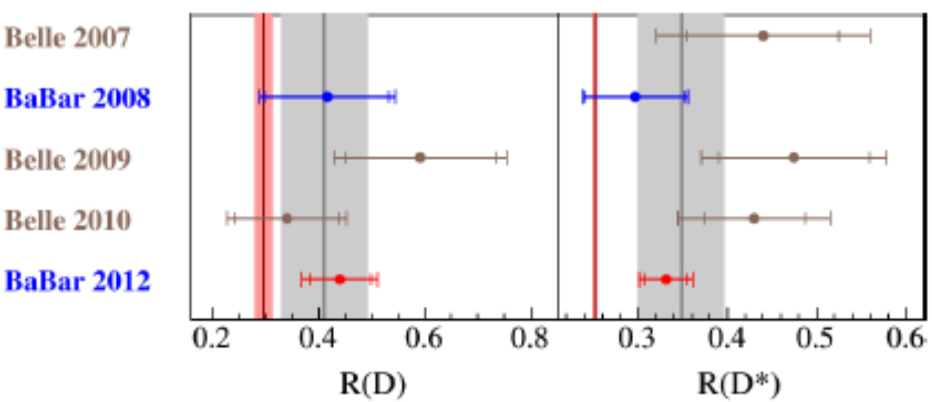
TEST of LEPTON UNIVERSALITY

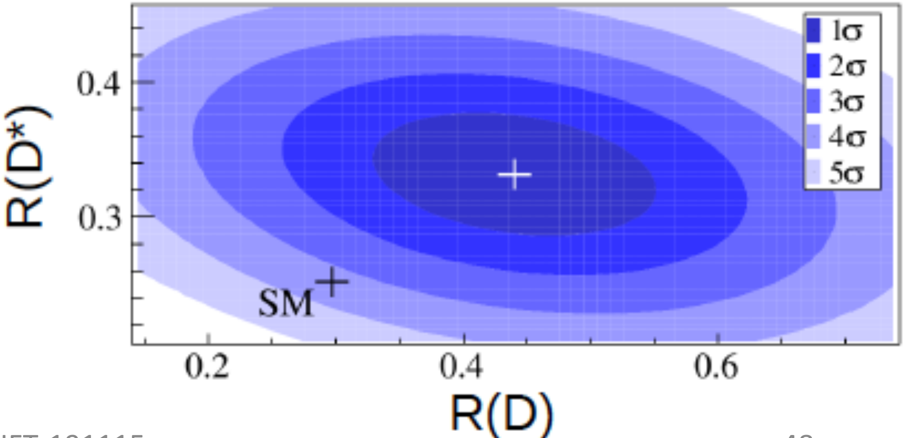
$B \rightarrow D^{(*)}\tau\nu$

T-lepton our best friend!

- Powerful channel to test lepton universality
  - ratios $R(D^{(*)}) = \mathcal{B}(B \rightarrow D^{(*)}\tau\nu)/\mathcal{B}(B \rightarrow D^{(*)}\mu\nu)$ could deviate from SM values, e.g. in models with charged Higgs bosons
- Heightened interest in this area
  - anomalous results from BaBar
  - other hints of lepton universality violation, e.g. R_K , $H \rightarrow \tau\mu$

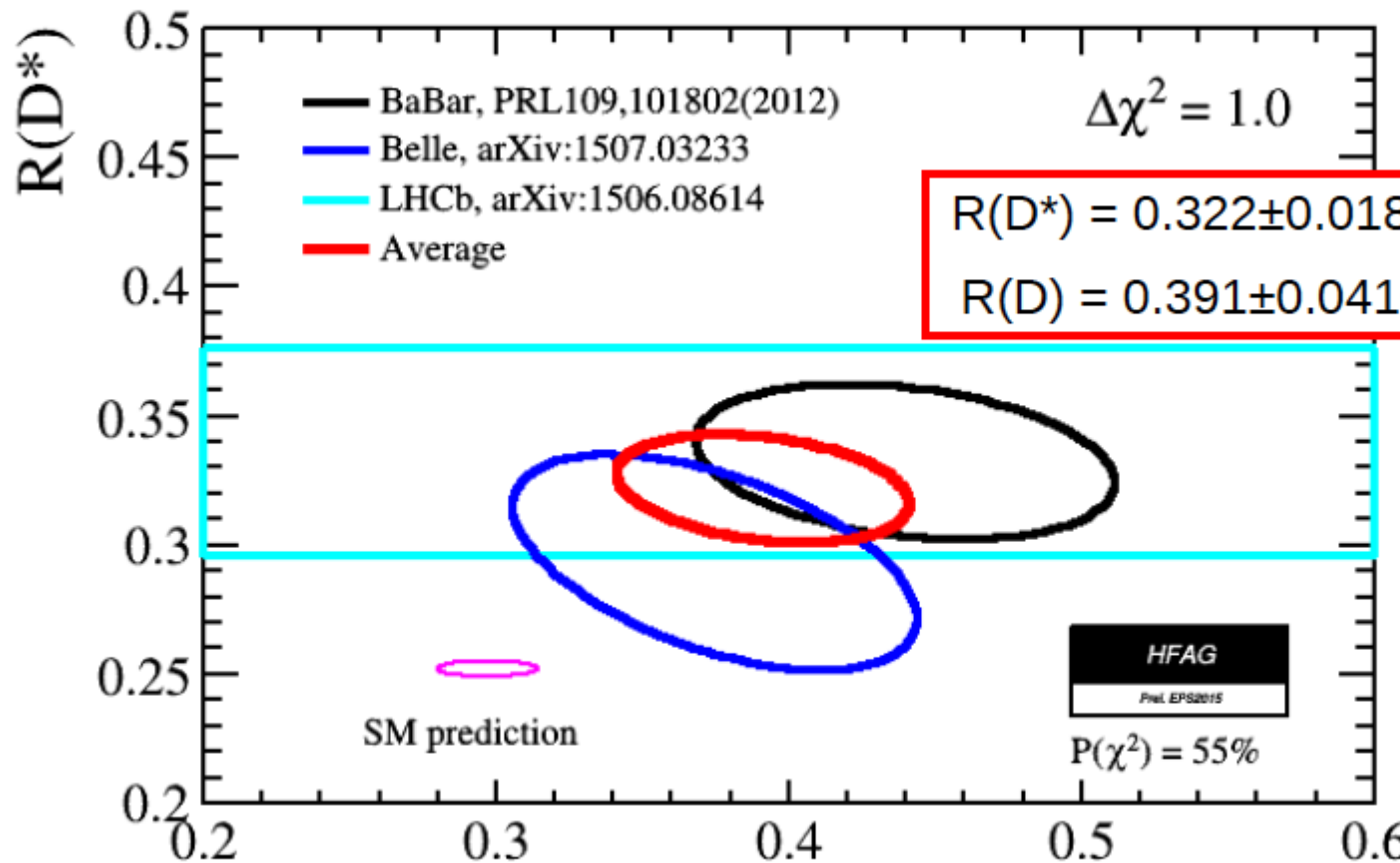
PRL 109 (2012) 101802
& PRD 88 (2013) 072012





$B \to D^{(*)}\tau\nu$

Tension with SM at 3.9σ



SM predictions from
PRD 85 (2012) 094025

Expand the Lepton Universality Physics programme to electron & TAU's and search for Lepton Number Violation in parallel: B->τμ, Kτμ, Keμ etc.

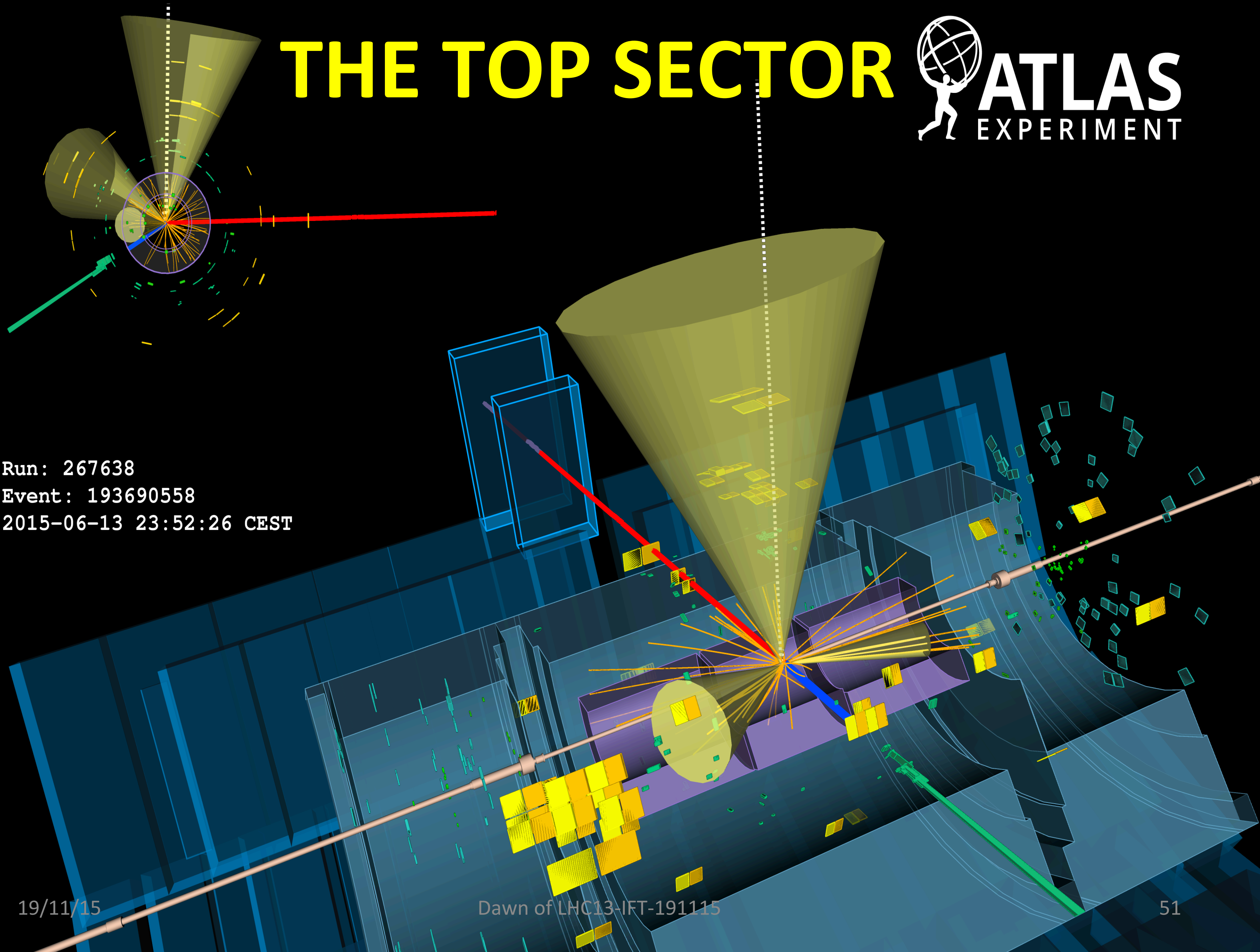
CMS: H->τμ

Studies for ECFA HL-LHC workshop

Table 2: Expected sensitivities that can be achieved on key heavy flavour physics observables, using the total integrated luminosity recorded until the end of each LHC run period. Discussion of systematic uncertainties is given in the text. Uncertainties on ϕ_s are given in radians. The values for flavour-changing neutral-current top decays are expected 95% confidence level upper limits in the absence of signal.

		LHC era			HL-LHC era	
		Run 1	Run 2	Run 3	Run 4	Run 5+
$\frac{\mathcal{B}(B^0\to\mu^+\mu^-)}{\mathcal{B}(B^0_s\to\mu^+\mu^-)}$	CMS	> 100%	71%	47%	...	21%
	LHCb	220%	110%	60%	40%	28%
$q_0^2\ A_{\rm FB}(K^{*0}\mu^+\mu^-)$	LHCb	10%	5%	2.8%	1.9%	1.3%
	Belle II	—	50%	7%	5%	—
$\phi_s(B^0_s\to J/\psi\phi)$	ATLAS	0.11	0.05–0.07	0.04–0.05	...	0.020
	LHCb	0.05	0.025	0.013	0.009	0.006
$\phi_s(B^0_s\to\phi\phi)$	LHCb	0.18	0.12	0.04	0.026	0.017
γ	LHCb	7°	4°	1.7°	1.1°	0.7°
	Belle II	—	11°	2°	1.5°	—
$A_\Gamma(D^0\to K^+K^-)$	LHCb	3.4×10^{-4}	2.2×10^{-4}	0.9×10^{-4}	0.5×10^{-4}	0.3×10^{-4}
	Belle II	—	18×10^{-4}	4–6×10^{-4}	3–5×10^{-4}	—
$t\to qZ$	ATLAS	...	...	23×10^{-5}	...	4.1–7.2×10^{-5}
	CMS	100×10^{-5}	...	27×10^{-5}	...	10×10^{-5}
$t\to q\gamma$	ATLAS	...	...	7.8×10^{-5}	...	1.3–2.5×10^{-5}
LHCb ∫ L dt		3/fb	8/fb	23/fb	46/fb	70/fb (?)
ATLAS/CMS ∫ L dt		25/fb	100/fb	300/fb	...	3000/fb

THE TOP SECTOR



THE TOP

- Our best friend:

  - Largely produced at LHC & now well known in its SM suit
  - Like the HF sector, the top can be used now for high precision measurements in order to detect any possible deviation from SM.
- Our best enemy:
  - Physics background for a large variety of BSM searches

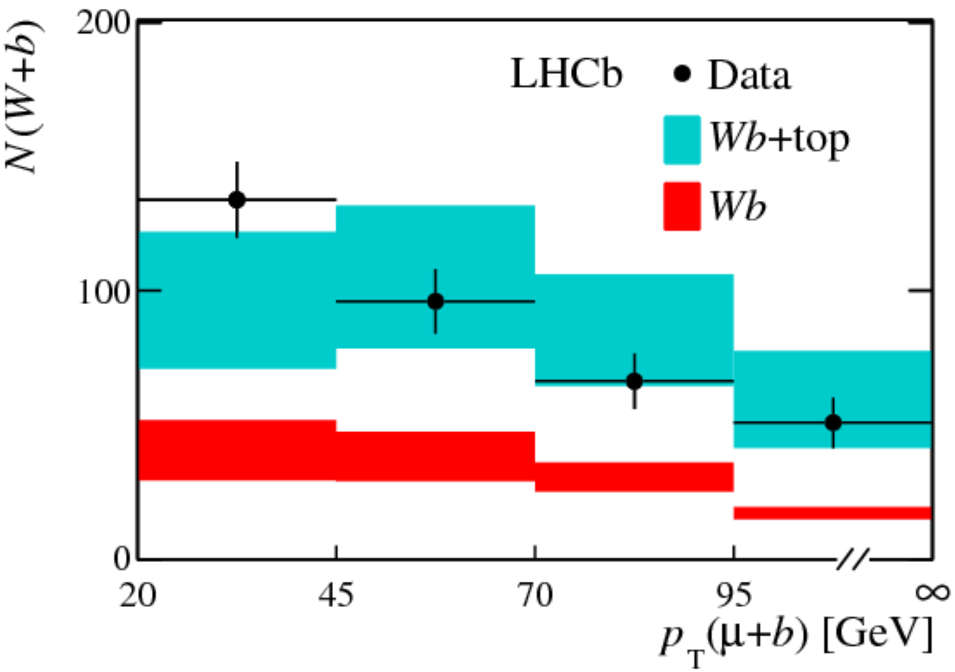
And among the main objectives of LHC13 era:

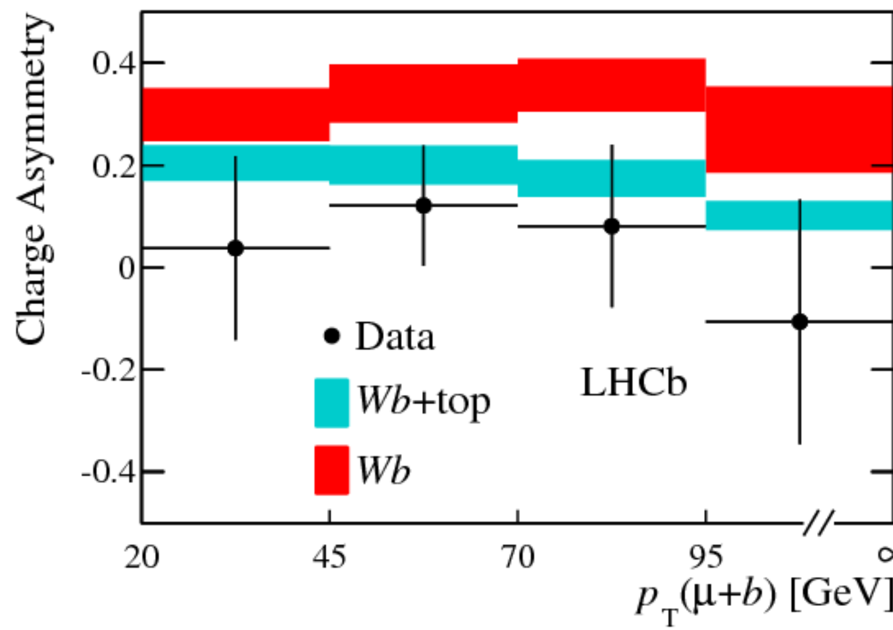
The ttbar H production

First time observation of top production in the Forward region (2.0<η<4.5) *(Sept 2015)*

σ(top)[7TeV]=239±53(stat)±38(syst)fb

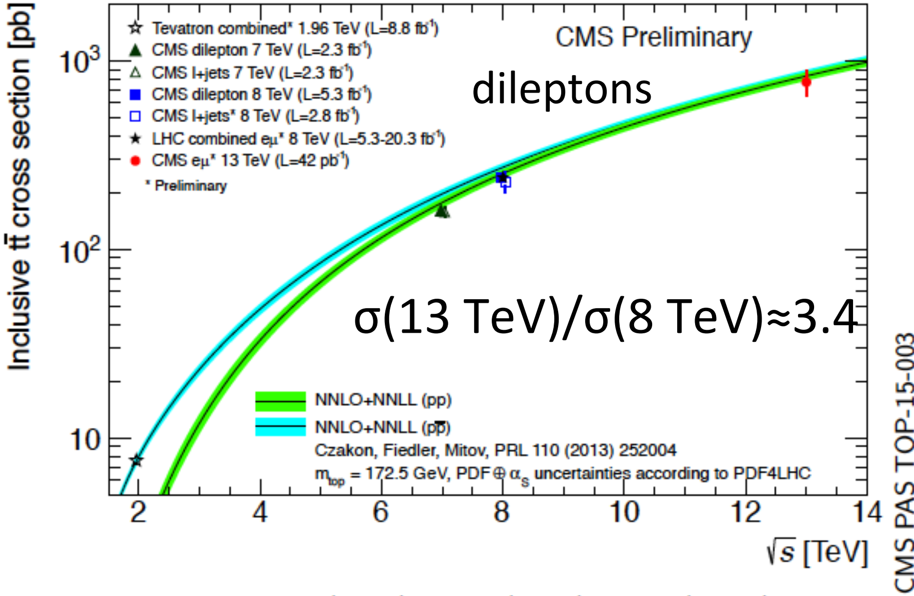
σ(top)[8TeV]=289±43(stat)±46(syst)fb



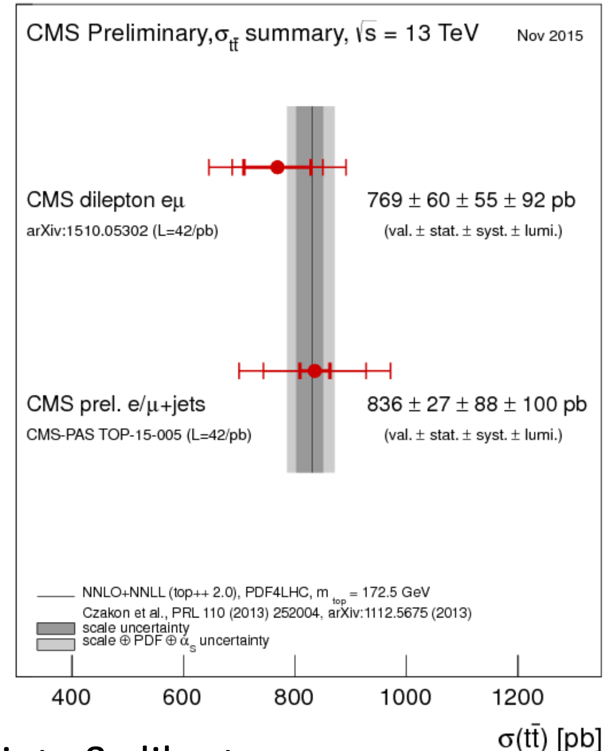


Results for the W+B yield (left) and charge asymmetry (right) versus Pt(μ+b) compared to SM predictions obtained at NLO using MCFM.

The enhancement at forward rapidities of ttbar production via qq and qg scattering / gg fusion **can result in larger charge asymmetries may be sensitive to BSM physics.**



Good Agreement with Theory @ NLO

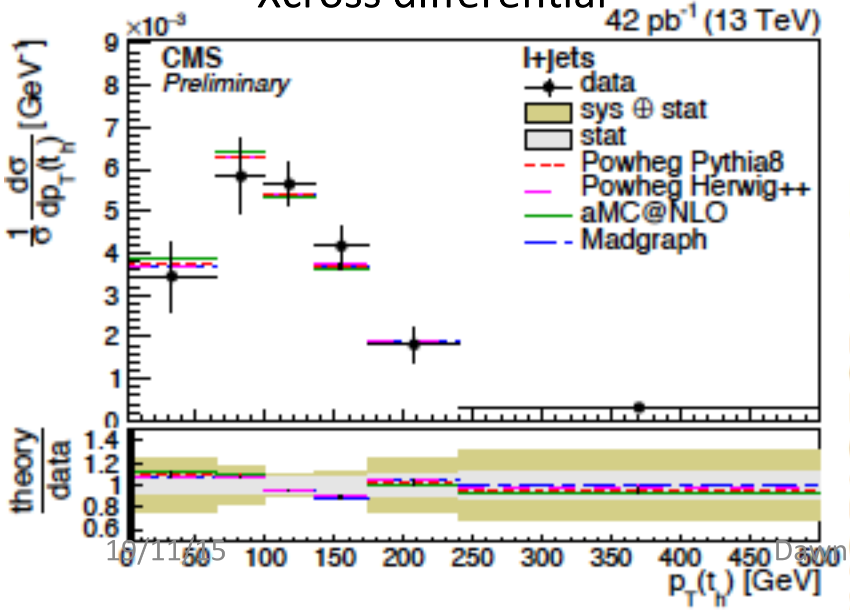


$$\sigma_{t\bar{t}} = 772 \pm 60(\text{stat}) \pm 62(\text{syst}) \pm 93(\text{lumi})\ \text{pb}$$

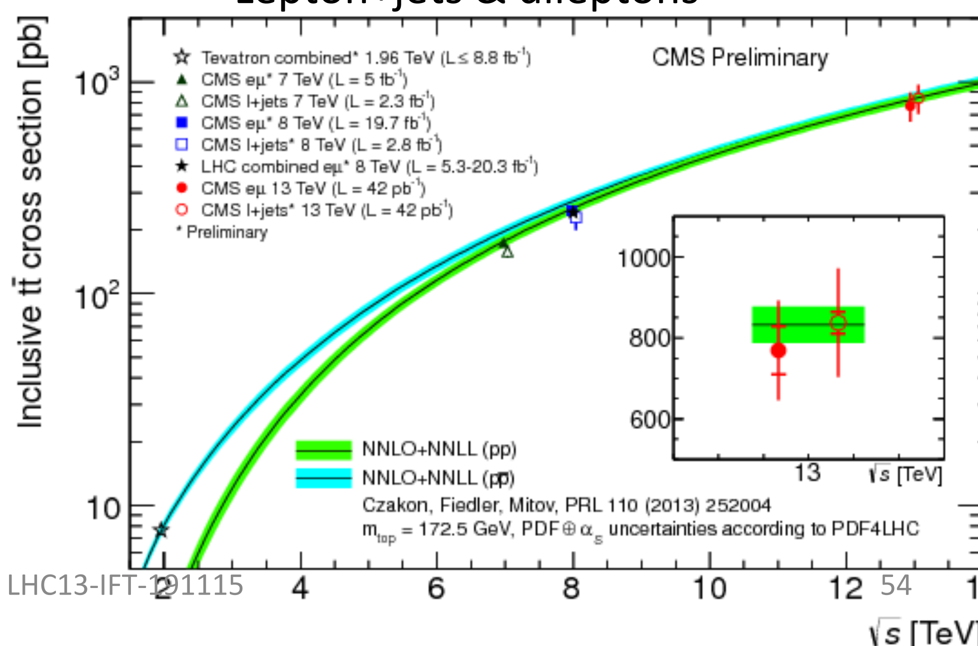
In agreement with the expectations from the standard model

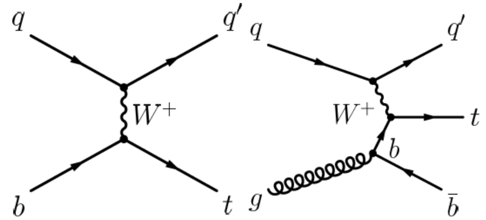
$$\sigma_{t\bar{t}}^{\text{NNLO+NNLL}} = 832 \pm 46\ \text{pb}$$

Xcross differential

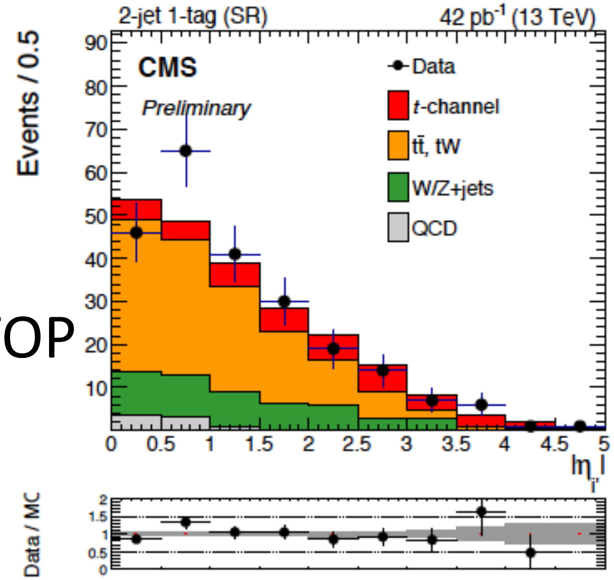


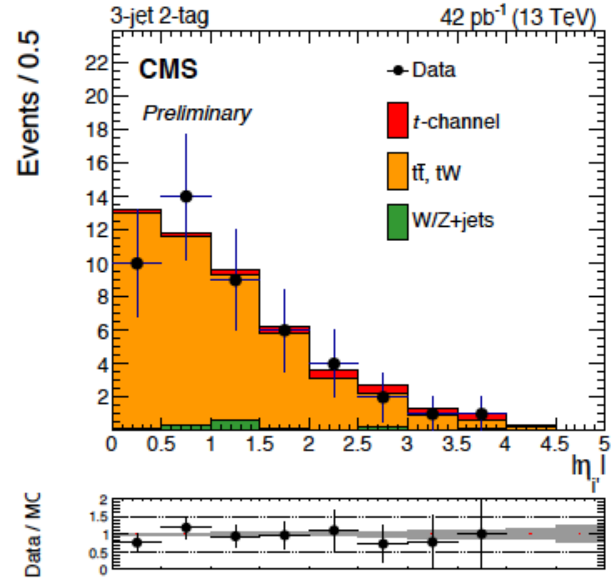
Lepton+jets & dileptons





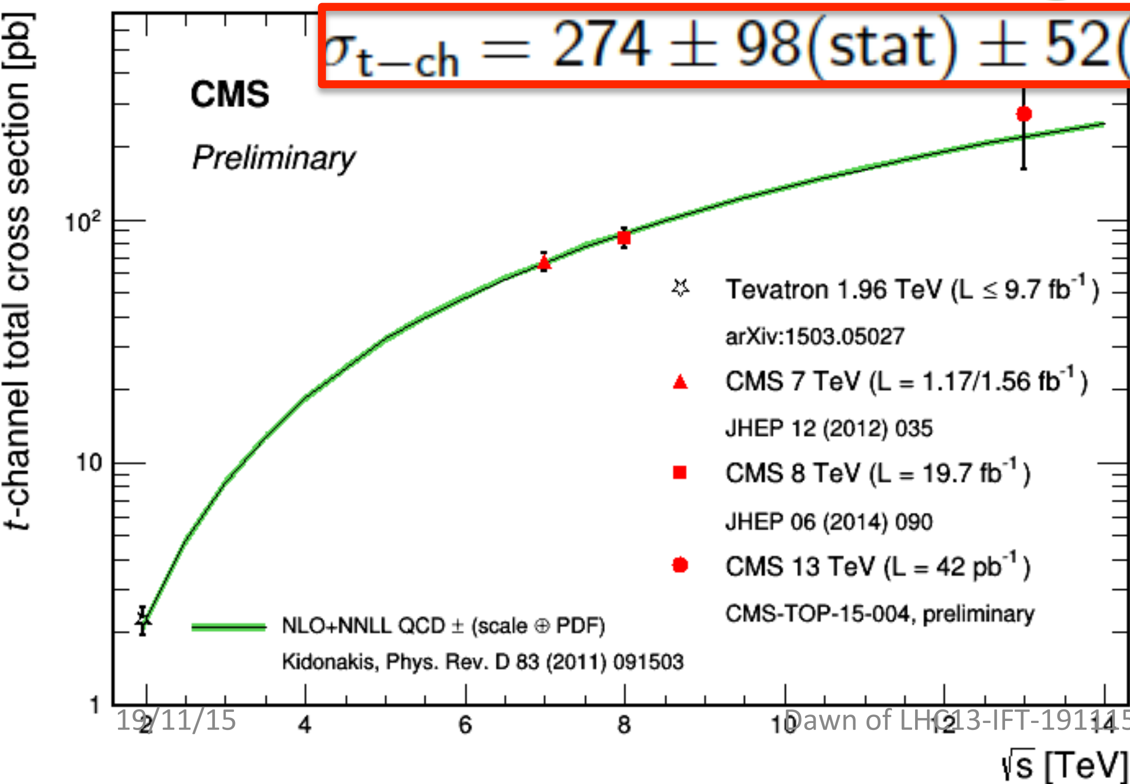
REDISCOVERING SINGLE TOP in ONLY 42 pb-1 at LHC13!!





3.5 σ observed significance, while 2.7 σ is expected

$$\sigma_{t-ch} = 274 \pm 98(\text{stat}) \pm 52(\text{syst}) \pm 33(\text{lumi})\ \text{pb}$$



$$|V_{tb}| = 1.12 \pm 0.24(\text{exp}) \pm 0.02(\text{theo})$$

In agreement with SM

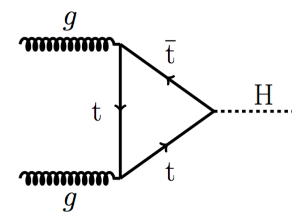
Looking for ttbarH and Yukawa coupling of Top and Higgs => IS THE HIGGS SO ***RRRRRR***EALLY STANDARD***?????***

PREMISES:

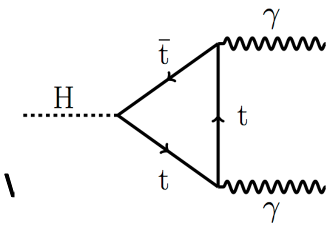
- Strong H coupling to TOP vs other fermions
- Because its high mass, Top Yukawa coupling expected to be 1.
- Because m(top)>m(H) its coupling cannot be assessed by measuring Higgs decays to top quarks.
- Obervation of production of H in association with pair of tops => direct measurement of Top-Higgs Yukawa coupling and allow disambiguation of NP (in tree-level & loop-level measurements)

The ttbarH search strategy

- H coupling to top can be experimentally constrained through measurements involving: gluon fusion production via a fermion loop where top is the dominant contribution assuming there is NO BSM Physics contributing to the loop.



- Likewise Higgs to photons decay involves both a fermion loop diagram dominated by top contribution and a W boson loop contribution.



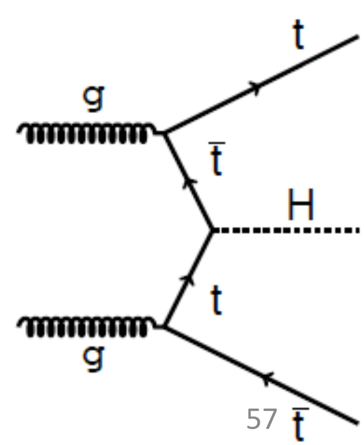
Current measurements of Higgs production via gluon fusion are consistent w expectation for top Yukawa coupling within experimental uncertainties

Probing Top Yukawa coupling directly requires a process that results in both a H-boson and top quarks explicitly reconstructed via their final-state decay products (see next slide)

The production of H in association with a Top-pair satisfies this request.

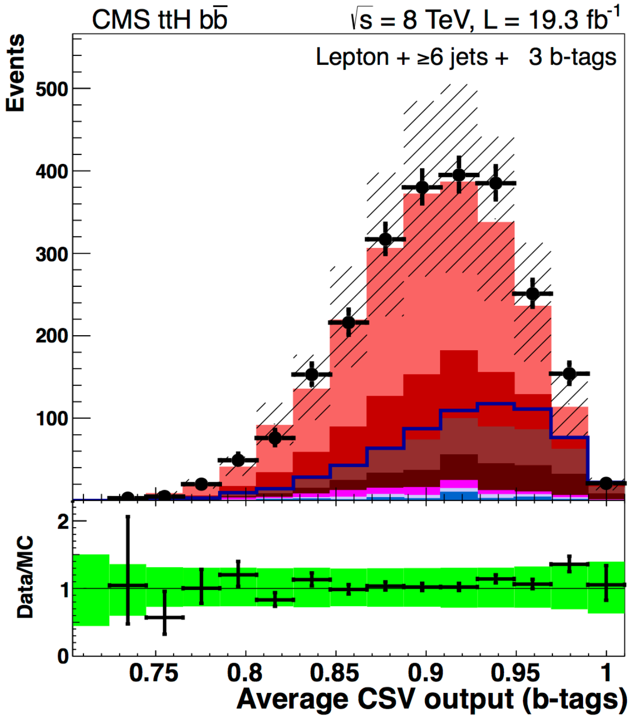
PB: relatively VERY LOW xcross: 130fb at 8TeV cms

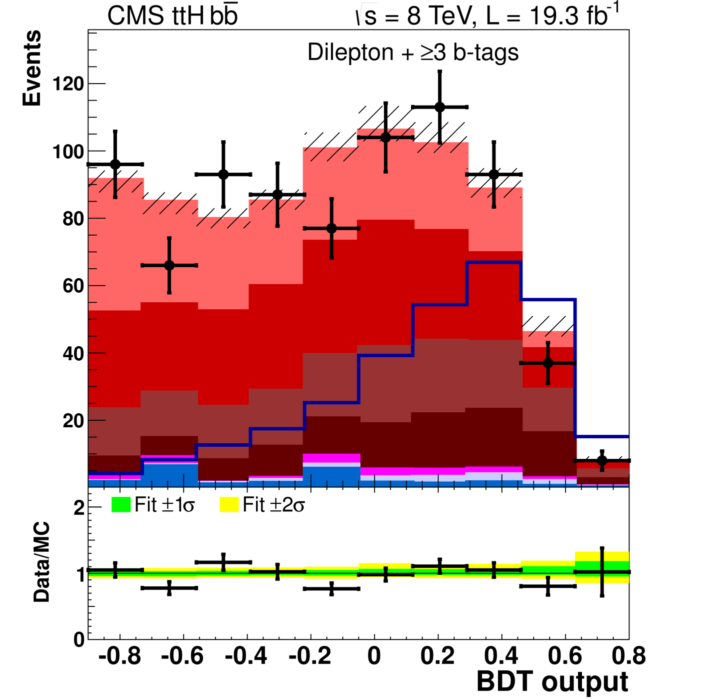
x 4 (at 13 TEV) but σ(top-pair) x 3 as well…

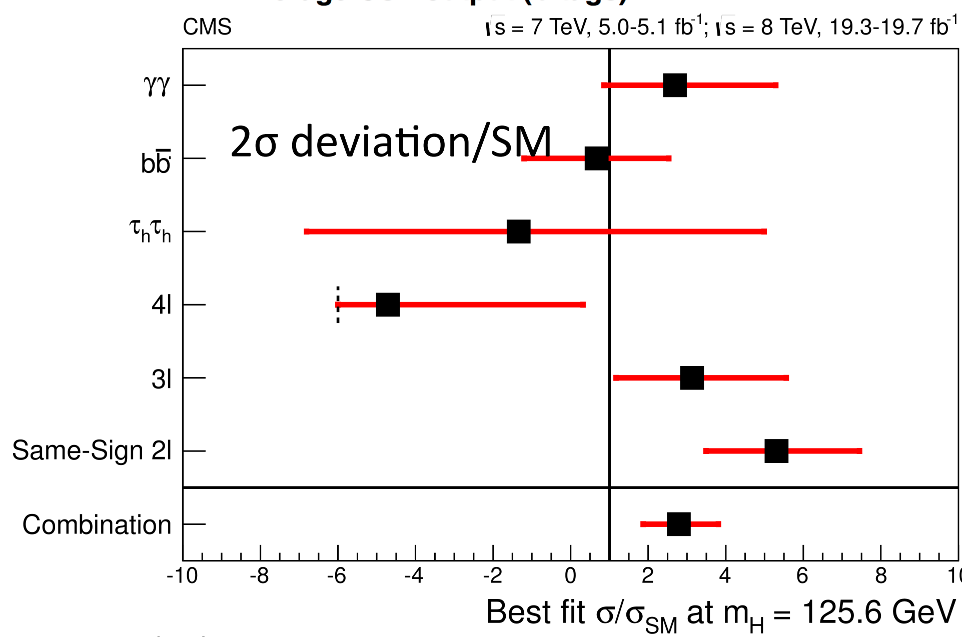


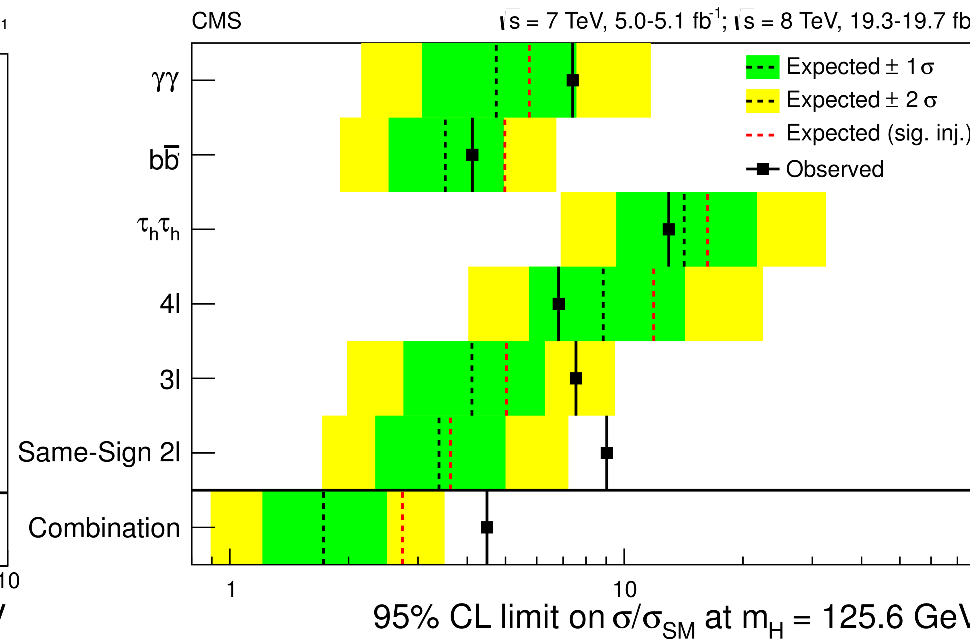
NP predict heavy states decaying into a Top + H => any deviation/SM in ttH production rate => indirect indication of unknown phenomena

Category	Signature	Trigger	Signature
$H \to$ Hadrons $H \to b\bar{b}$ $H \to \tau_h \tau_h$ $H \to WW$	Lepton + Jets ($t\bar{t}H \to \ell\nu jjbbbb$)	Single Lepton	1 e/μ, $p_T > 30$ GeV $\geq$4 jets + $\geq$2 b-tags, $p_T > 30$ GeV
	Dilepton ($t\bar{t}H \to \ell\nu\ell\nu bbbb$)	Dilepton	1 e/μ, $p_T > 20$ GeV 1 e/μ, $p_T > 10$ GeV $\geq$3 jets + $\geq$2 b-tags, $p_T > 30$ GeV
	Hadronic τ ($t\bar{t}H \to \ell\nu\tau_h[\nu]\tau_h[\nu]jjbb$)	Single Lepton	1 e/μ, $p_T > 30$ GeV 2 τ_h, $p_T > 20$ GeV $\geq$2 jets + 1-2 b-tags, $p_T > 30$ GeV
$H \to$ Photons $H \to \gamma\gamma$	Leptonic ($t\bar{t}H \to \ell\nu jjbb\gamma\gamma$, $t\bar{t}H \to \ell\nu\ell\nu bb\gamma\gamma$)	Diphoton	2 γ, $p_T > m_{\gamma\gamma}/2\,(25)$ GeV for 1st (2nd) $\geq$1 e/μ, $p_T > 20$ GeV $\geq$2 jets + $\geq$1 b-tags, $p_T > 25$ GeV
	Hadronic ($t\bar{t}H \to jjjjbb\gamma\gamma$)	Diphoton	2 γ, $p_T > m_{\gamma\gamma}/2\,(25)$ GeV for 1st (2nd) 0 e/μ, $p_T > 20$ GeV $\geq$4 jets + $\geq$1 b-tags, $p_T > 25$ GeV
$H \to$ Leptons $H \to WW$ $H \to \tau\tau$ $H \to ZZ$	Same-Sign Dilepton ($t\bar{t}H \to \ell^{\pm}\nu\ell^{\pm}[\nu]jjj[j]bb$)	Dilepton	2 e/μ, $p_T > 20$ GeV $\geq$4 jets + $\geq$1 b-tags, $p_T > 25$ GeV
	3 Lepton ($t\bar{t}H \to \ell\nu\ell[\nu]\ell[\nu]j[j]bb$)	Dilepton, Trielectron	1 e/μ, $p_T > 20$ GeV 1 e/μ, $p_T > 10$ GeV 1 $e(\mu)$, $p_T > 7(5)$ GeV $\geq$2 jets + $\geq$1 b-tags, $p_T > 25$ GeV
	4 Lepton ($t\bar{t}H \to \ell\nu\ell\nu\ell[\nu]\ell[\nu]bb$)	Dilepton, Trielectron	1 e/μ, $p_T > 20$ GeV 1 e/μ, $p_T > 10$ GeV 2 $e(\mu)$, $p_T > 7(5)$ GeV $\geq$2 jets + $\geq$1 b-tags, $p_T > 25$ GeV









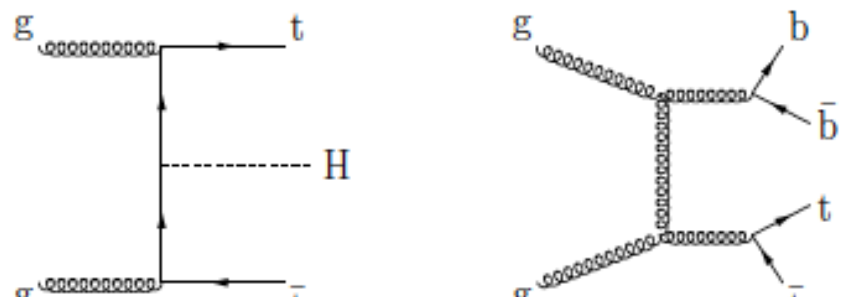
Best fit value is μ =2.8 ± 1.0 at 68% CL

Search for ttH with H->bb & 1lepton + 5 jets or 2 opposite sign leptons with 4 jets signatures

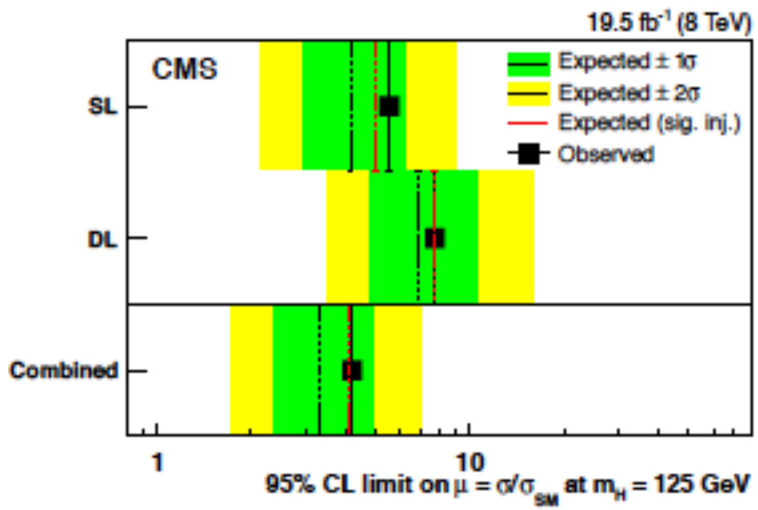
Different (matrix element) analysis

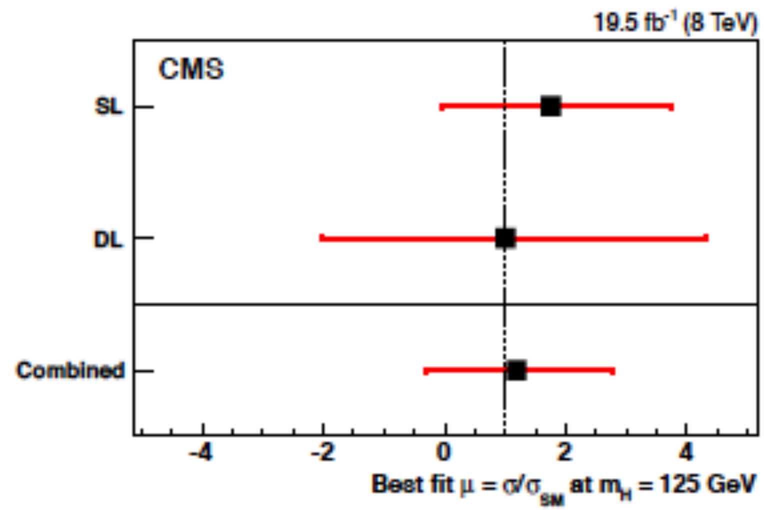
Method: better systematics handle

Signature 1l+5jets or l+l- +4 jets



Results:





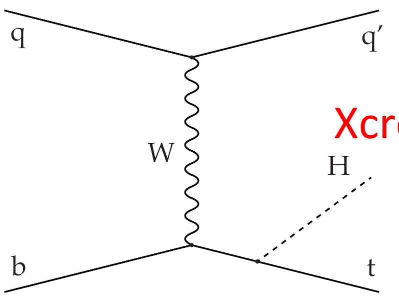
No evidence of a signal is found. The expected upper limit at a 95% CL is $\mu < 3.3$ under the background-only hypothesis. The observed limit is $\mu < 4.2$, corresponding to a best-fit value of $1.2^{+1.6}_{-1.5}$

For completeness:

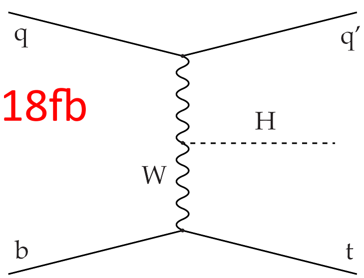
- **H production in association with single top in CMS: 1st time results on anomalous tHq production reported**

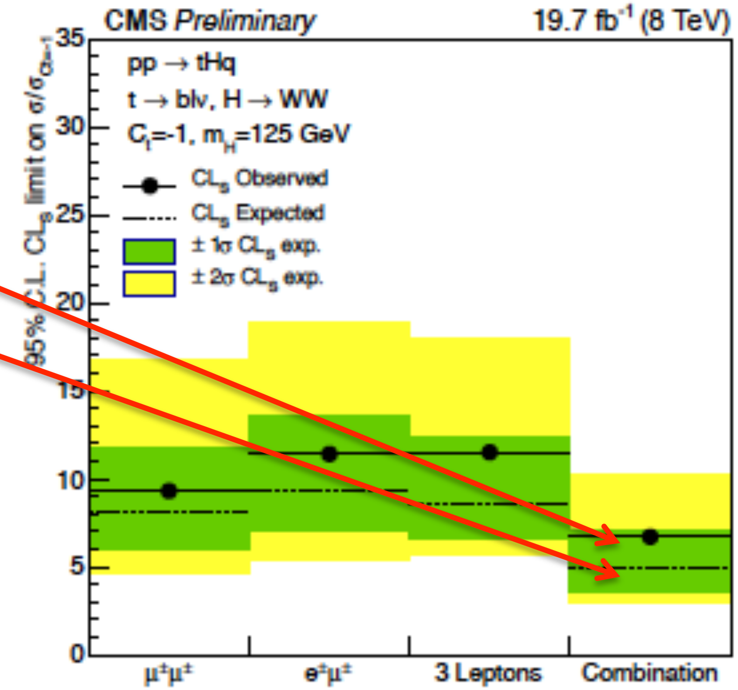
taking C(top))=-1 & multi lepton signatures

=> 95%CL upper limit on σ(tHq) of 6.7 times predicted value with expected limit 5.



Xcross=18fb





- **ttH production with ATLAS**

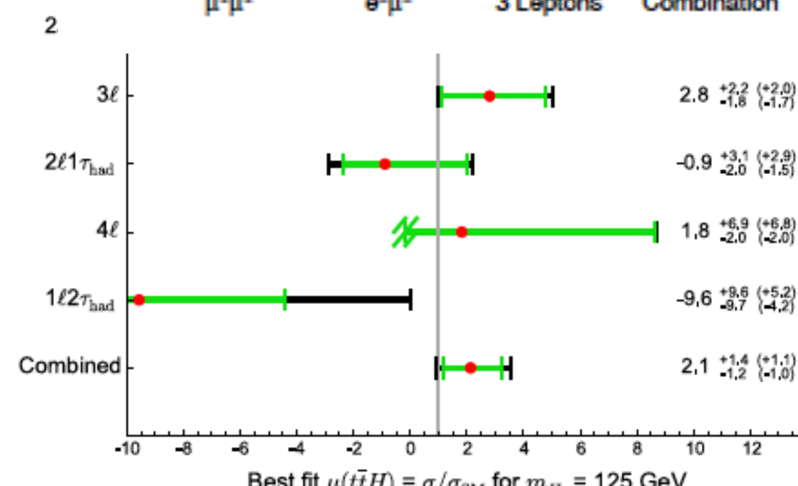
in multilepton signatures, (τ's included)

=> NO EXCESS/SM expectation; Best fit:

$\sigma(ttH)=2.1^{+1.4}_{-1.2}$ times SM expectation

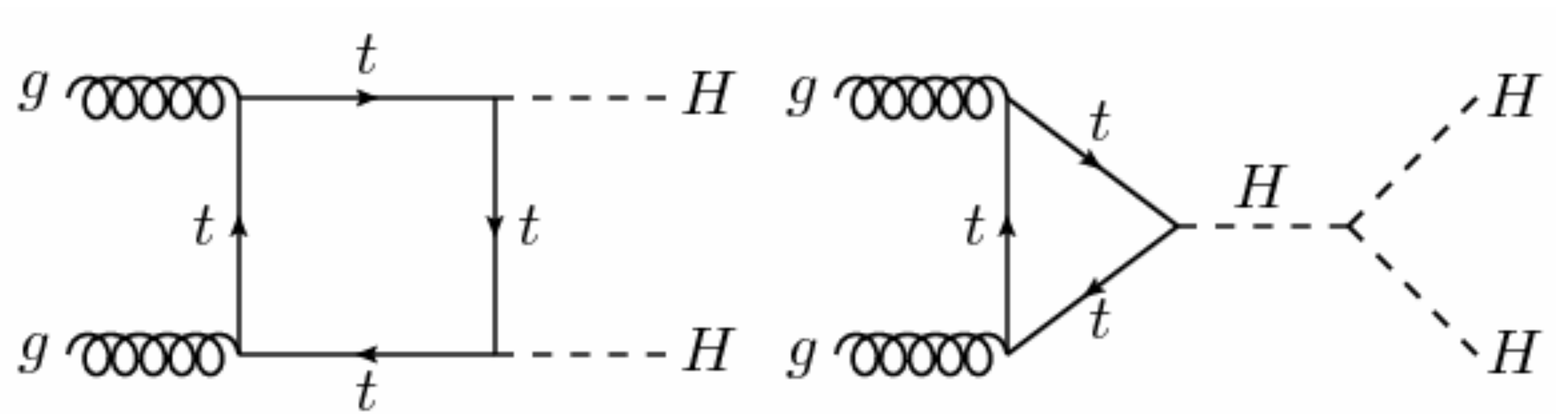
& the observed (expected) upper limit

Is 4.7 (2.4) times the SM rate at 95% CL



A glimpse on Double Higgs production

- ✓ Double Higgs production at the LHC provides a good opportunity to probe various couplings of the Higgs boson.
- ✓ Since gluon fusion is still the dominant channel for H pair production
- ✓ just like single H production, with strong dependence on ttH coupling.
- ✓ At the same time, it can give access to Higgs trilinear coupling as well.

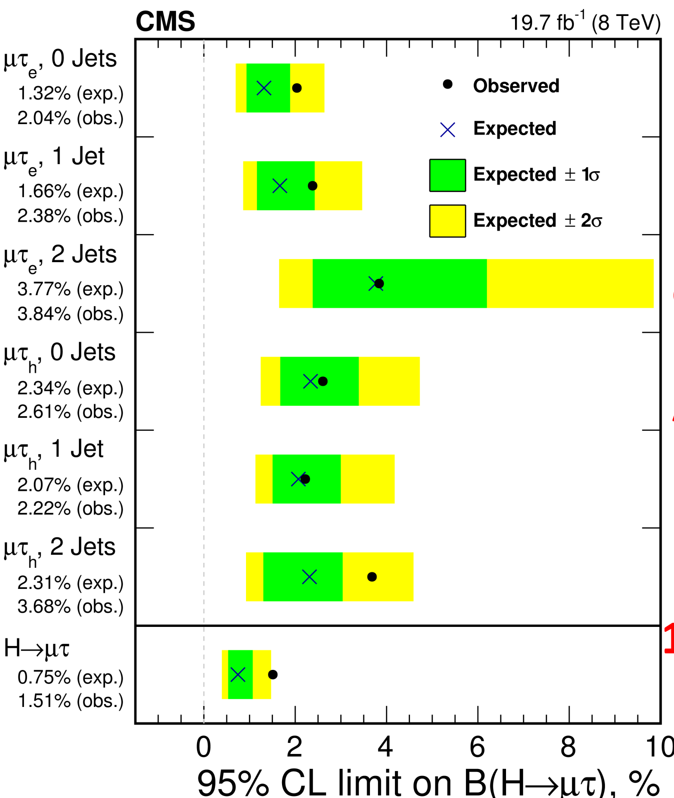


But this is not anymore at the dawn but in the full spendlor of LHC14....
Stay tuned....

Search for LFV Higgs decay

$H\to\mu\tau_e$ and $H\to\mu\tau_h$ channels

The sensitivity of the search is an order of magnitude better than the existing indirect limits. A slight excess of signal events with a significance of 2.4σ is observed. The p-value of this excess at M(H)= 125 GeV is 0.010. The best fit branching fraction is B(H→μτ)= (0.84 +0.39−0.37)%. A constraint on the branching fraction, B(H→μτ) less than 1.51% at 95% confidence level, is set. This limit is used to constrain the μ-τ Yukawa couplings to be less than 3.6×10^{-3}.

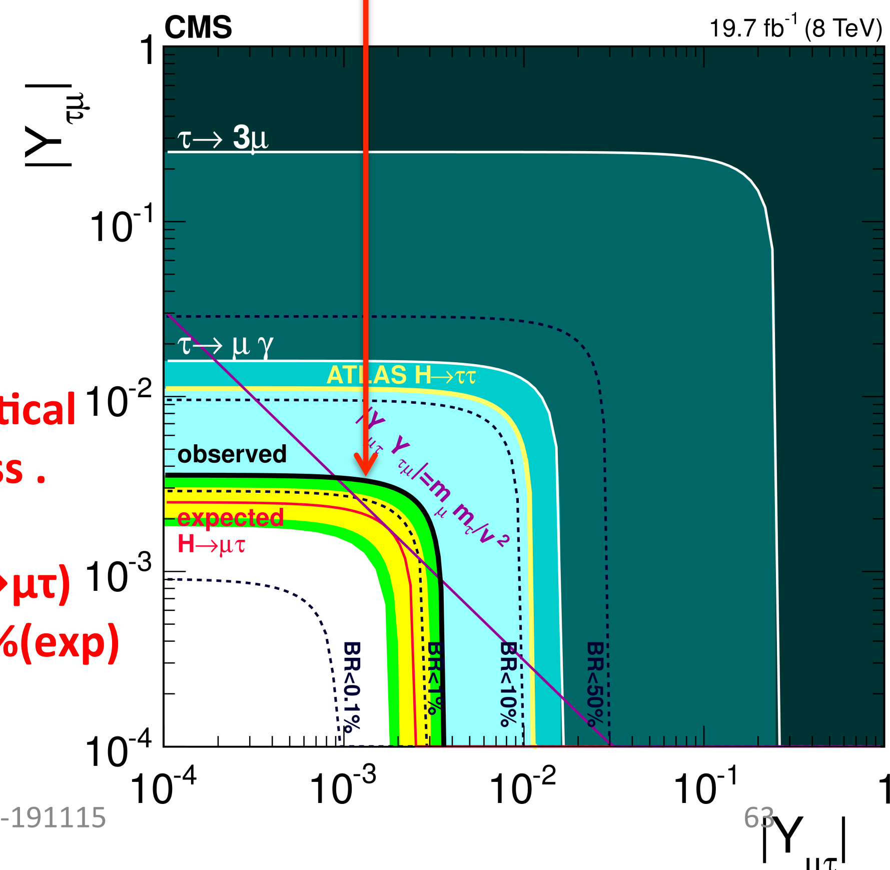


Stat fluctuation or??

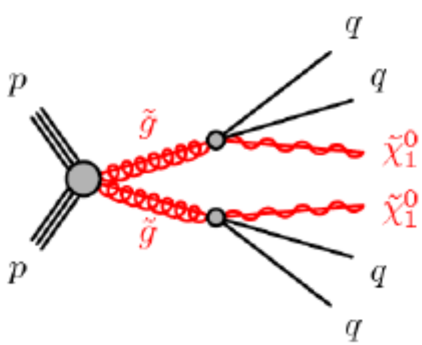
No excess in electron-Channel

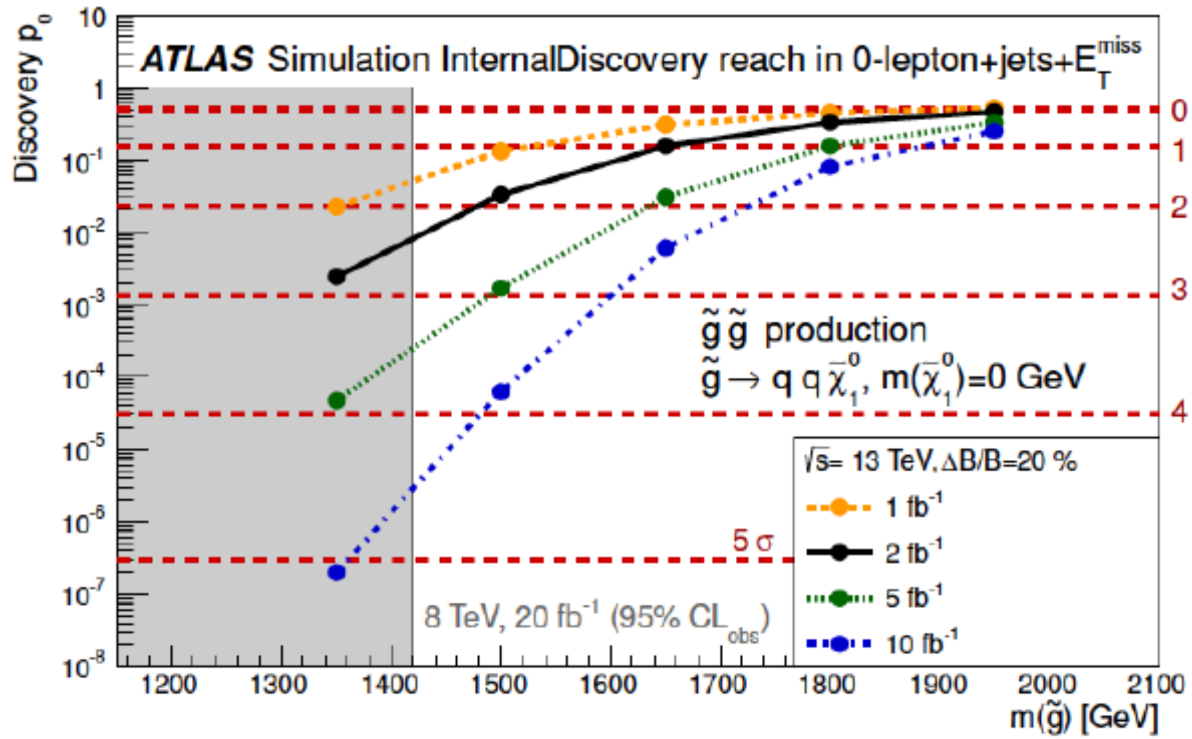
ATLAS: No statistical significant excess .

Upper limit B(H→μτ) 1.85% (obs)/1.24%(exp) at 95%CL



Searches for new particles

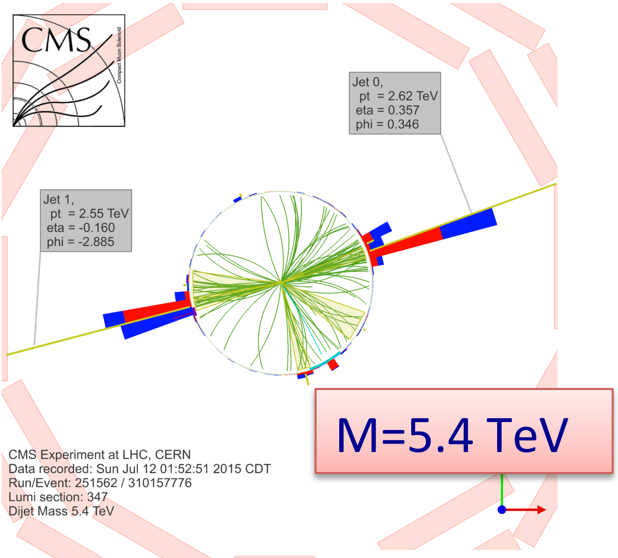


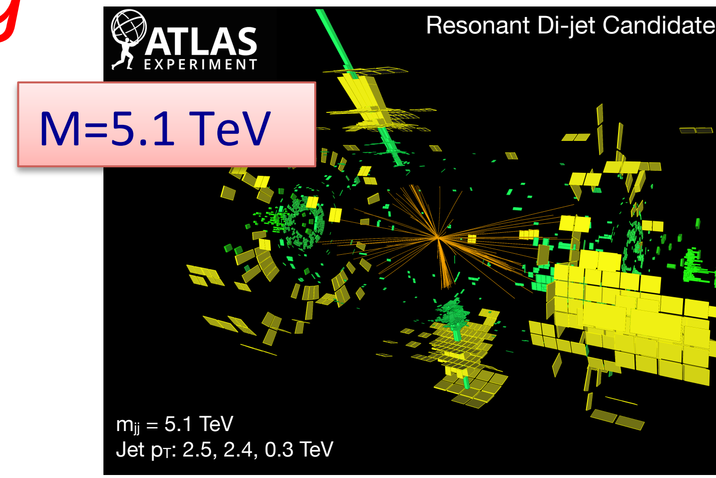


- **Could find evidence (3σ) up to ~1.5 TeV with 5 fb^{-1}**

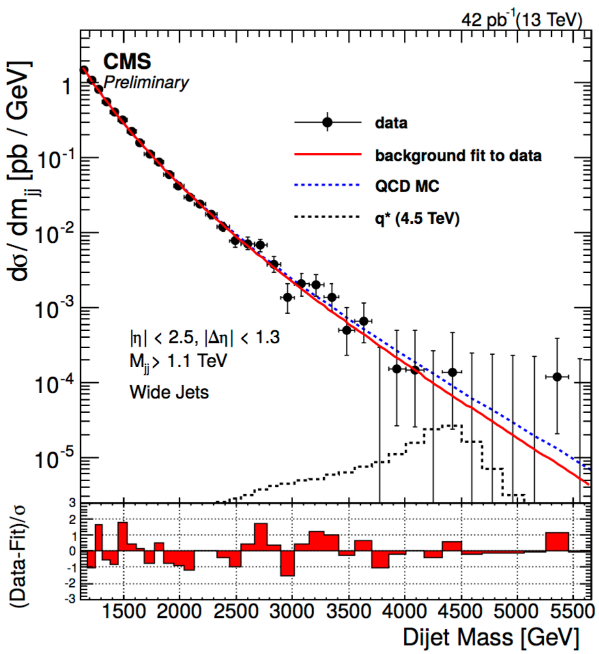
Slide from Beate Heinemann, LP2015

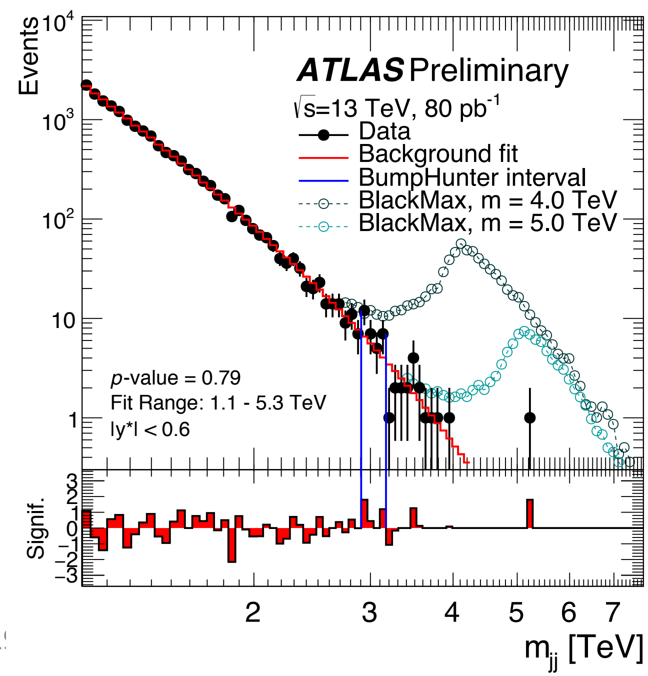
High Mass dijet & dilepton events: Promising





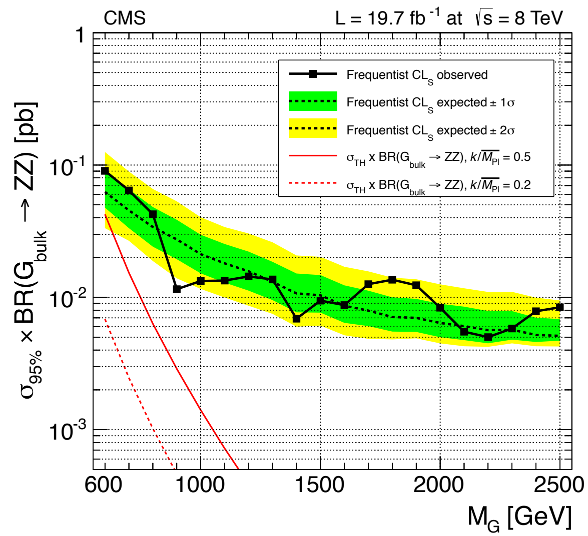
Stay tuned

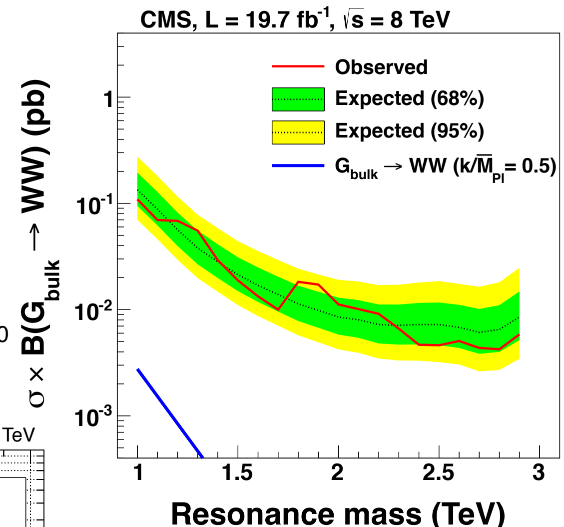


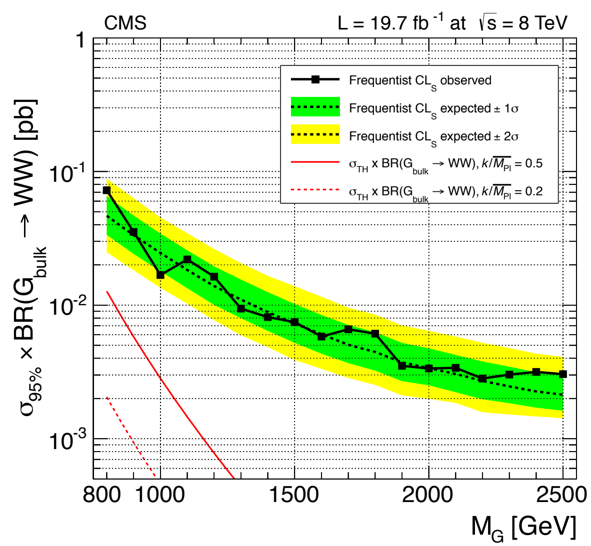


Exotic VV Resonances

- One of the core Physics analyses of SPRACE
  - Leadership for Run2
- Run 1 recap:
  - Limits around ~ 20 fb for resonances around 1 TeV
  - Excesses around 1.8—2 TeV region
    - Observed in different channels:VV(both had), VW(had+lept+MET),
      VZ (had +dilepton)
    - Also observed in ATLAS
  - Originated analyses with Higgs bosons (VH, HH)



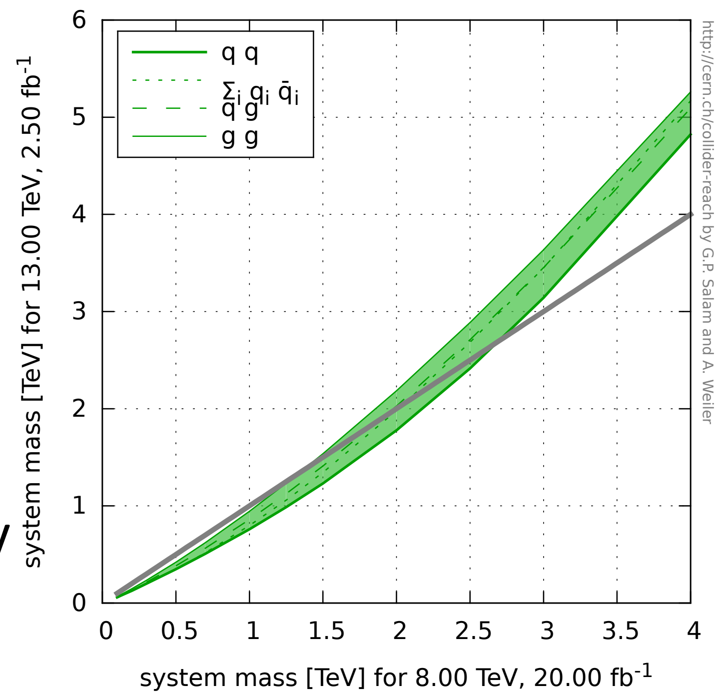




(Courtesy of Thiago Tomei, SPRACE-UNESP)

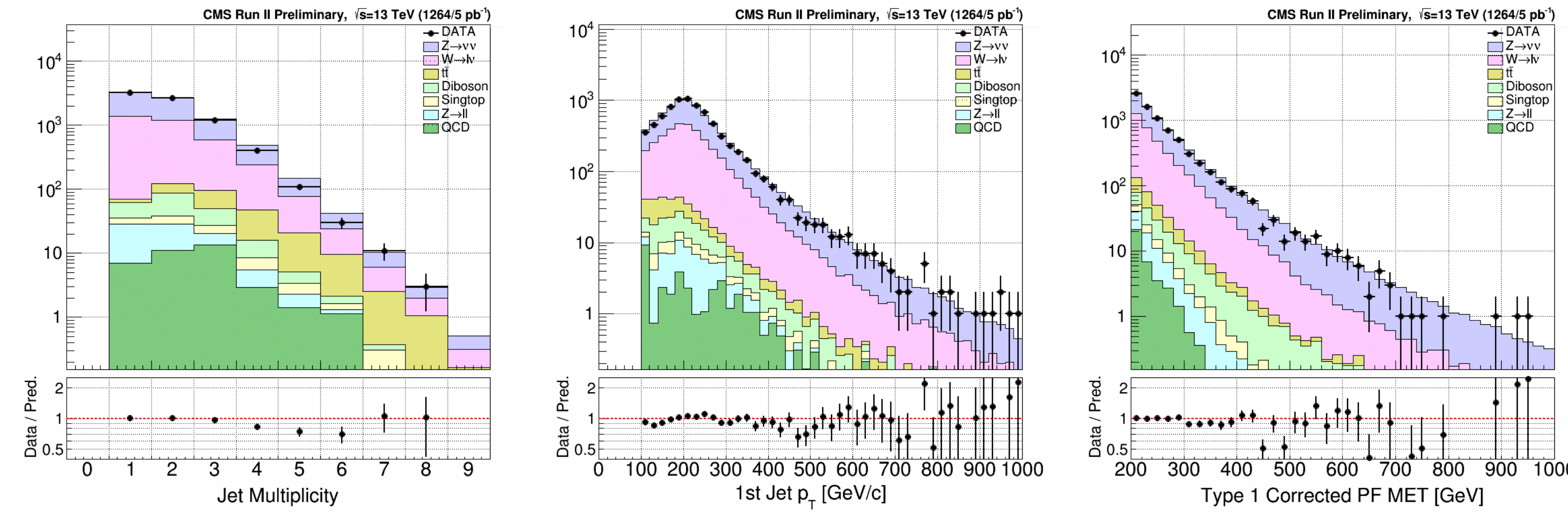
Exotic VV Resonances

- Run 2 preparations:
  - ~ 2.5/fb good data collected by CMS
    - Ballpark to be able to say something about 1.8—2 TeV
  - Preparation for usage of new tools:
    - PUPPI
      - arXiv:1407.6013
    - SoftDrop
      - arXiv:1402.2657
  - Results shown at the Scientific Policy Committee 2015:
    - https://indico.cern.ch/event/440939/

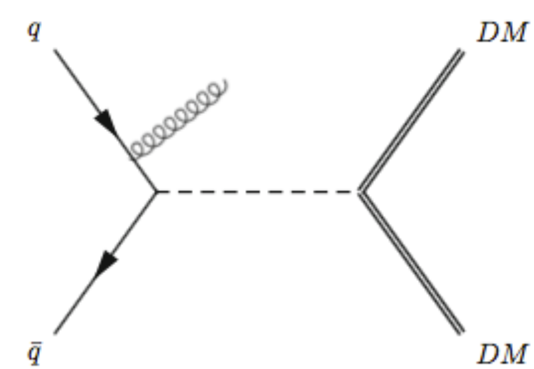


(Courtesy of Thiago Tomei, SPRACE-UNESP)

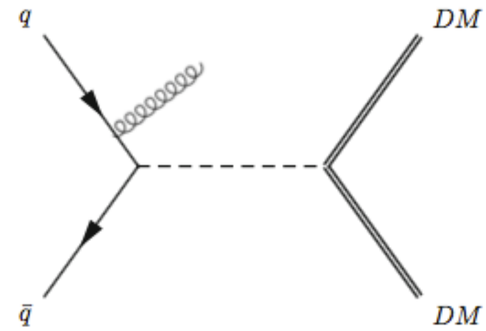
Search for DM in Monojet final state



- Picked up 1 out of 5 events from Data due to blink policy.
- Signal event selection.
  - Veto events for Muons, Electrons, Taus, Photons,
  - b-tagged jets
  - Leading jet $p_T > 100$ GeV
  - Leading jet passes cleaning cuts
  - $\Delta phi(jet, MET)_{min} > 0.5$
  - MET > 200 GeV



Expected Limits

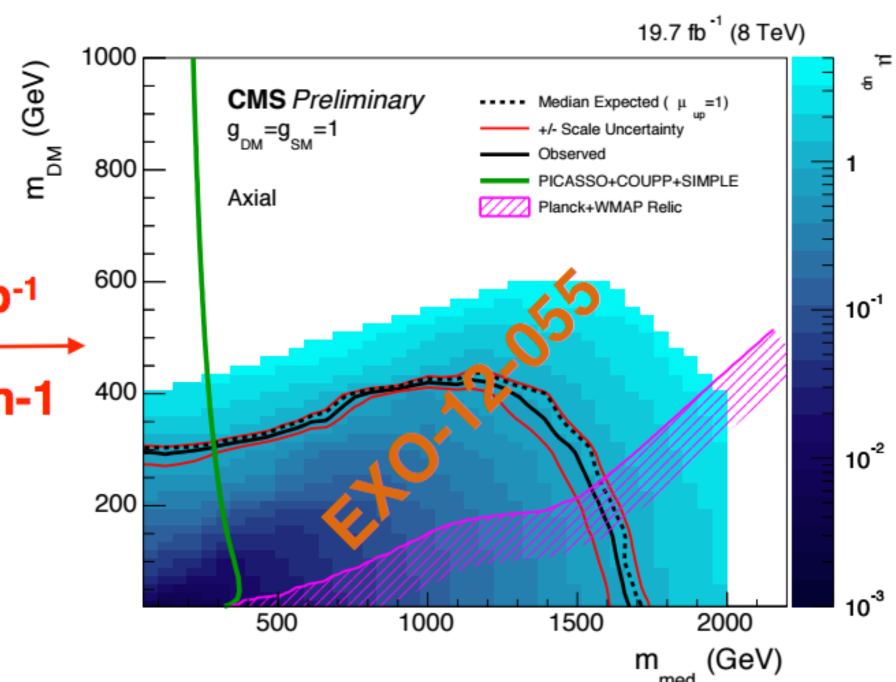


- Full mass scan for limits in progress
- Not ready for today but we show results for 1 point
  - Axial-vector model, mediator mass = 2 TeV, DM mass = 1 GeV [scan param (1GeV -1TeV)](gSM = 0.25)

Control Regions Used	95% CL expected UL on σ/σ_0
Z(μμ) & γ+jets; W(μν)	14.7
Adding electron channels	13.2
Adding Z/W constraint	12.7

Need ~5 fb^{-1}

to beat Run-1



(Courtesy of C.S. Moon, SPRACE-UNESP)

YES we are ONLY at the DAWN… but we already are preparing for the next important step:

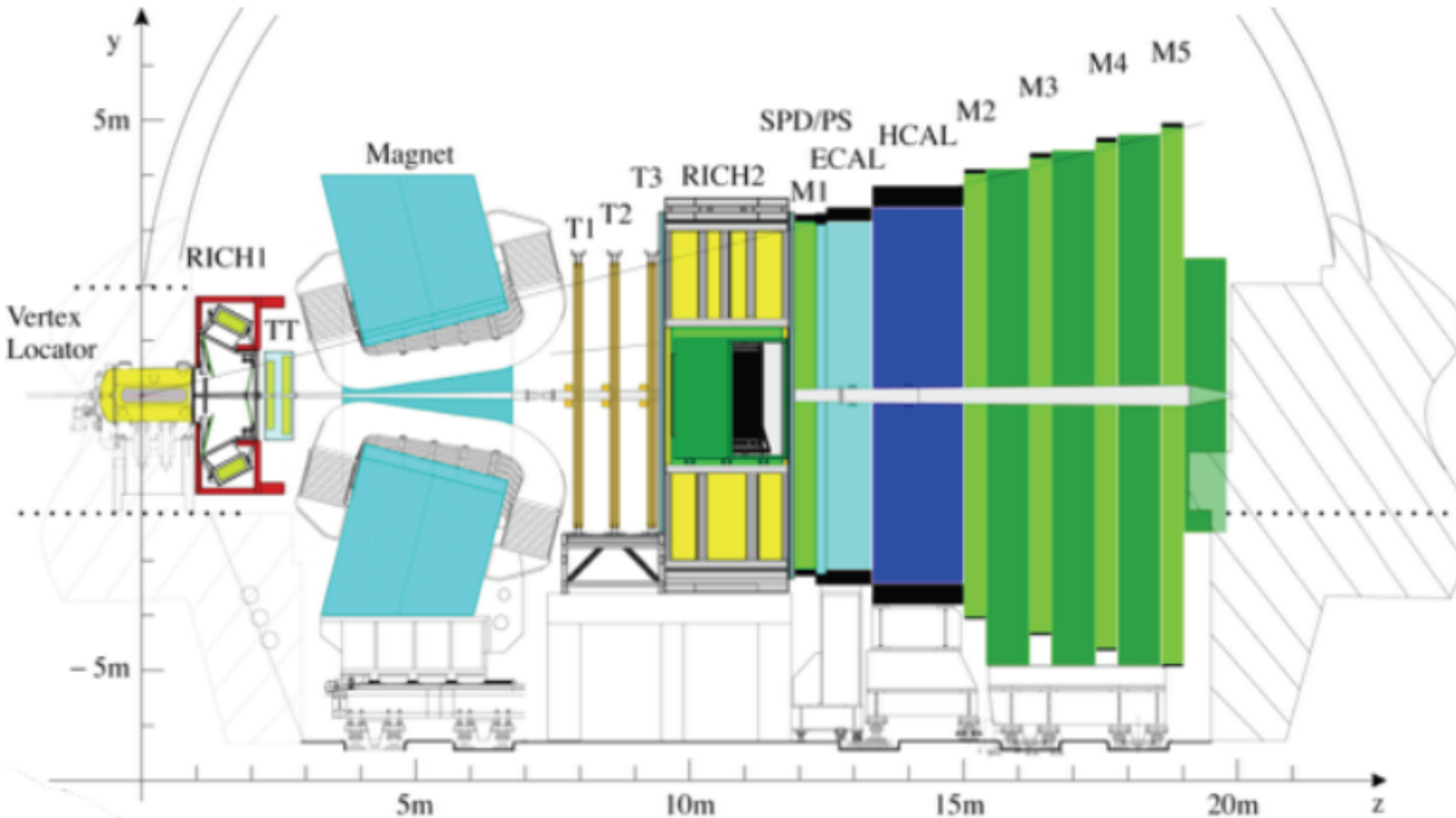
the BEYOND HL-LHC

=> All the experiments will be rebuilt for HL-LHC
For exploiting the new Physics potential: this is a task of 10-15 years (R&D's based on novel high tech and construction)

$\Rightarrow$ **And New Machines are under study** since 2000 & even before….

Upgrade overview

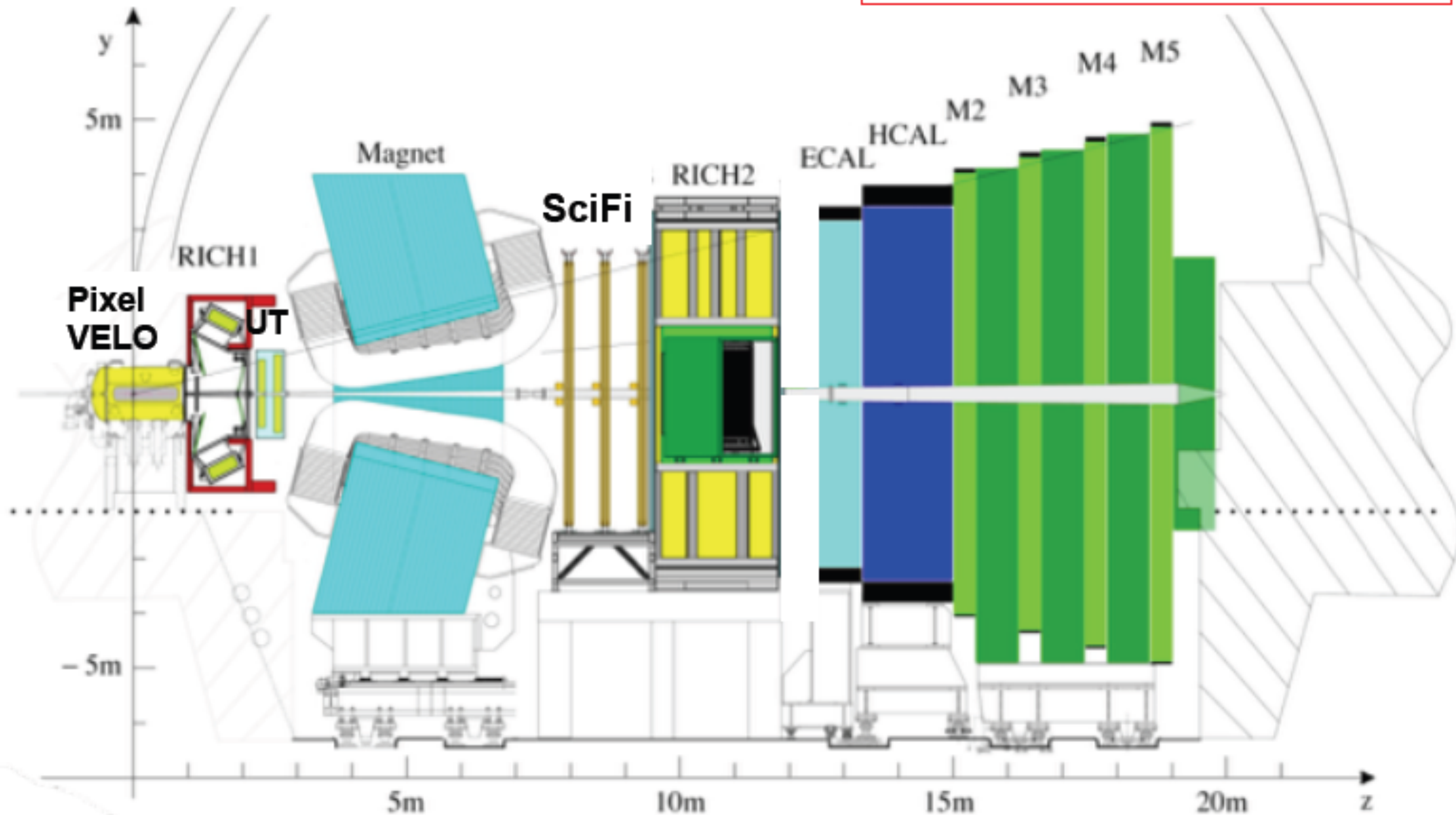
Current detector



Upgrade overview

Current detector → upgraded detector

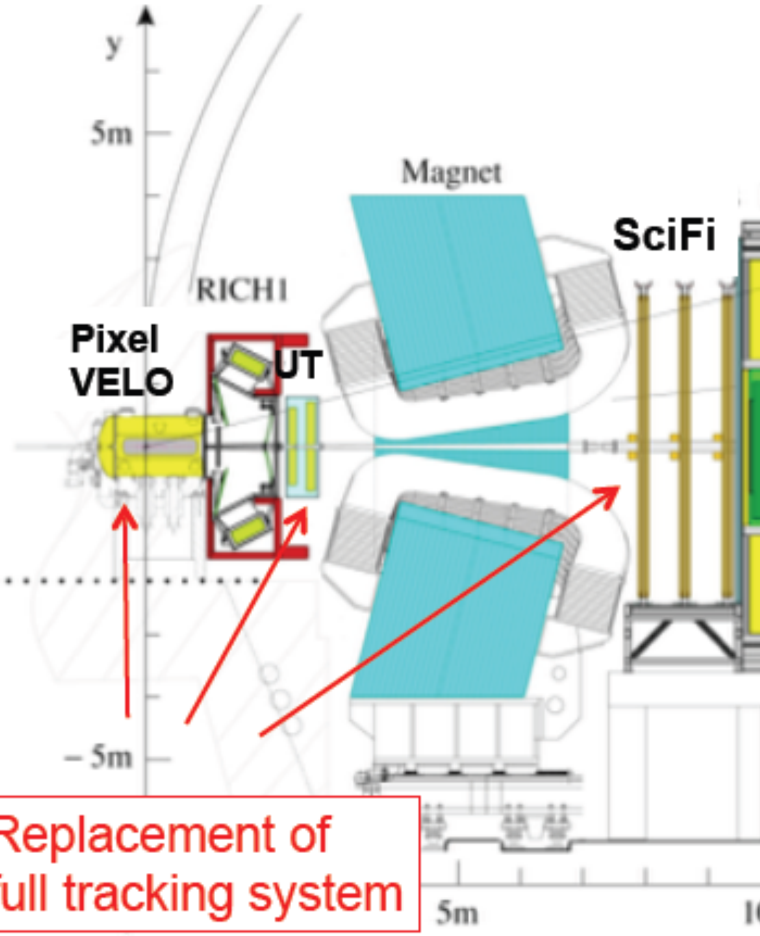
All sub-detectors read out at 40 MHz for software trigger



Upgrade overview

Current detector → upgraded detector

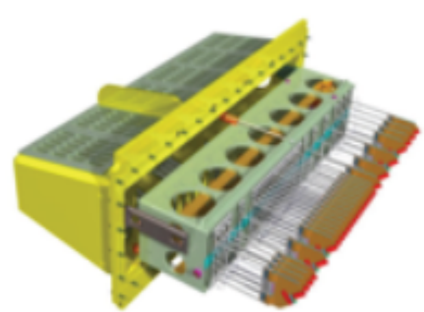
All sub-detectors read out at 40 MHz for software trigger



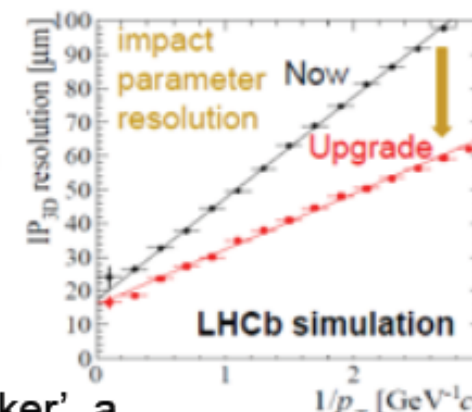
Replacement of full tracking system

Pixel Vertex Locator (VELO)

Half of VELO system



Improved performance

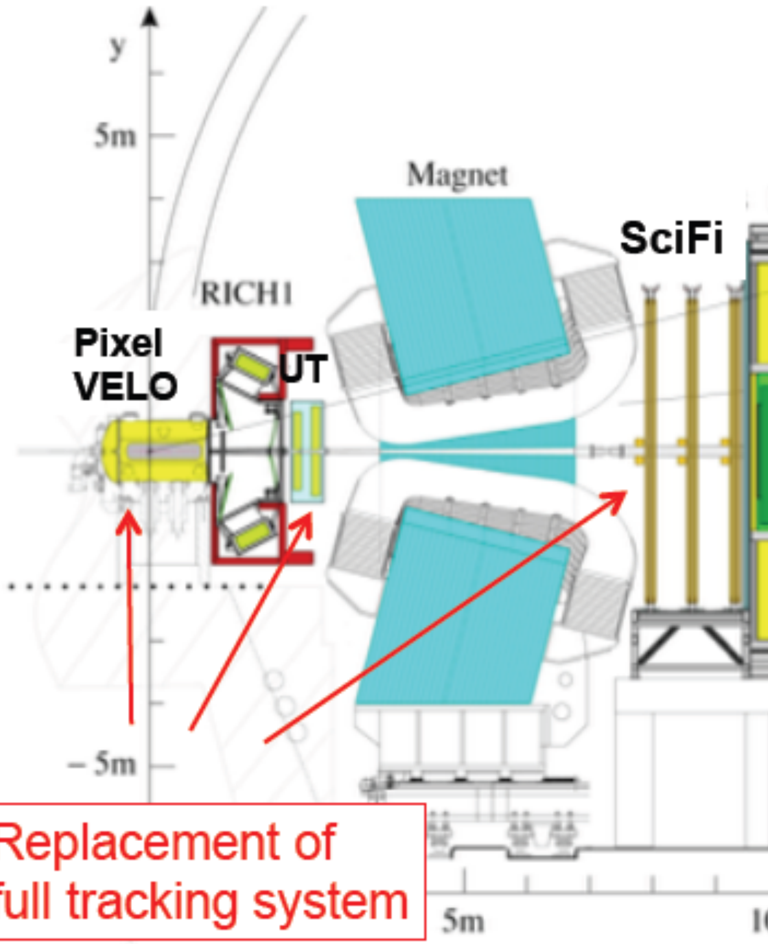


('UT' = 'Upstream tracker', a high performance Si strip detector)

Upgrade overview

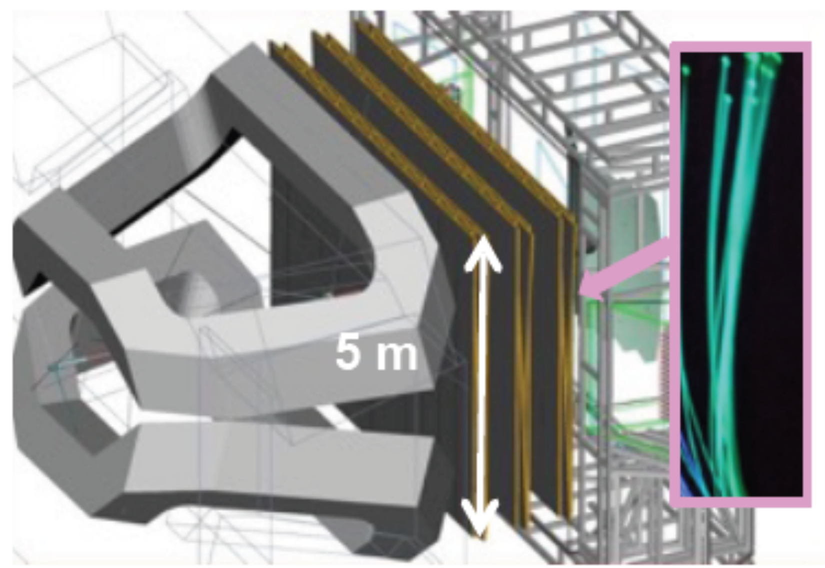
Current detector → upgraded detector

All sub-detectors read out at 40 MHz for software trigger



Replacement of full tracking system

Scintillating Fibre Tracker



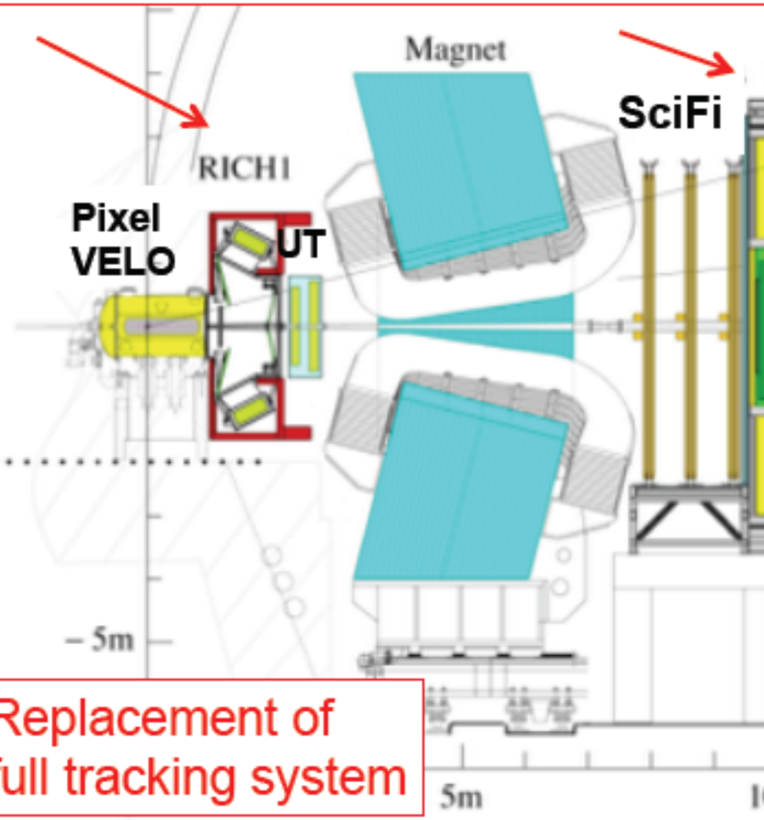
Large scale system (~12,000 km of fibres)

Upgrade overview

Current detector → upgraded detector

All sub-detectors read out at 40 MHz for software trigger

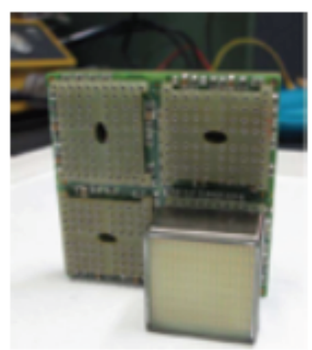
RICH 1 redesigned; new photodetectors installed for RICH 1 and RICH 2



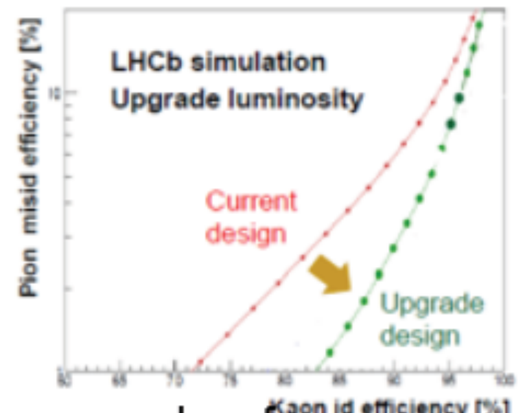
Replacement of full tracking system

RICH system

New photodetector



New optics….



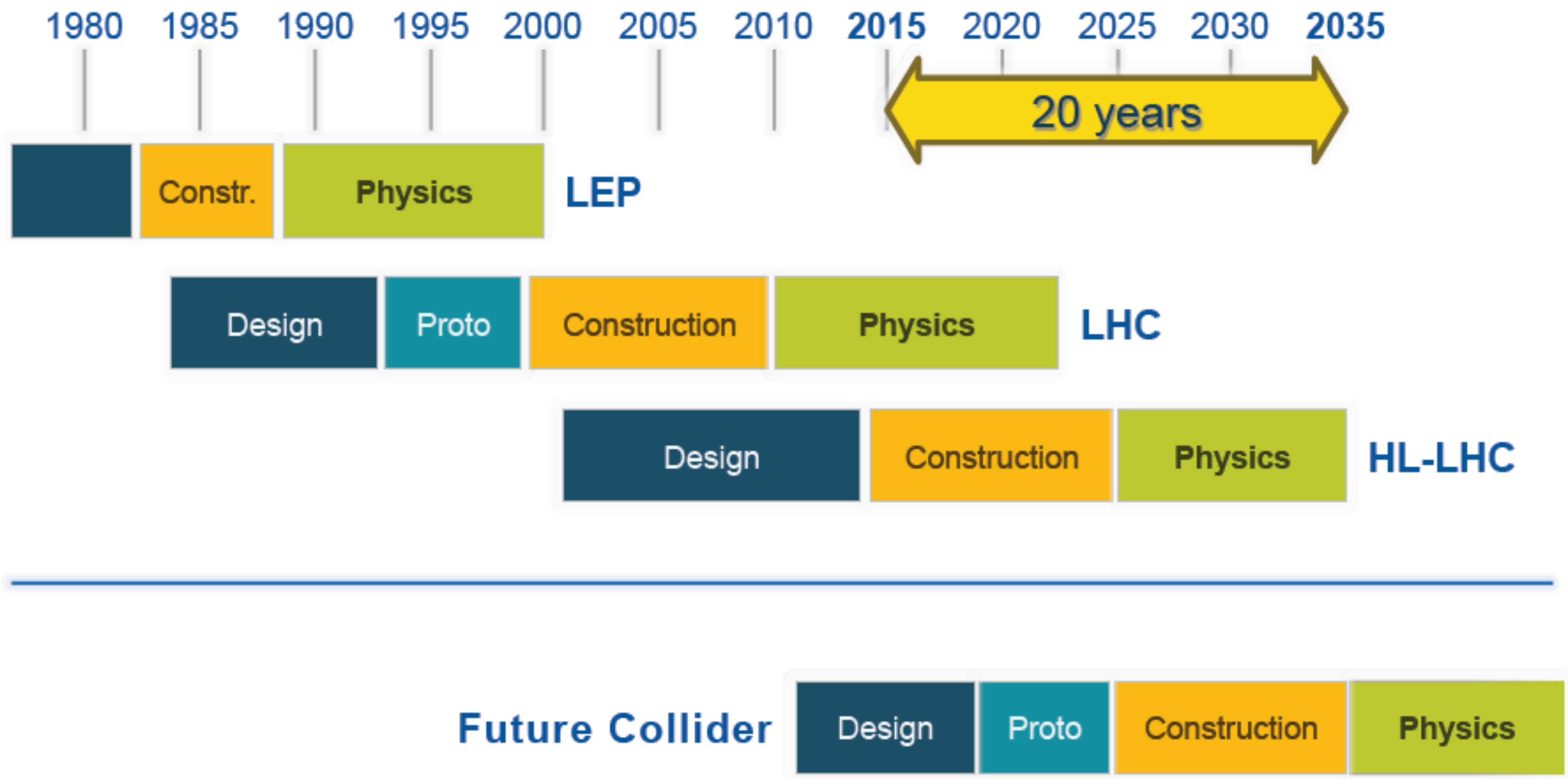
…good performance at high luminosity

BEYOND-LHC: NEW MACHINES

=> Future Circular Collider (FCC)
both FFC-hh & FCC-e+e-
Conceptual Design Report
By end 2018
In time for next
European Strategy Update

=> CLIC: 3-5 TeV e+ e- LC
=> ILC: 0.5- 1TeV e+ e- LC

CERN Circular Colliders + FCC



Key Parameters FCC-hh

Parameter	FCC-hh	LHC
Energy [TeV]	100 c.m.	14 c.m.
Dipole field [T]	16	8.33
# IP	2 main, +2	4
Luminosity/IP_{main} [$cm^{-2}s^{-1}$]	5 - 25 x 10^{34}	1 x 10^{34}
Stored energy/beam [GJ]	8.4	0.39
Synchrotron rad. [W/m/aperture]	28.4	0.17
Bunch spacing [ns]	25 (5)	25

Key Parameters FCC-ee

Parameter	FCC-ee			LEP2
Energy/beam [GeV]	45	120	175	105
Bunches/beam	13000-60000	500-1400	51- 98	4
Beam current [mA]	1450	30	6.6	3
Luminosity/IP x 10^{34} $cm^{-2}s^{-1}$	**21 - 280**	**5 - 11**	**1.5 - 2.6**	0.0012
Energy loss/turn [GeV]	0.03	1.67	7.55	3.34
Synchrotron Power [MW]	100			22
RF Voltage [GV]	0.3-2.5	3.6-5.5	11	3.5

Dependency: crab-waist vs. baseline optics and 2 vs. 4 IPs

THE EXPERIMENTALIST: *''AVOIR DES CLARTES DE TOUT''*

(PERSONAL VIEW)