Centro Científico Tecnológico de Valparaíso

ACT 1406 ATLAS EXPERIMENT Theory Meets Experiment at LHC

DGIP/UTFSM grant PI_M_18_03
DGIP/UTFSM grant PI_M_18_13

The Detector Laboratory of UTFSM/CCTVAL

Sergey Kuleshov, Cesar Silva, Rimsky Rojas, Gonzalo Carvajal, Sergey Kovalenko, Rafael Mena, Christopher Nikulin

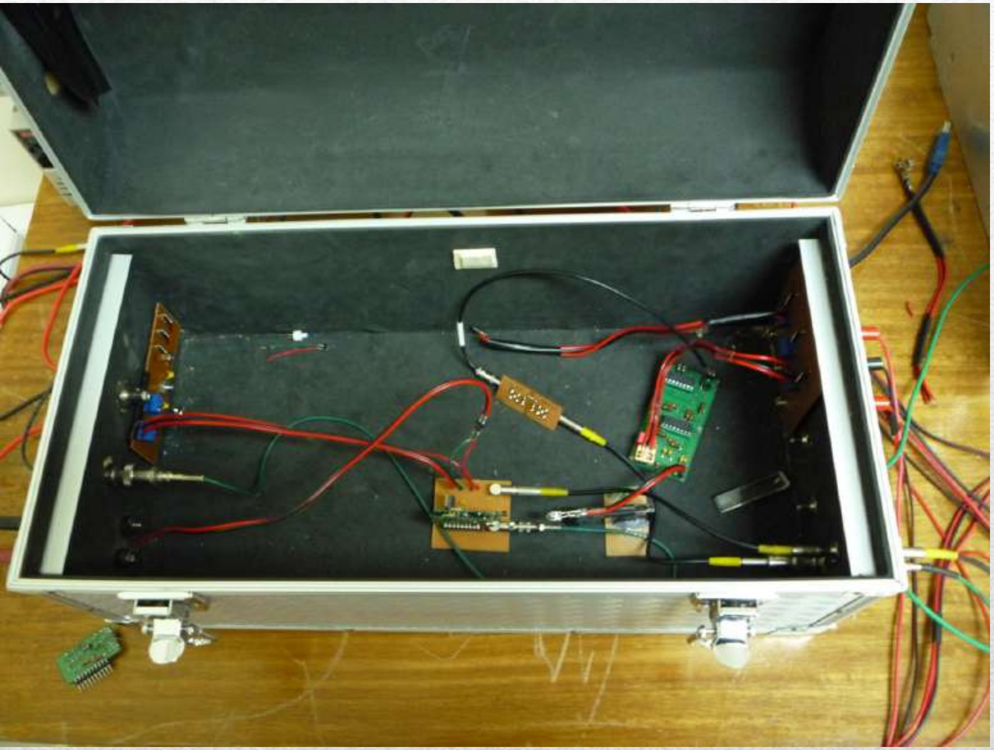
- Experimental nuclear and particle physics group of UTFSM was created by Will Brooks and Sergey Kuleshov in 2008. Will Brooks was staff of JLAB (CLAS, Hall B and GlueX, Hall D) and Sergey Kuleshov was leading scientist of ITEP (Moscow) and worked in CMS (CERN) and JLAB (USA), as visiting scientists before 2008.
- The Detector Laboratory was established by selection 5 best students of Electronic Department of UTFSM and recruited them as candidates for engineer position of the laboratory.
- UTFSM and PUC jointed ATLAS Collaboration. We worked on ZDC for HI at ATLAS and experiments of GlueX and CLAS during 2008-2009.
- Because I was participating in tests of the first silicone photomultiplier and Will was a doer of JLAB, GlueX Collaboration proposed a contract to our team to test MPPC arrays (MAMANATSU SiPM) for the barrel calorimeter of GlueX. We had to buy and tests 4000 MPPC arrays. The contract with JLAB was about 2M USD. This contract and participation in the GlueX Collaboration opened a possibility to apply to large Chilean grant BASAL and create CCTVAL.

A mechanical facility, CNC machine shop, was selected as the first step.

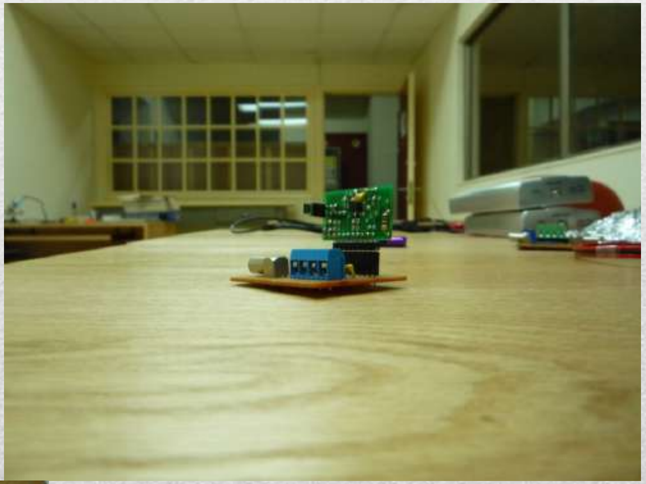
First steps to the laboratory

The Detector Laboratory in 2009

The first MPPC test set up in 2009.

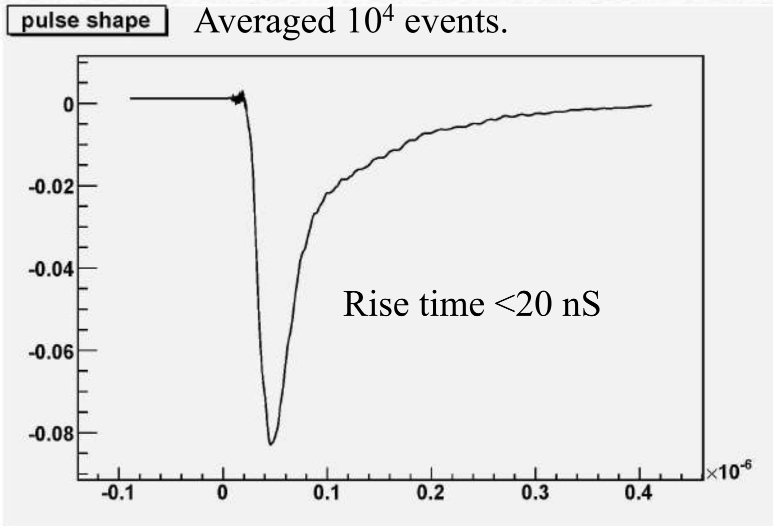


The current amplifier with 1 K feedback and 39 Ω in the output.
On the scope we see
V= Imppc *1000*50/89 (v)=
= Imppc*561.

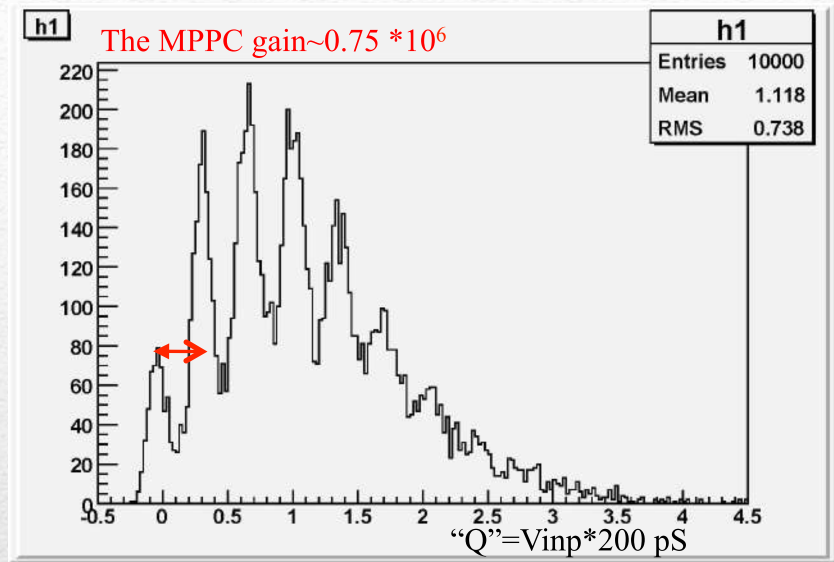


LED pulse duration was stetted <10 nS.

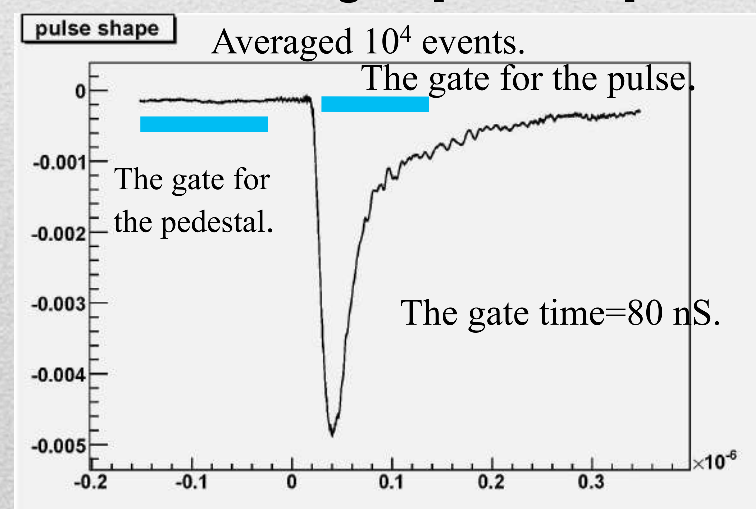
The large signal pulse shape.



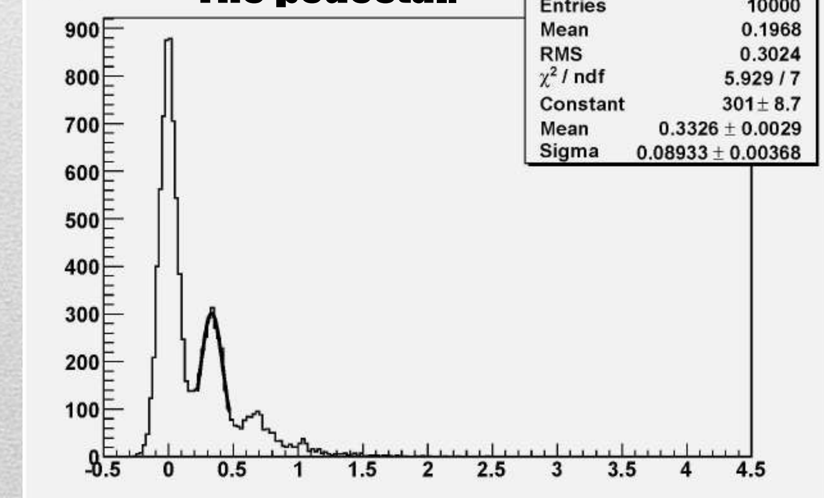
Q in the gate.



The small signal pulse shape.



The pedestal.

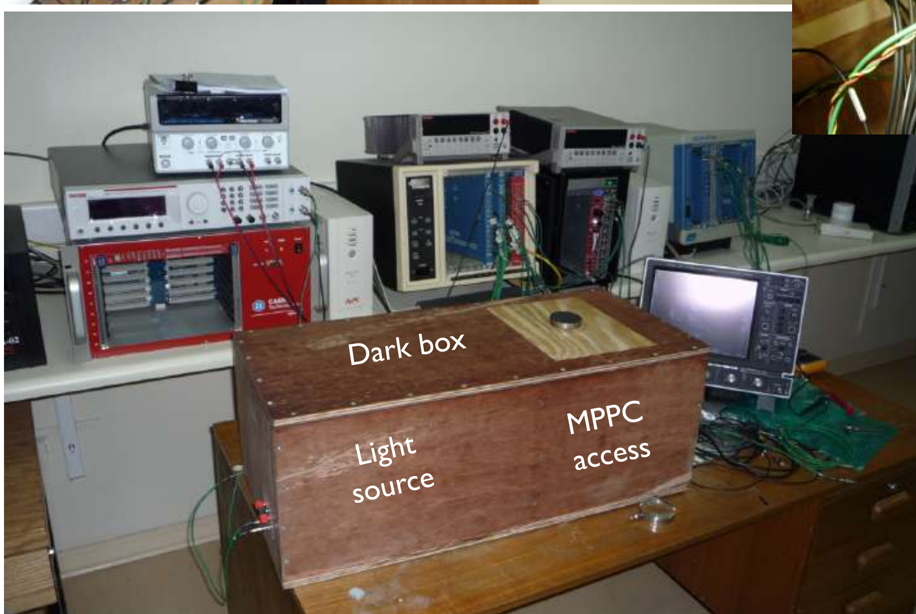


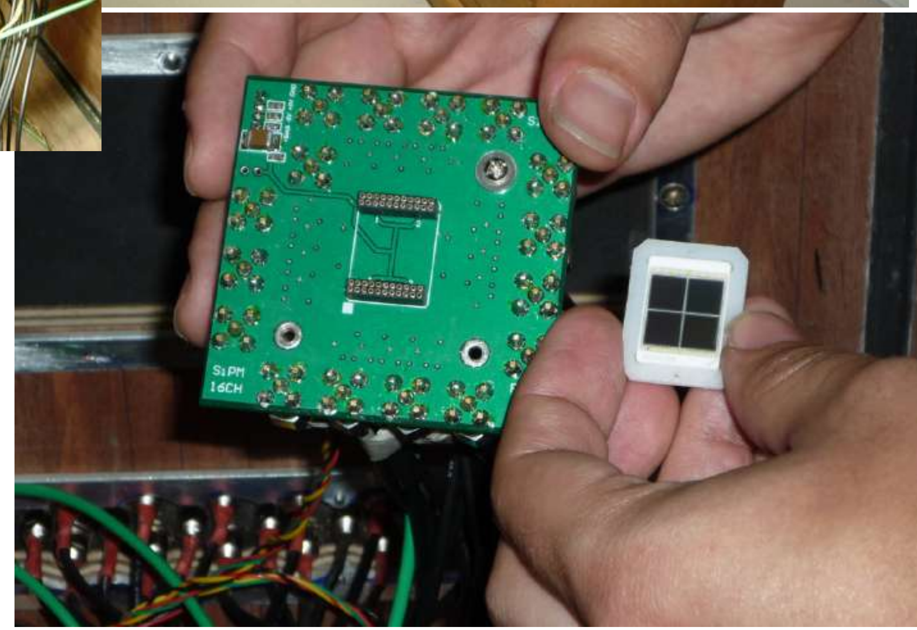
- The novel Hamamatsu Multi-Pixel Photon Counter (MPPC) S12045(X) is an array of 16 individual 3 x 3 mm2 MPPC devices each with 3600 Geiger-mode Avalanche Photodiode pixels of 50 50 μm2. Each MPPC in the array operates at a reverse bias of approximately 70 V. MPPC arrays used in the GlueX experiment in Hall D at Thomas Jefferson National Accelerator Facility (Jefferson Lab). We studied the main features of each of the 16 MPPC array channels for 2800 MPPC arrays at several different temperatures. Two measurement stations were built to extract gain, breakdown voltage, photon detection efficiency, optical crosstalk and dark rate for each of the 64000 MPPC array channels at each temperature setting. The hardware and the data analysis are described, and new analytical expressions for the mean number of photoelectrons and optical crosstalk are presented, as well as systematic trends of the performance parameters.
- Orlando Soto, Rimsky Rojas, Sergey Kuleshov, Hayk Hakobyan n, Alam Toro, William K. Brooks, Rene Rios “Novel Hamamatsu Multi-Pixel Photon Counter (MPPC) array studies for the GlueX experiment: New results.” Nuclear Instruments and Methods in Physics Research A 739 (2014) 89–97
- Orlando Soto n, Rimsky Rojas, Sergey Kuleshov, Hayk Hakobyan, Alam Toro, William K. Brooks

“Characterization of novel Hamamatsu Multi Pixel Photon Counter (MPPC) arrays for the GlueX experiment “Nuclear Instruments and Methods in Physics Research A 732 (2013) 431–436

Test and characterization of 4000 (x16) SiPM matrix for JLAB. It was done during 2010-2014

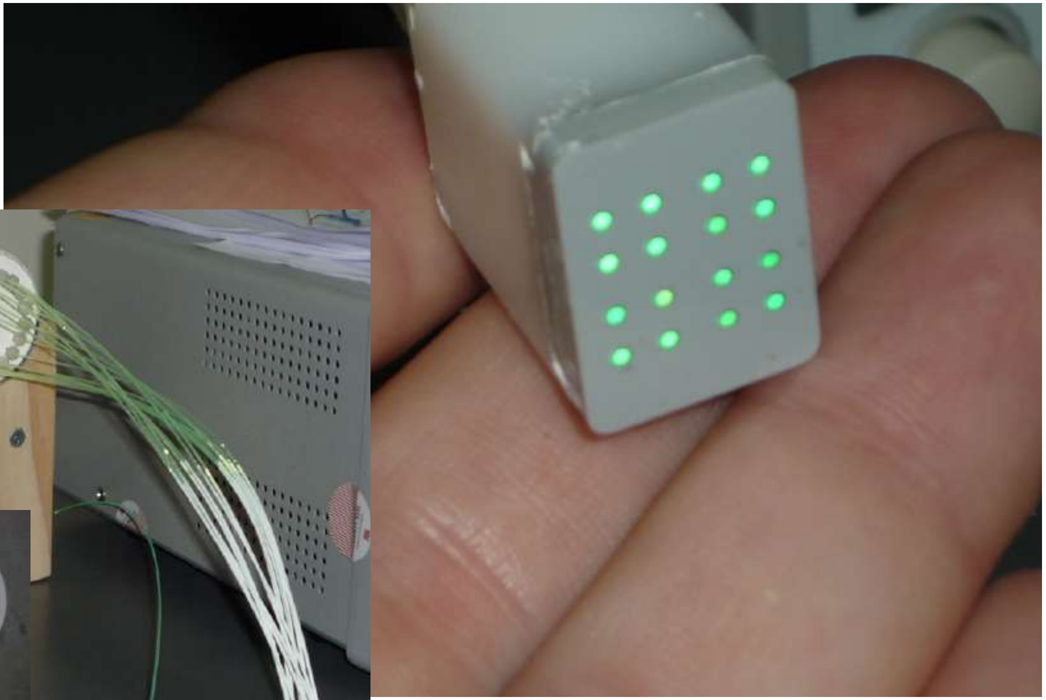
PDE Station (Stage II)

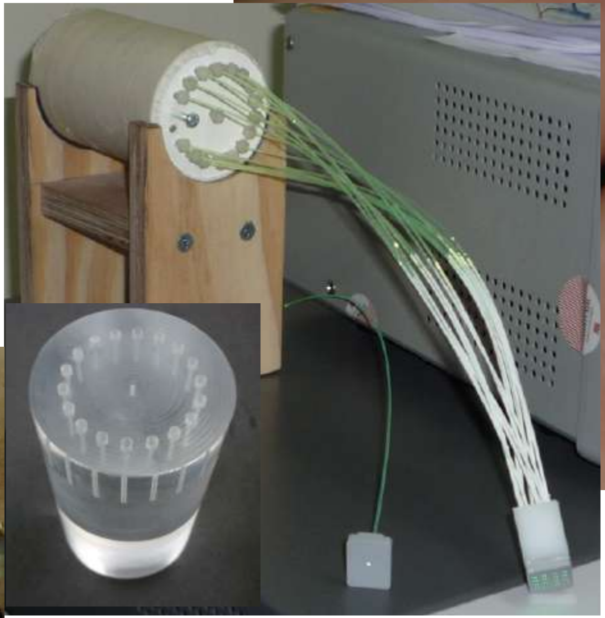




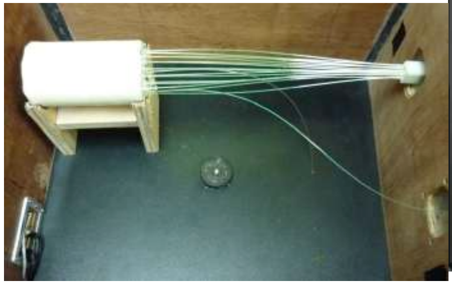
USM PDE Station Light Source

Recessed positioner; fibers on this side, MPPC on other side





Light mixer (clear fiber goes into center)

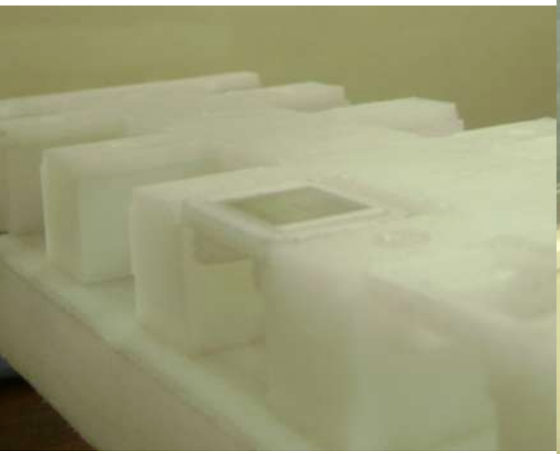


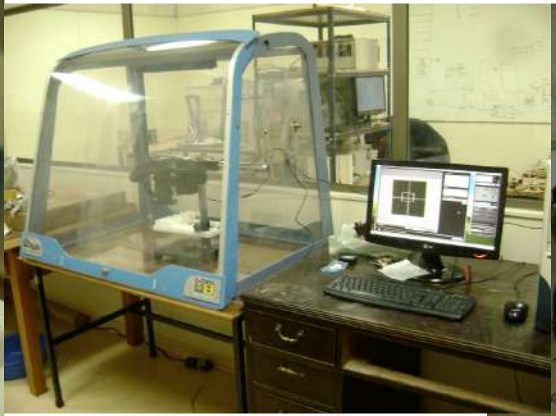
Output of 16 green fibers following mixer

1-fiber input, 17-fiber output (16 to MPPC, 17th to monitor PMT

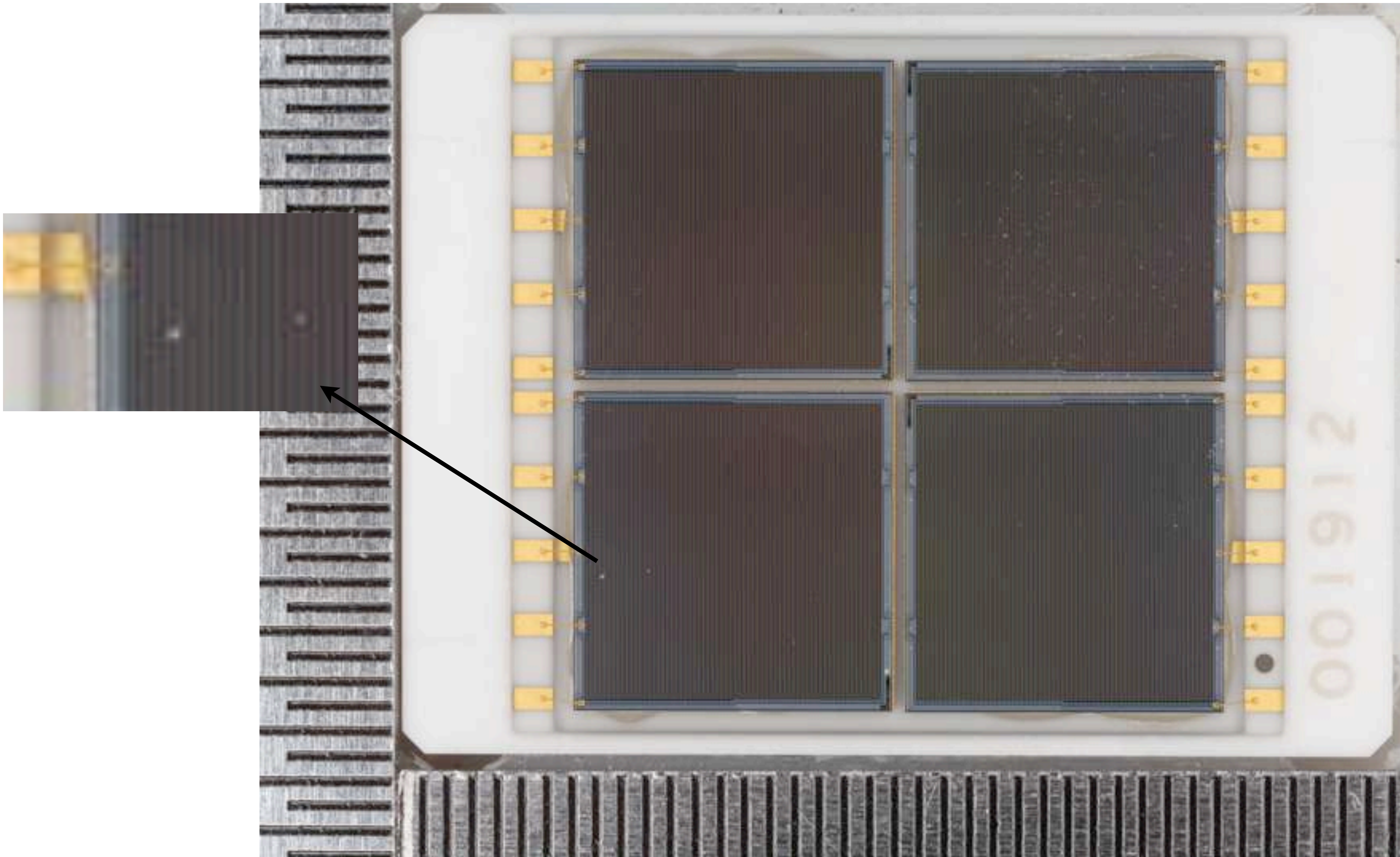
Blue LED feeding clear fiber

Inspection Station (Stage I)

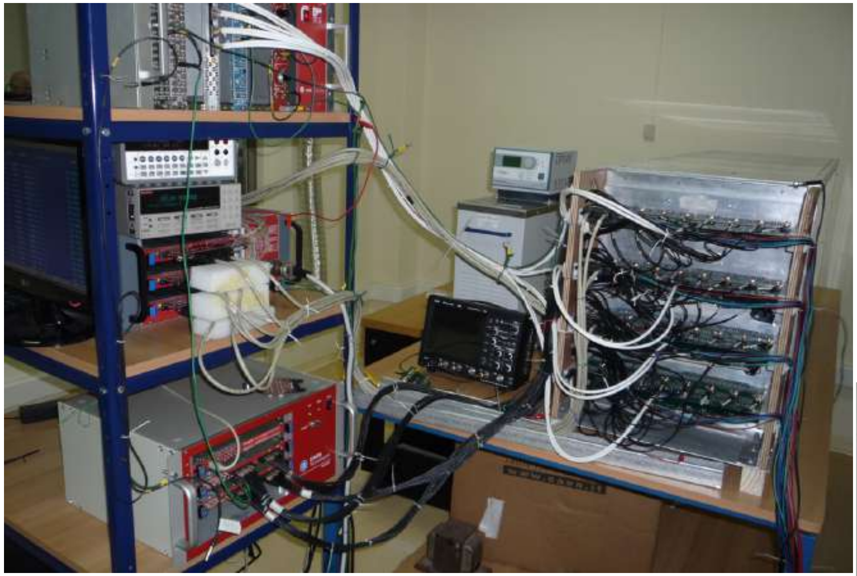


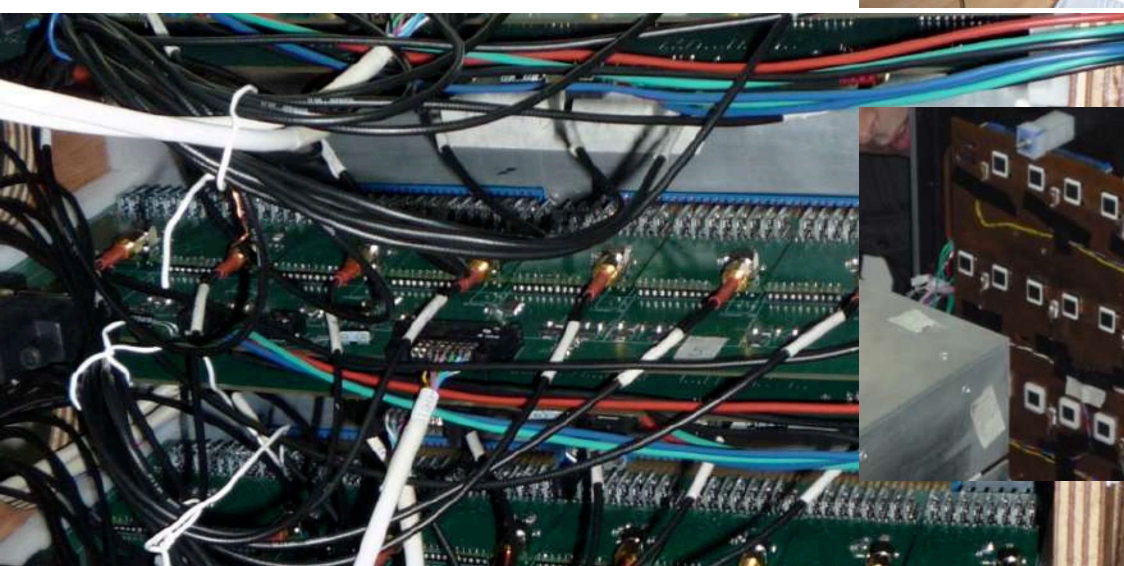


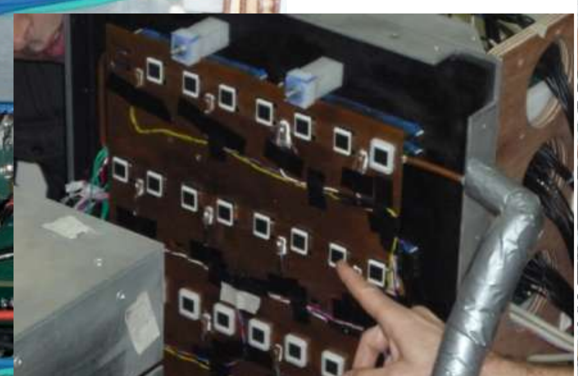
MPPC image

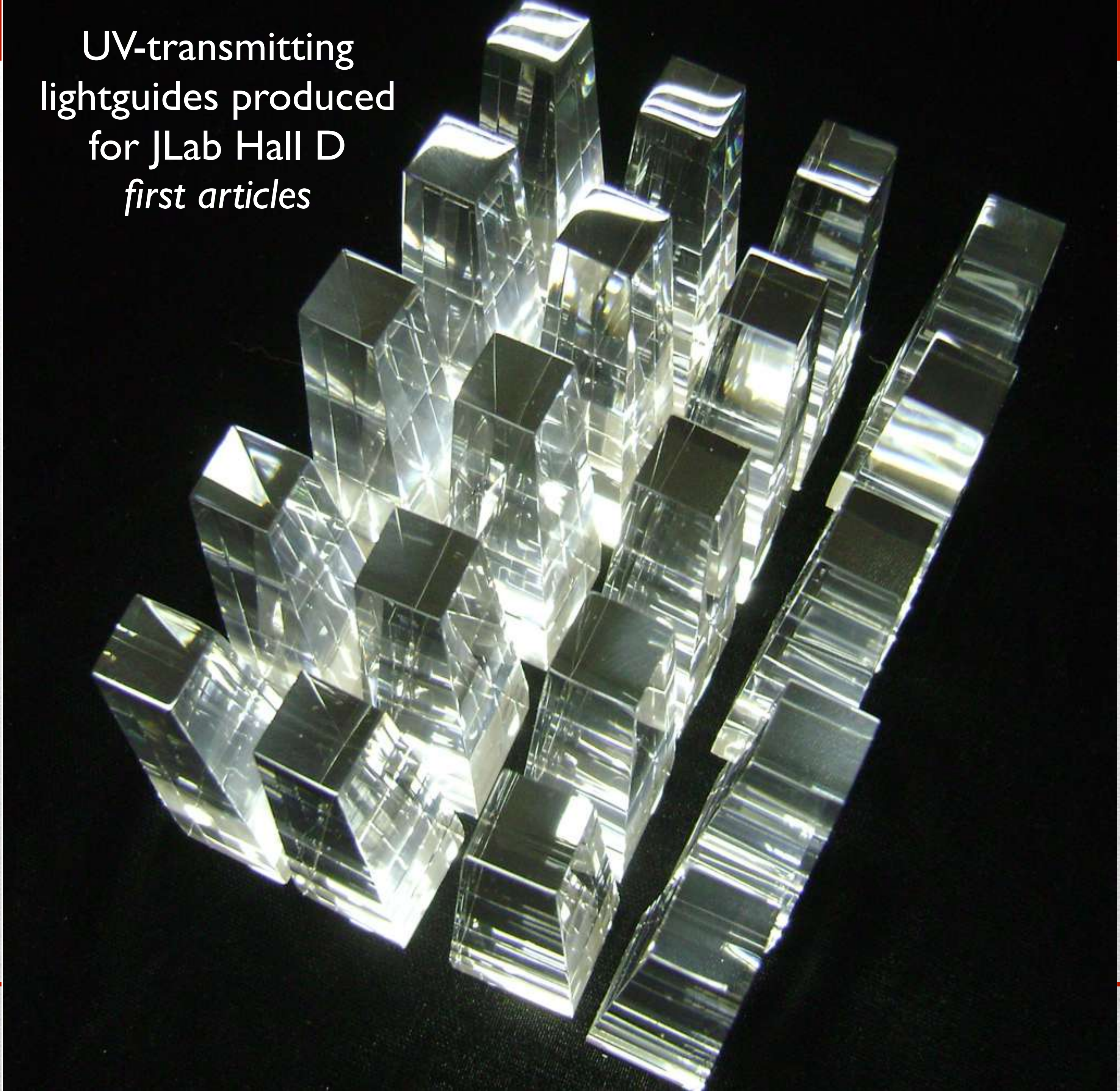


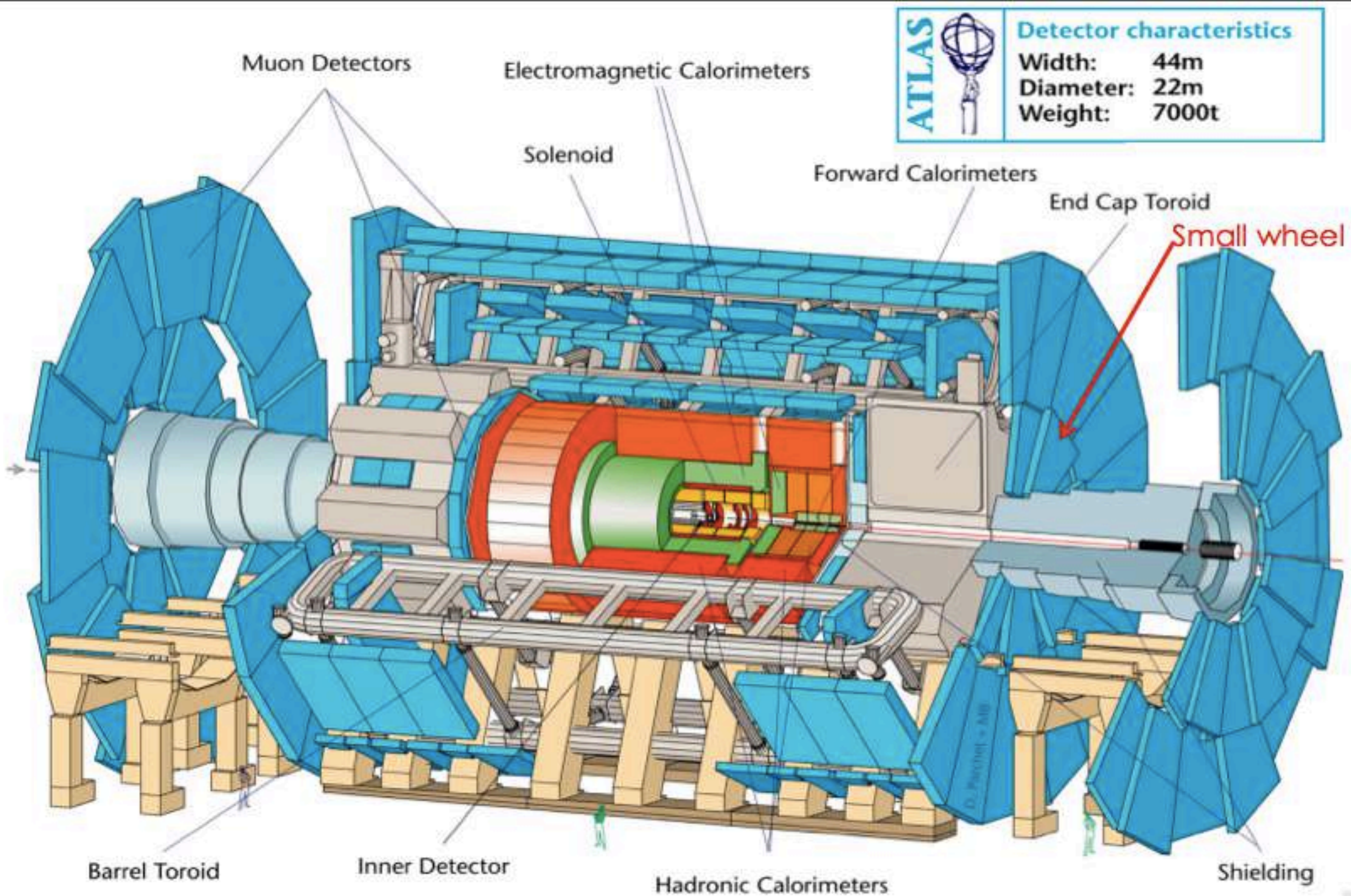
Temperature-Controlled Station (Stage III)





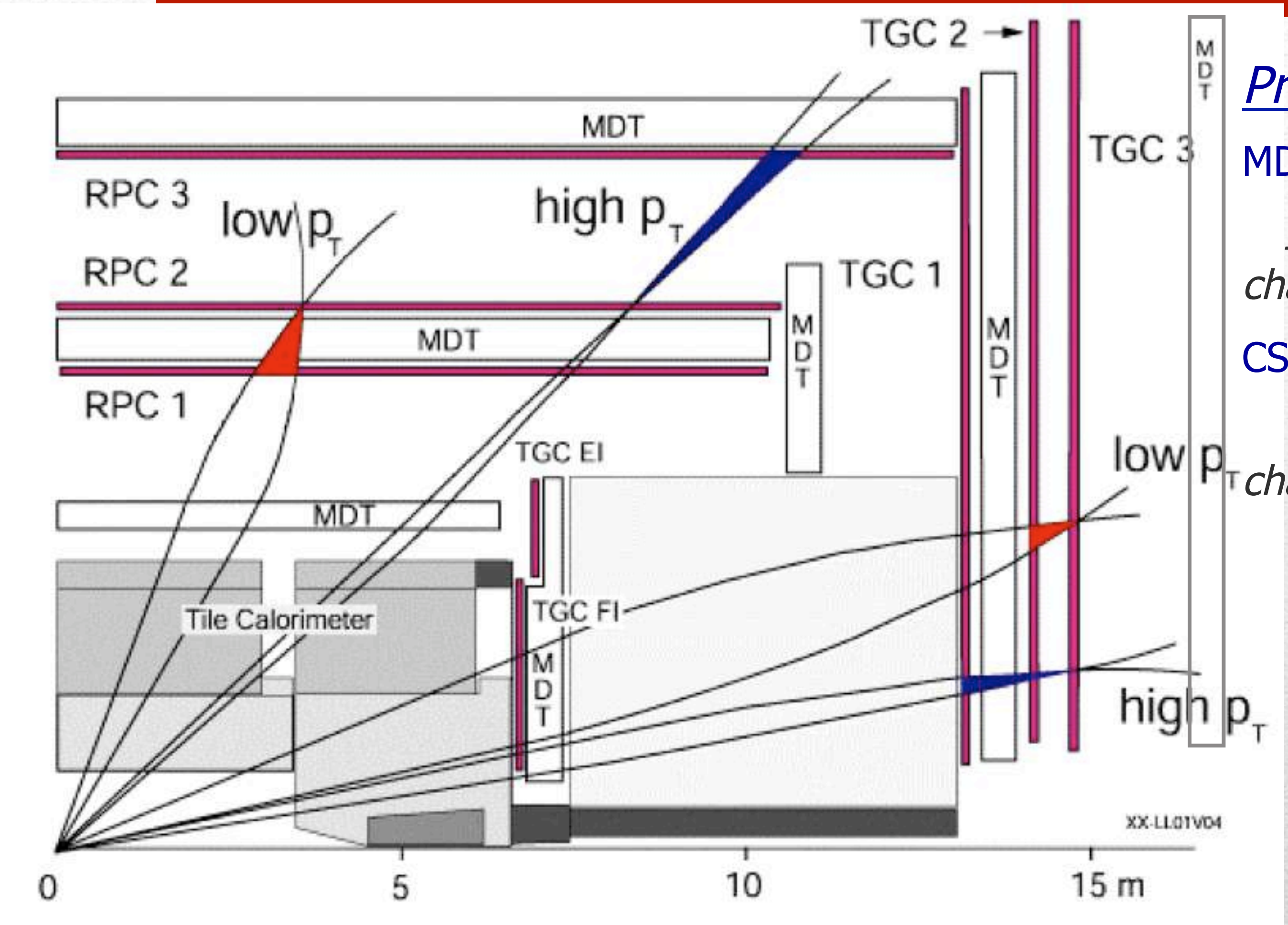



UV-transmitting
lightguides produced
for JLab Hall D
first articles



Diameter	*25 m*
Barrel toroid length	*26 m*
End-cap end-wall chamber span	*46 m*
Overall weight	*7000 Tons*
Material cost	*540MCHF*

THE ATLAS Detector



Precision chambers :

MDT : monitored drift tubes

1108 chambers, 339 k channels

CSC : cathode strip chambers

32 chambers, 31 k channels

Trigger chambers (LVL

RPC : resistive plate chamb

560 chambers, 359 k cha

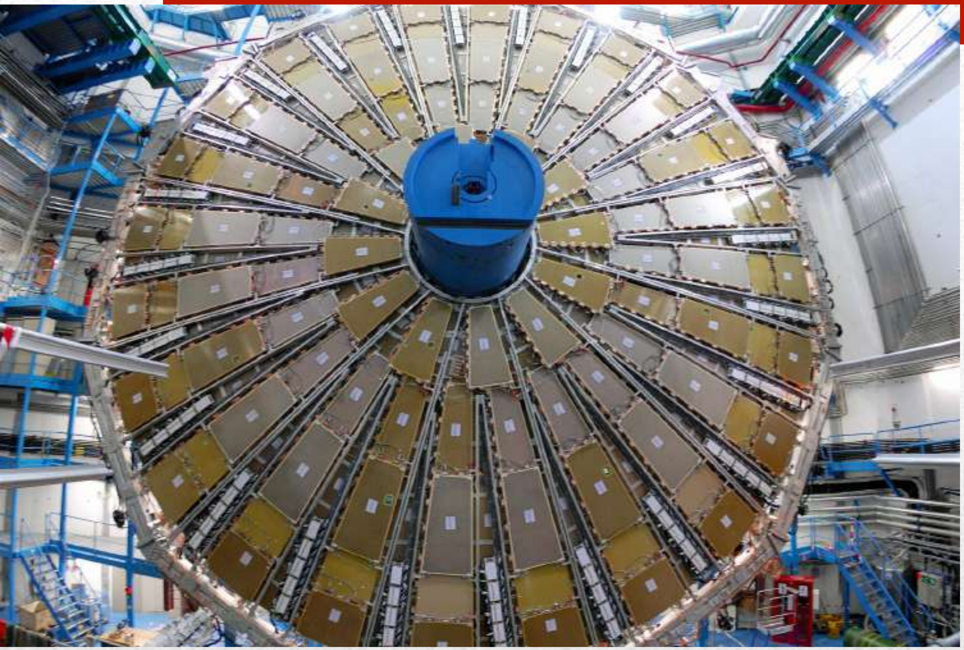
TGC : thin gap chambers

3588 chambers, 318 k ch

$\Delta p_T/p_T$ ~ 3% for p_T = 10-100 GeV in standalone mode

Total : ~12’000 m^2, ~ 1.1 M channels

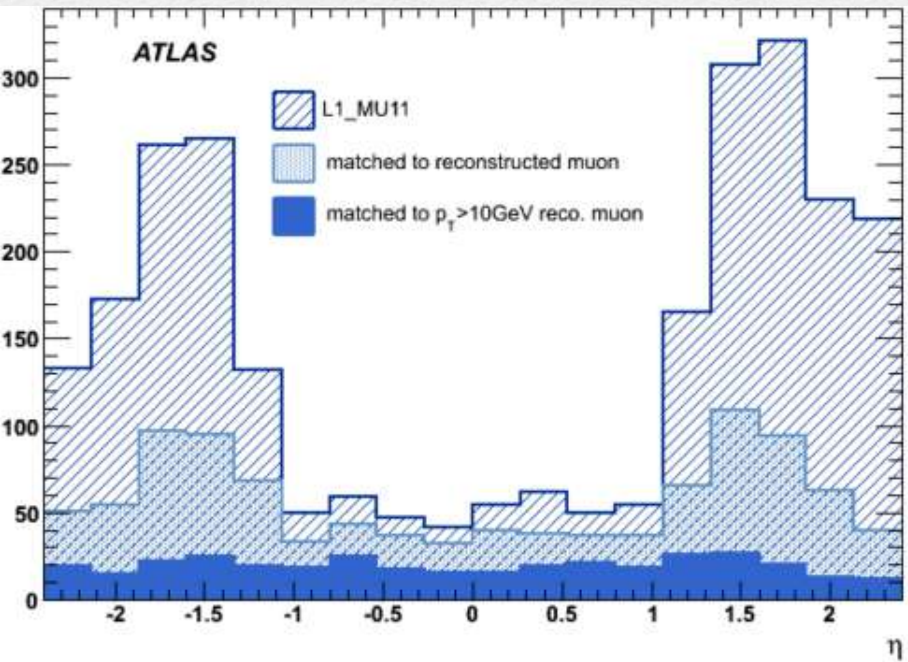
The Muon Spectrometer

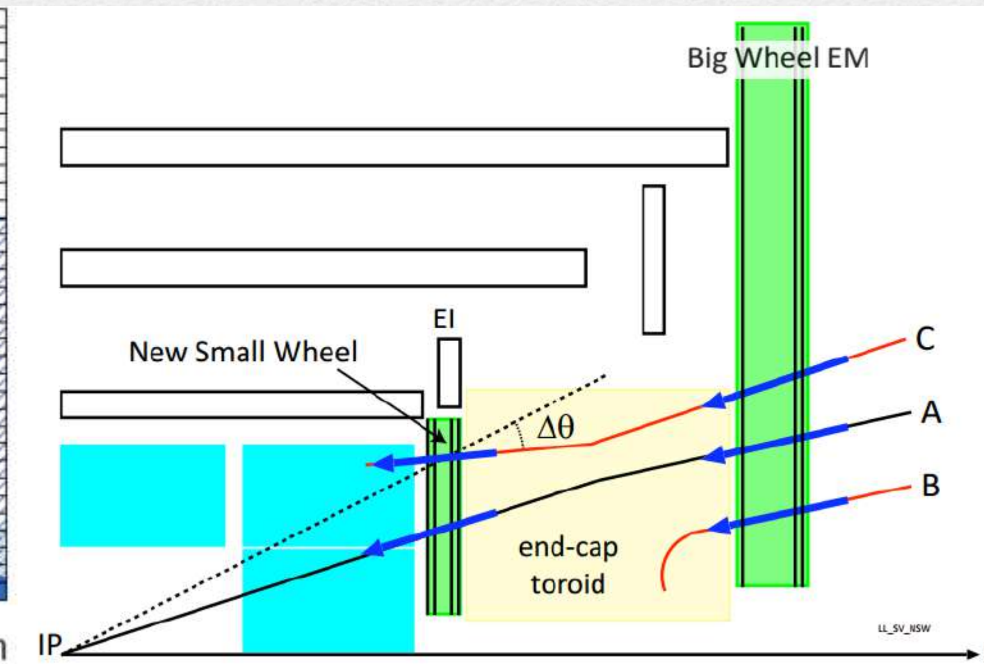


Motivation

- The instantaneous luminosity of the Large Hadron Collider at CERN will be increased up to a factor of five with respect to the design value by undergoing an extensive upgrade program over the coming decade.
- The largest phase-1 upgrade project for the ATLAS Muon System is the replacement of the present first station in the forward regions with the so-called New Small Wheels (NSWs) during the long-LHC shutdown in 2019/20

- Precise position measurement in front of the end-cap magnet is crucial for the momentum determination of the muon.
- Low energy particles produce fake triggers by hitting the end-cap trigger chambers at an angle similar to that of real high *p*T muons. An analysis of 2012 data demonstrates that approximately 90% of the muon triggers in the end-caps are fake.

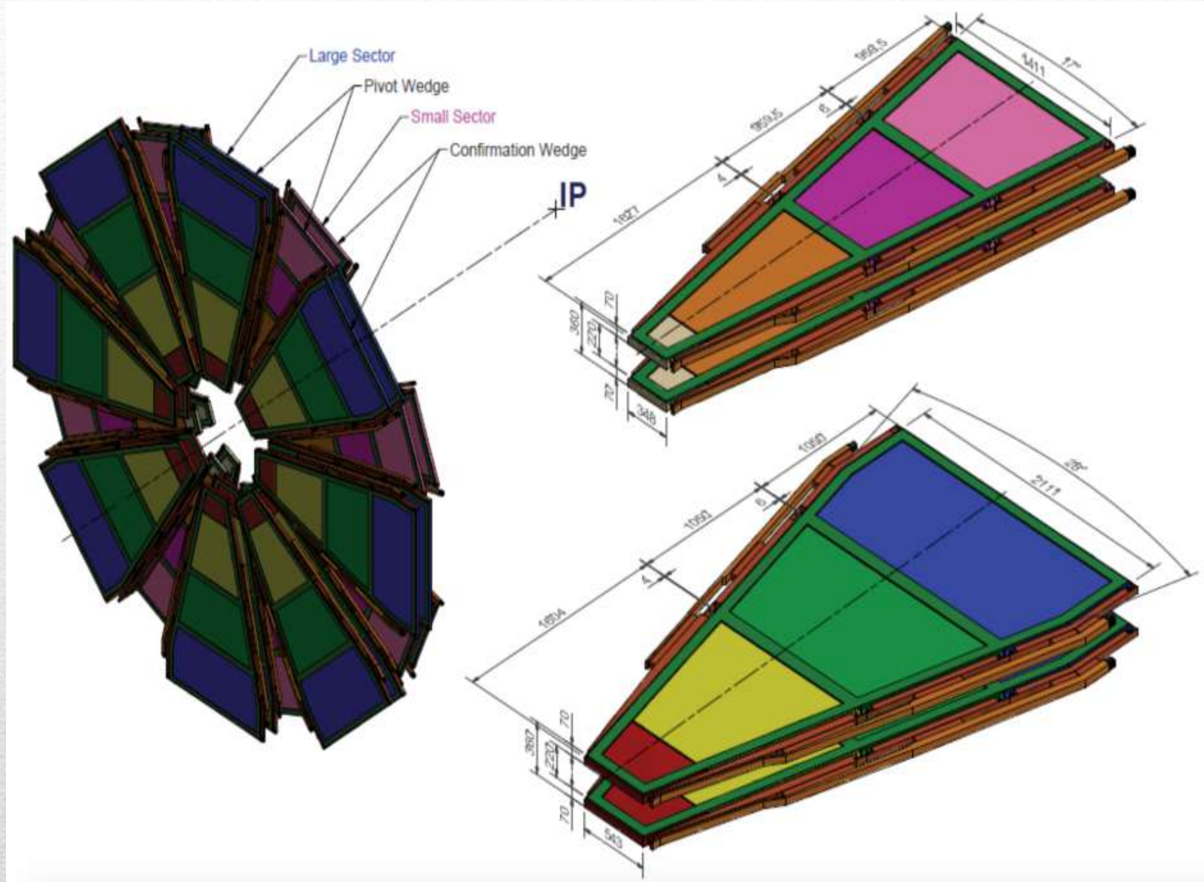




Principal reasons to change the Small Wheel

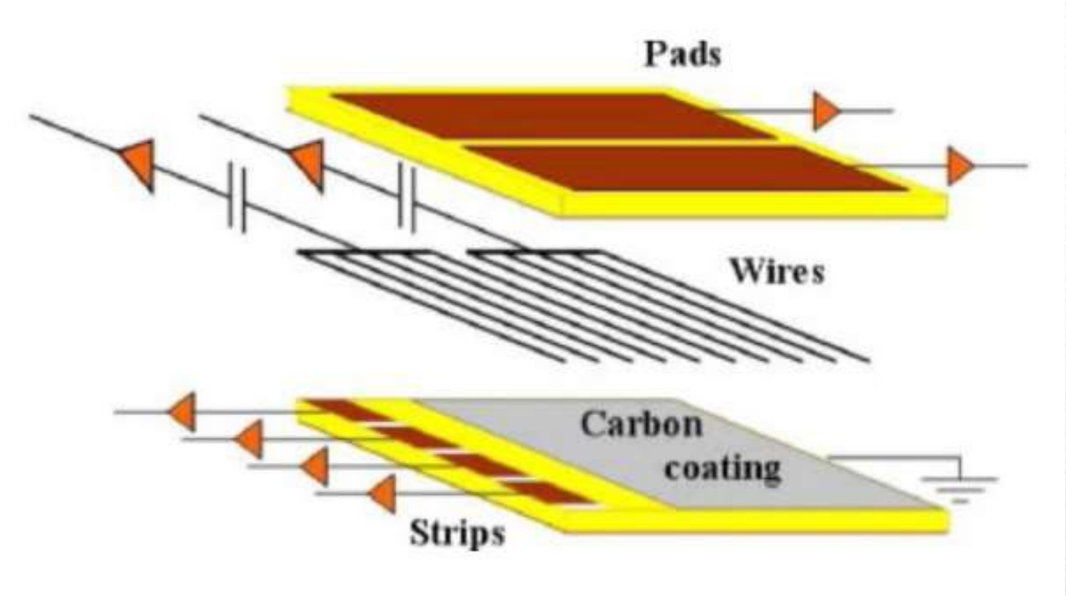
New Small Wheel

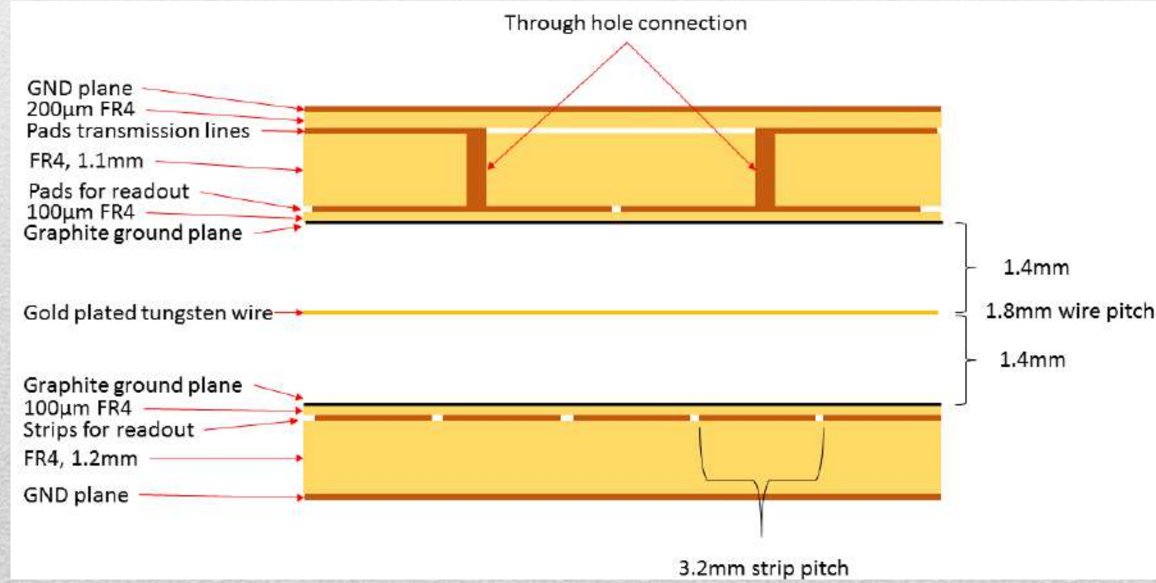
- The NSW is a set of precision tracking and trigger detectors able to work at high rates with excellent real-time spatial and time resolution. These detectors can complement the muon Level-1 trigger system with online track segments of good angular resolution (<1mrad) to improve the momentum measurement
- two sTGC wedges, pivot and confirm sandwiched the MicroMegas detector in small and large sectors.



sTGC structure

- The basic sTGC structure consists of a grid of gold-plated tungsten wires sandwiched between two resistive cathode planes at a distance of 1.4mm from the wire plane.
- The precision cathode plane has strips with a 3.2mm pitch for precision readout relative to a precision brass insert outside the chamber, and the cathode plane on the other side has pads for triggering .
- The gap is provided using precision frames machined and sanded to 1.4mm ±20µm and glued to the cathode boards





CONICYT had signed the MOU

Chilean contribution (core) :
sTGC 294K CHF
HV/LV power supply chain 40K CHF

CONICYT
Ministerio de Educación
Gobierno de Chile

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Programa de Cooperación Internacional

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Noticias

CONICYT Y CERN FIRMAN ACUERDO PARA LA CONSTRUCCIÓN EN CHILE DE PIEZA CLAVE EN LA RENOVACIÓN DEL EXPERIMENTO ATLAS

Publicado 11-06-2014

Con el apoyo de CONICYT además se financiará la incorporación como miembro pleno de la Universidad de Talca al experimento ALICE.

Small Wheel

CONICYT y la Organización Europea de Investigación Nuclear (CERN) firmaron la semana pasada un Memorandum de Entendimiento (MoU) para la construcción de la Pequeña Rueda de Mounes (Muon New Small Wheel Project) por parte de científicos de la Pontificia Universidad Católica y del Centro Científico Tecnológico de Valparaíso (CCTVal) de la Universidad Técnica Federico Santa María, como parte del proceso de renovación de ATLAS, el detector de partículas más grande del mundo.

CONICYT financiará con más de 200 millones de pesos el equipamiento necesario para la construcción de parte de la Pequeña Rueda de Muones, proyecto considerado clave en la renovación del experimento ATLAS que busca incrementar la eficiencia en la detección de partículas.

Por otro lado, CONICYT financiará la incorporación en calidad de miembro pleno de la Universidad de Talca a ALICE, experimento donde esta universidad colabora desde diciembre del 2011 como uno de los laboratorios de computación de alto rendimiento donde físicos del CERN envían sus dato para ser procesados.

En el 2014 el apoyo de CONICYT para potenciar la actividad de instituciones chilenas en CERN permitirá además a la Pontificia Universidad Católica y la Universidad Federico Santa María aumentar de cuatro a cinco sus investigadores en ATLAS.

CERN es el laboratorio de física de partículas más grande del mundo, que reúne en Suiza a más de 7.500 científicos, ingenieros, estudiantes y técnicos de 60 países, incluido Chile, para colaborar en la busca de nuevos fenómenos y partículas que forman la materia obscura.

En el 2007 CONICYT y CERN firmaron un Protocolo que ha servido de marco para la participación a largo plazo de estudiantes, científicos y técnicos de universidades e instituciones de investigación en Chile en los experimentos de CERN, permitiendo a la Pontificia Universidad Católica y la Universidad Federico Santa María incorporarse como miembros de ATLAS, dando un impulso sin precedentes al desarrollo de la física experimental en Chile.

FONDEQUIPT grant

Sherf Motion Technologies Ltd.

1. Winding machine 250 000 Nls or USD 70.6 K
2. Rotary table 200 000 Nls or USD 56.5 K

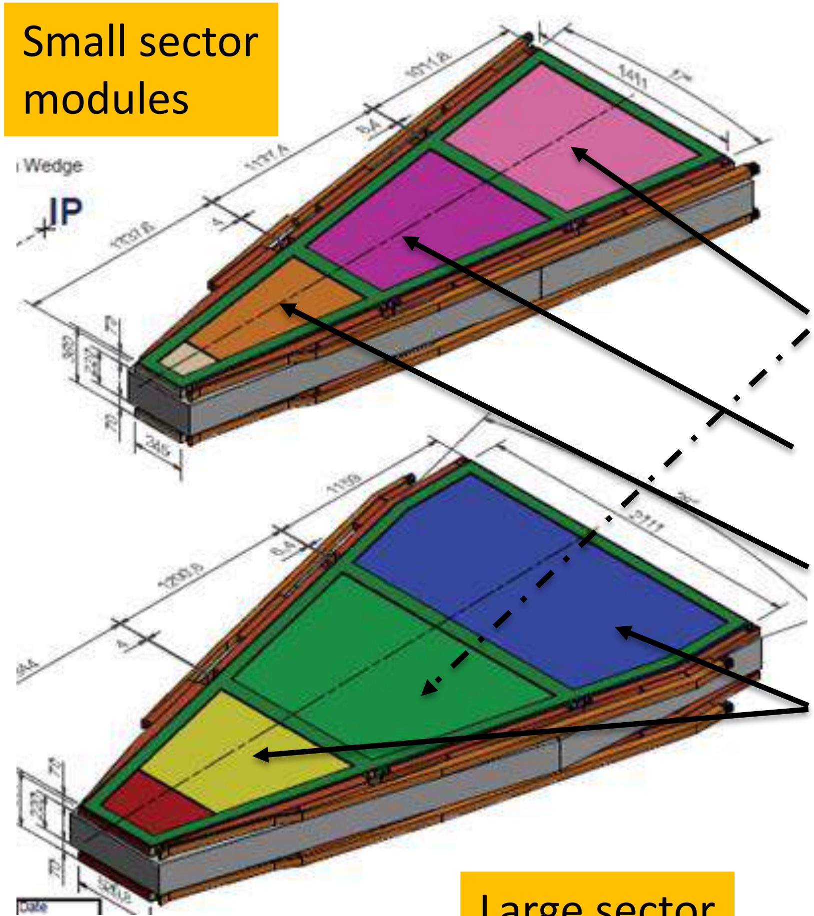
CEFLA finishing group, PRIMA machine USD 130 K

- The grant for industrial equipment only
- A machine price >> USD 120K
- 20% university, 80% CONICYT
- We have about USD 200K from contract with JLAB

sTGC project of ATLAS

Wedge Segmentation – sTGC:

Small sector modules



Large sector modules

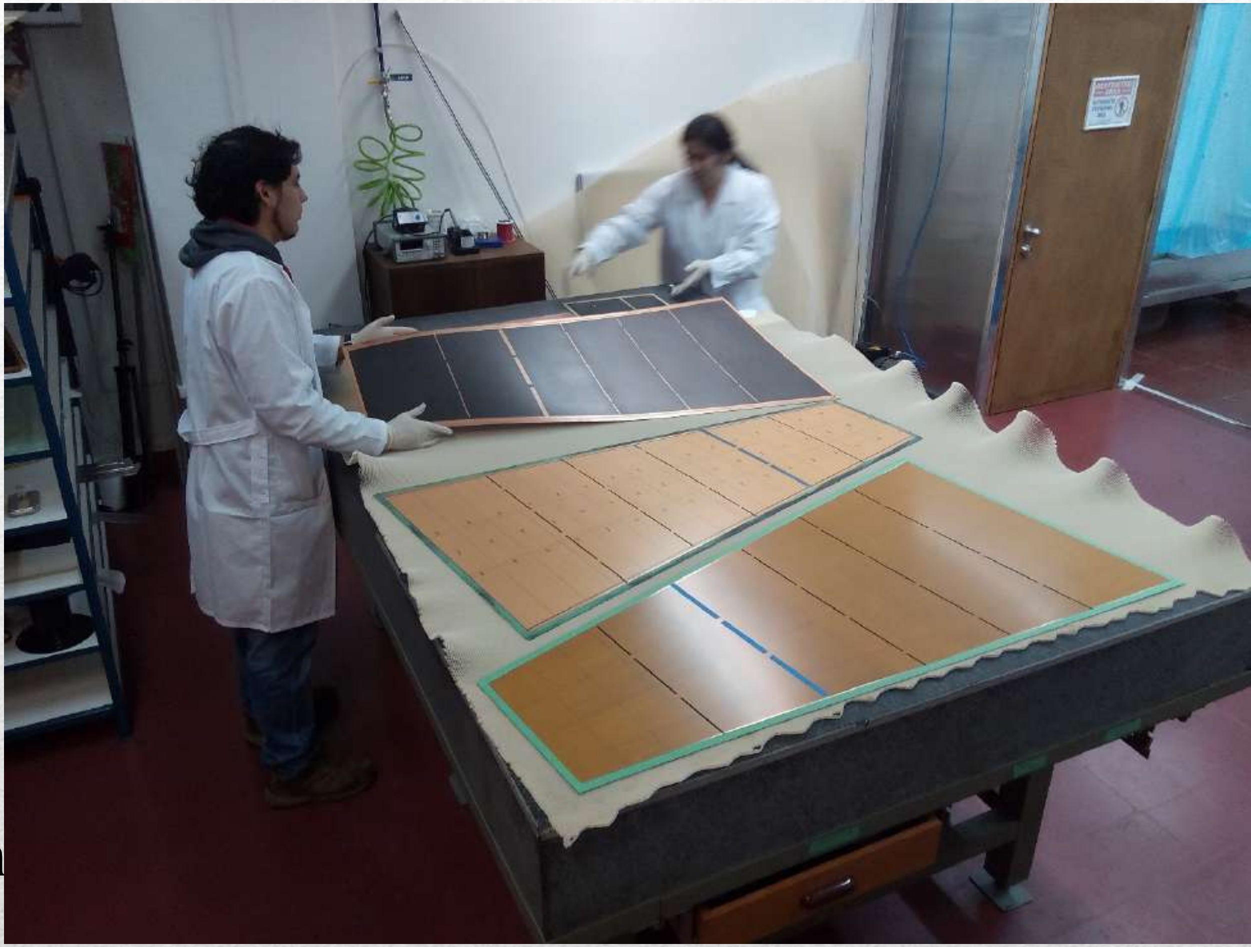
Radial segmentation in 3 modules per wedge

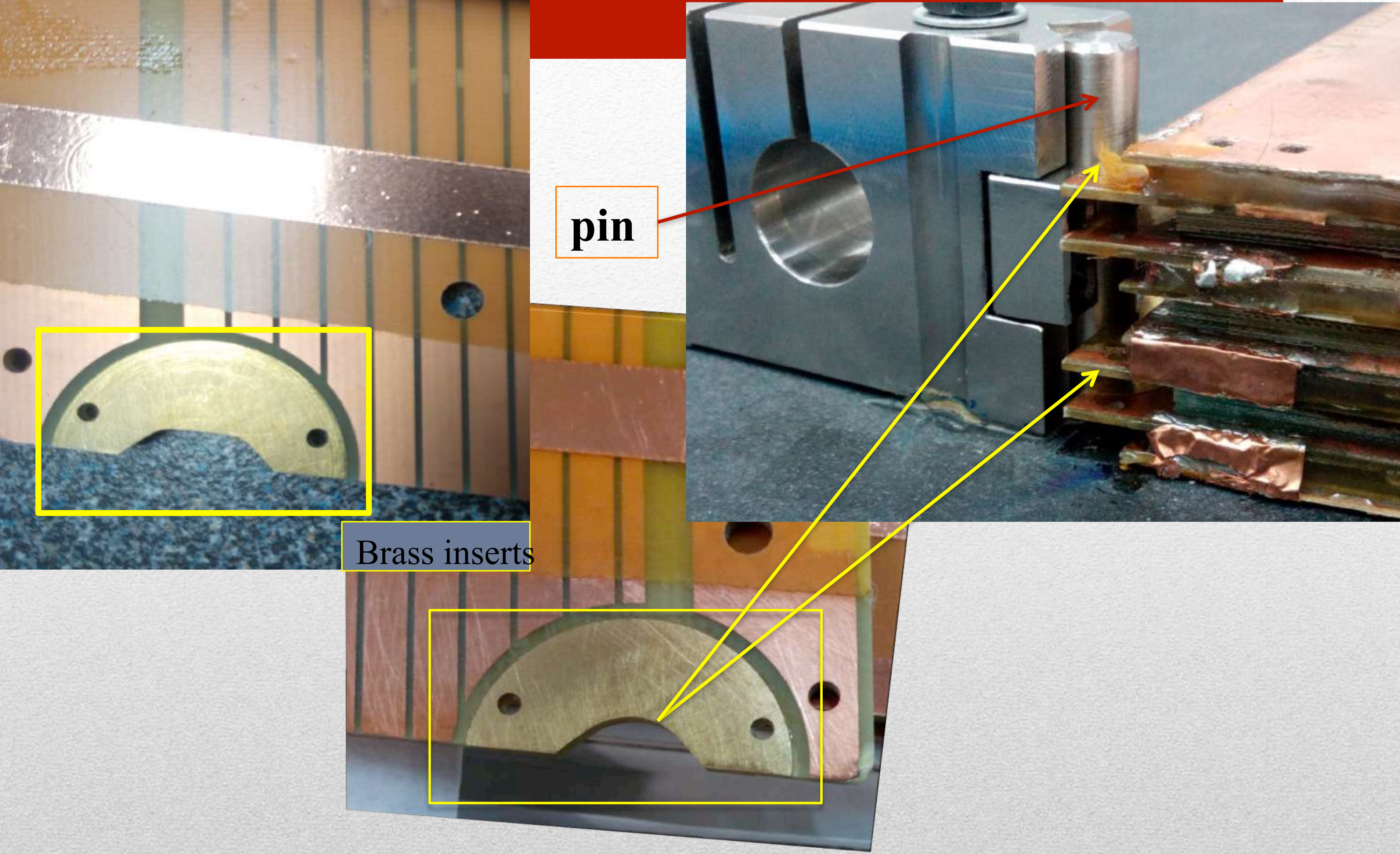
Construction sites:

- Canada (TRIUMF, Carleton, McGill clusters)
- China (Shandong)
- Chile (PUC Santiago, Valparaiso)
- Israel (Weizmann, Tel Aviv, Technion)

small-strip Thin Gap Chamber

- Pads readout provide fast pre-trigger to determine which strips to read.
- Precision strips for precision muon tracking reconstruction at level of 100μm
- High efficiency at high background rate.
- All quadruplets have trapezoidal shapes with surface areas up to 2 m2





Precision brass insert and alignment pin

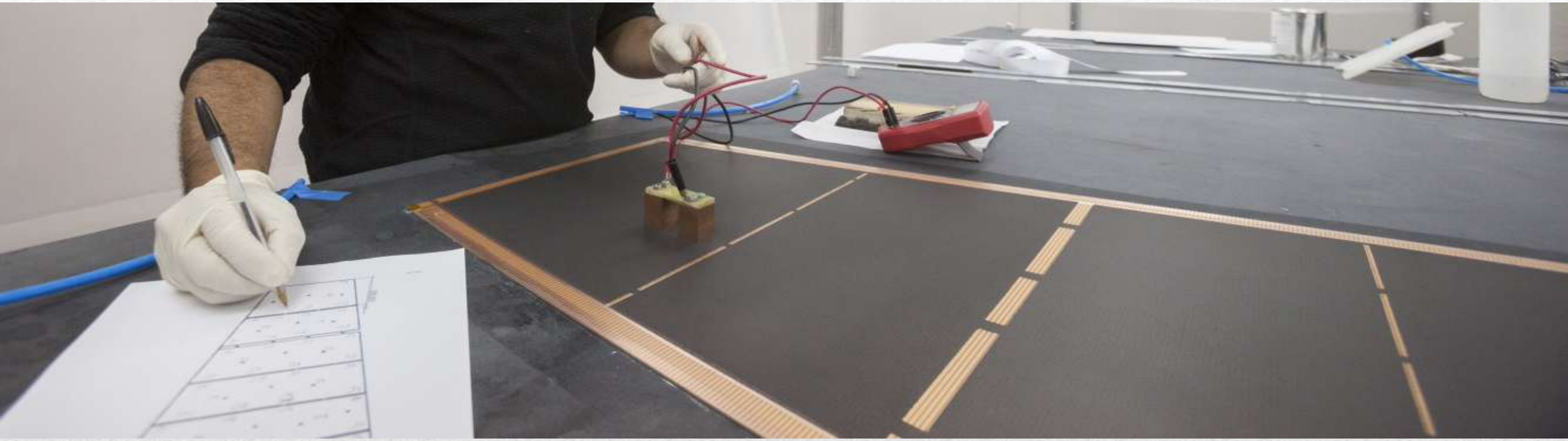
- Cathode boards check QA/QC
- Resistive layer spraying
- Polishing to get 100kohm/sqr. Surface resistivity
- Gluing of precision frames, QA/QC
- Winding of pad cathodes boards
- Soldering of wires, wash, solder resistors and cables, QA/QC
- Closing of single chambers, QA/QC flatness and thickness
- Test with HV during 7 days and gain uniformity with xrays, QA/QC
- Assembly of doublet/quadruplet, QA/QC

Construction steps

Horizontal spraying machine PRIMA

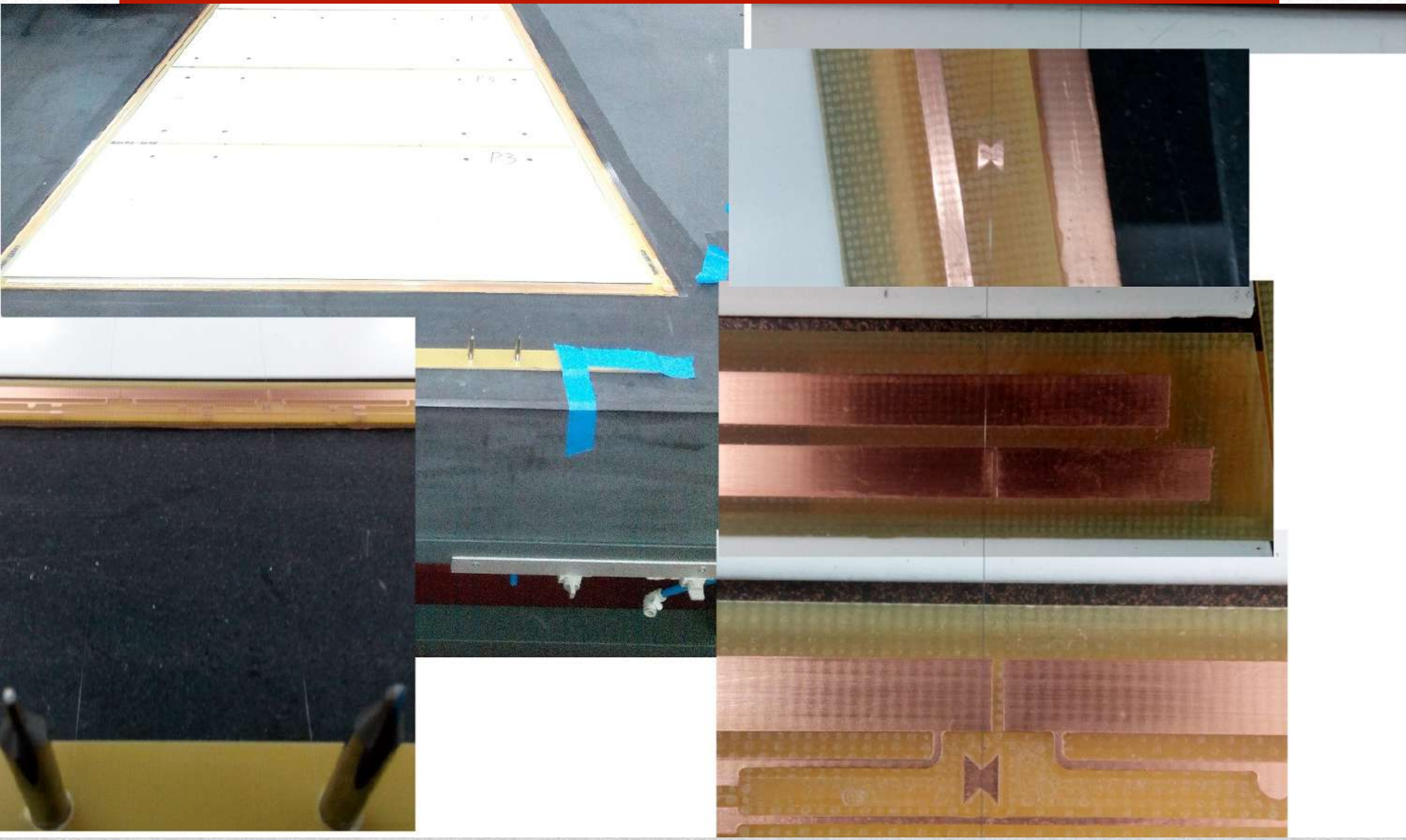
Frame gluing under vacuum

Spraying and frame gluing



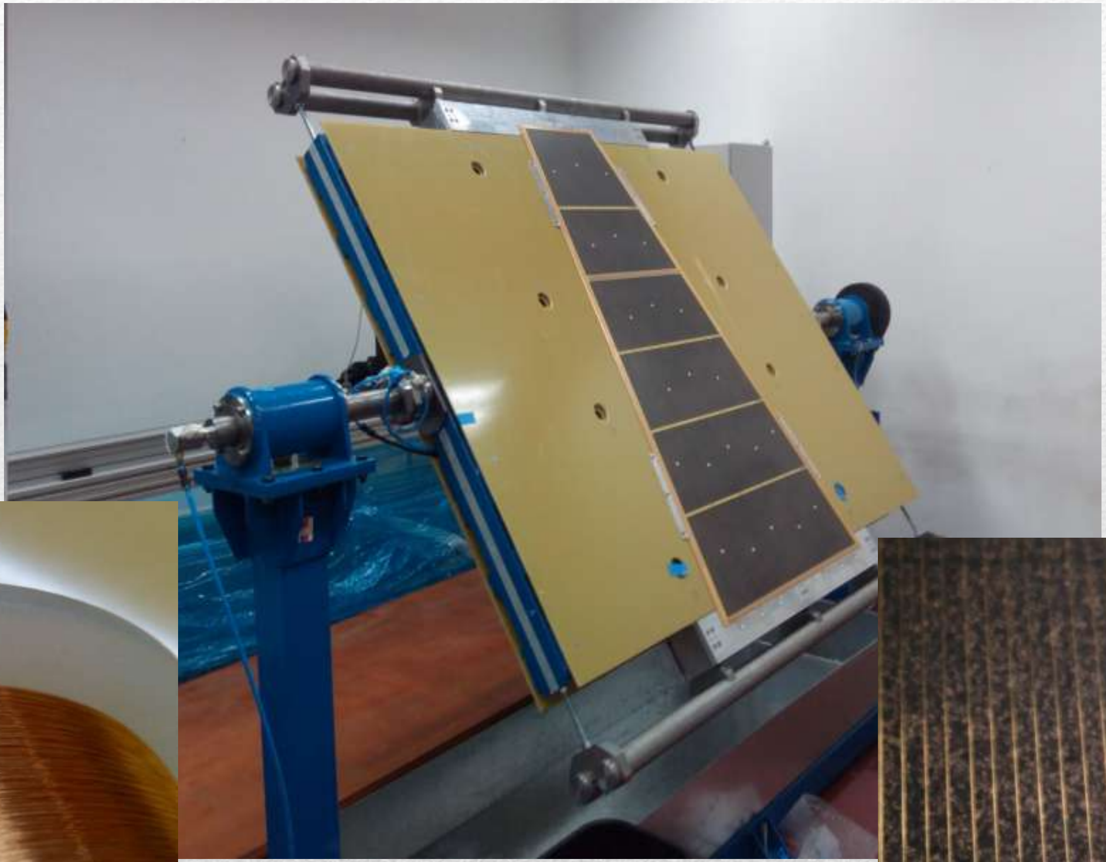
- Board is polished to get down the resistivity to 100kΩ/square ±20%
- Surface resistivity is recorded to DB
- If surface resistivity does not meet the requirement, cathode board is cleaned and sprayed again.

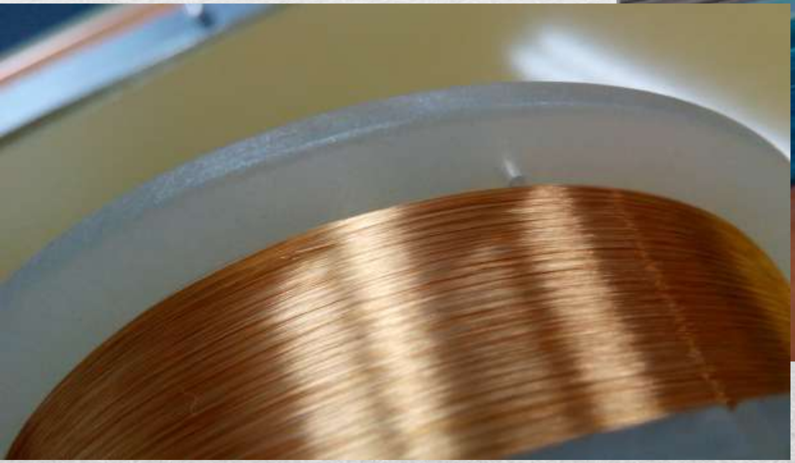
Polishing to get 100kohm/sqr. Surface resistivity



Gluing of precision rulers

- Two pad boards with frames glued are placed in a rotary table in which a gold plated tungsten wire is winded



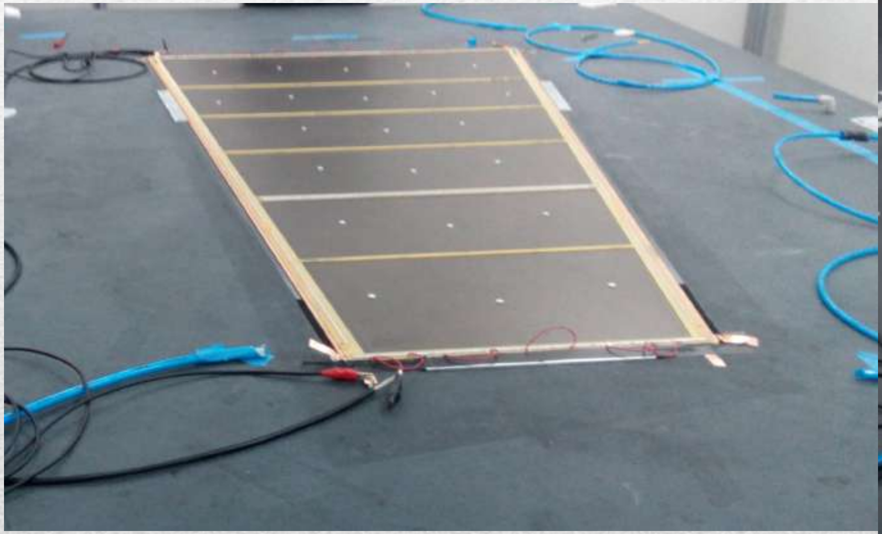


LUMA METALL 50 microns wire

Winding of pad cathodes boards

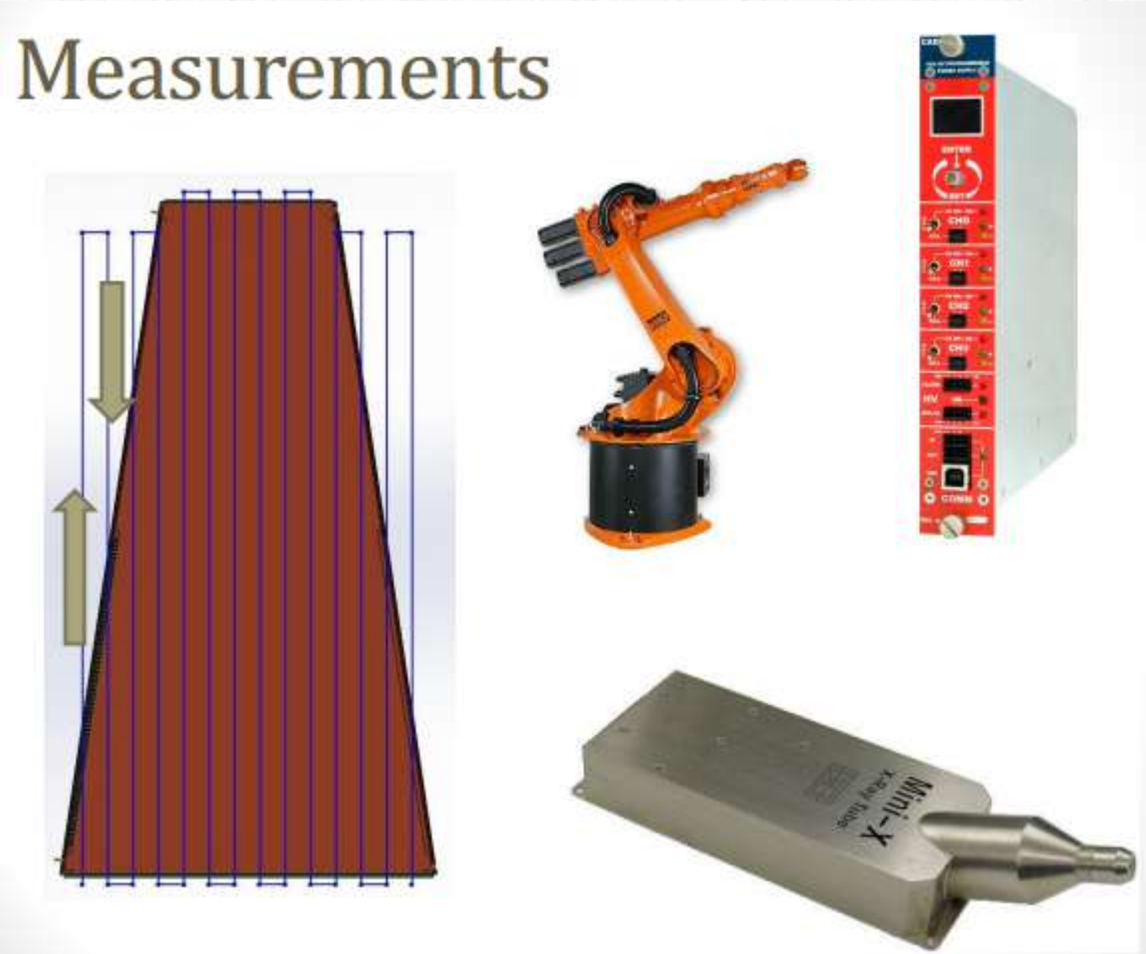
Soldering of wires, cut excess of wires, wash, solder resistors and cables...

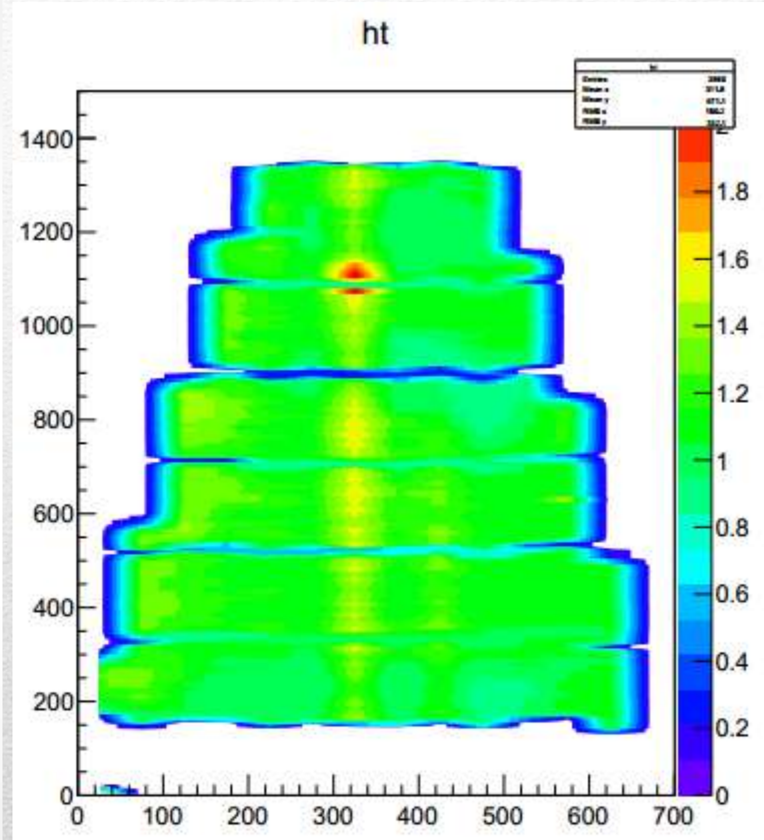
Pad cathode under high voltage



Chamber with aluminum honeycomb strong-back

Chamber closing





Uniformity test using x-ray

New room for HV test and X-ray test

December 2017
Two walls were disassembled for moving X-ray machine in the room.
X-ray machine was installed and checked
A construction of a clean zone around X-ray machine was began.
The floor was modified.
High voltage system was installed.
Work on gas lines was began.

New room for HV test and X-ray test

March 29, 2018

Gas lines and isolated area for X-ray machine

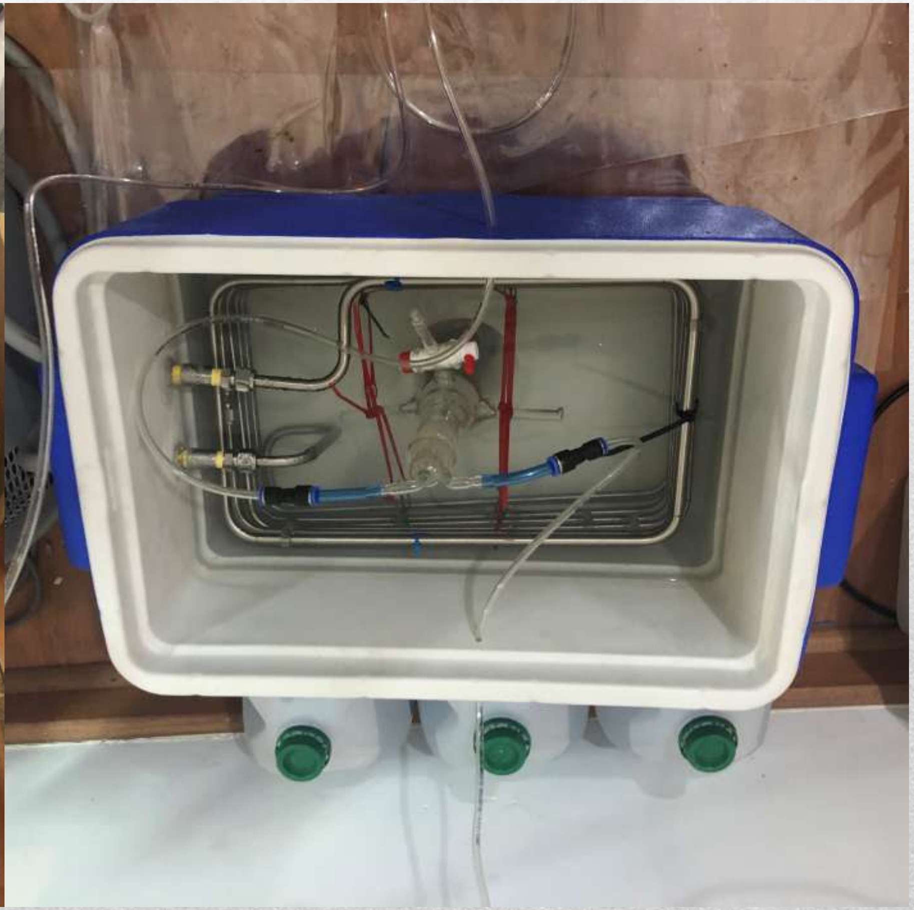
New room for HV test and X-ray test

Gas lines for 4 gaps

Temperature and humidity monitoring

New room for HV test and X-ray test

The new gas mixture system.



New room for HV test and X-ray test

X-ray set up, collimator&filter

HV test set up

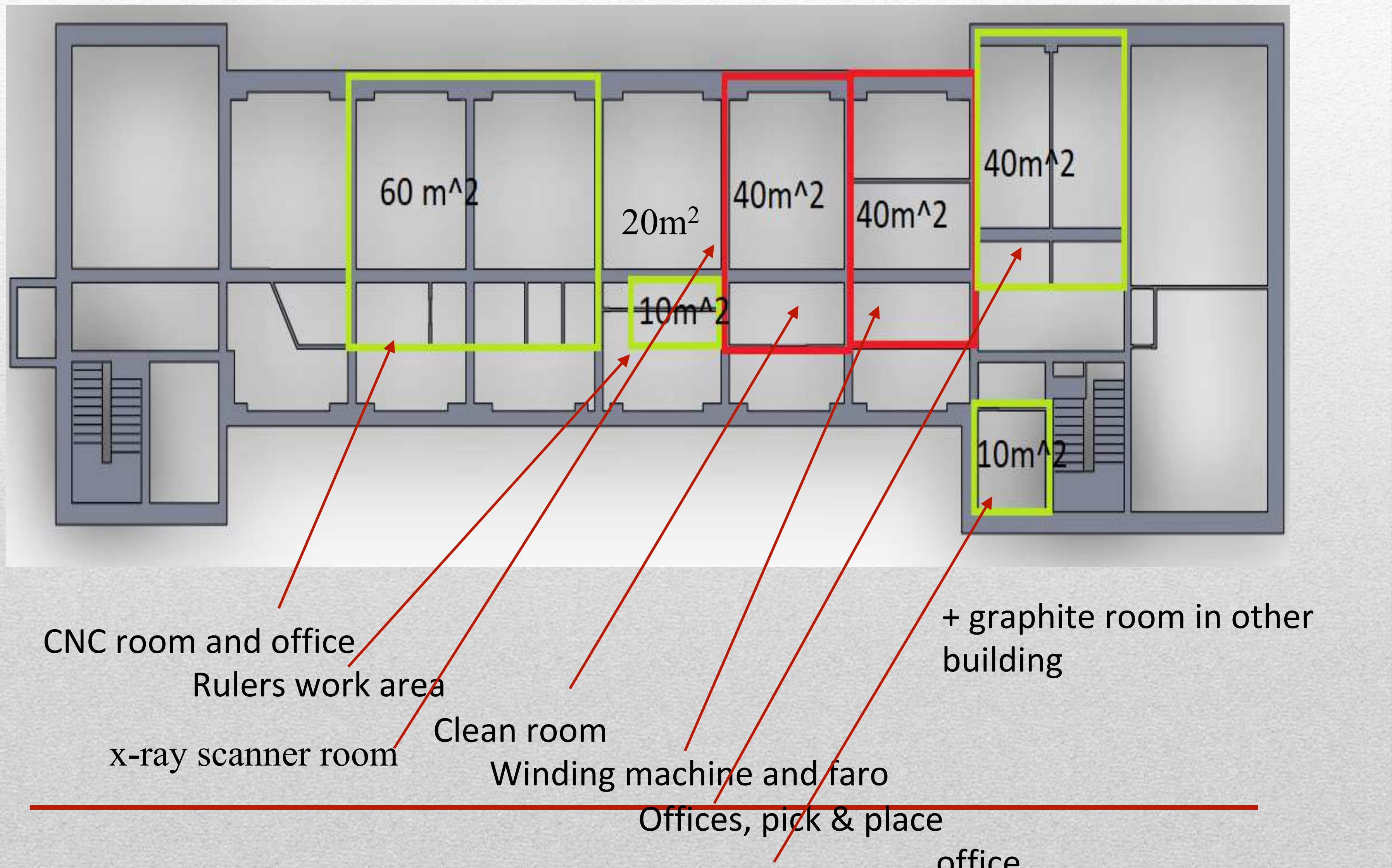
Work with the strong back

sTGC assembling facility of Chile

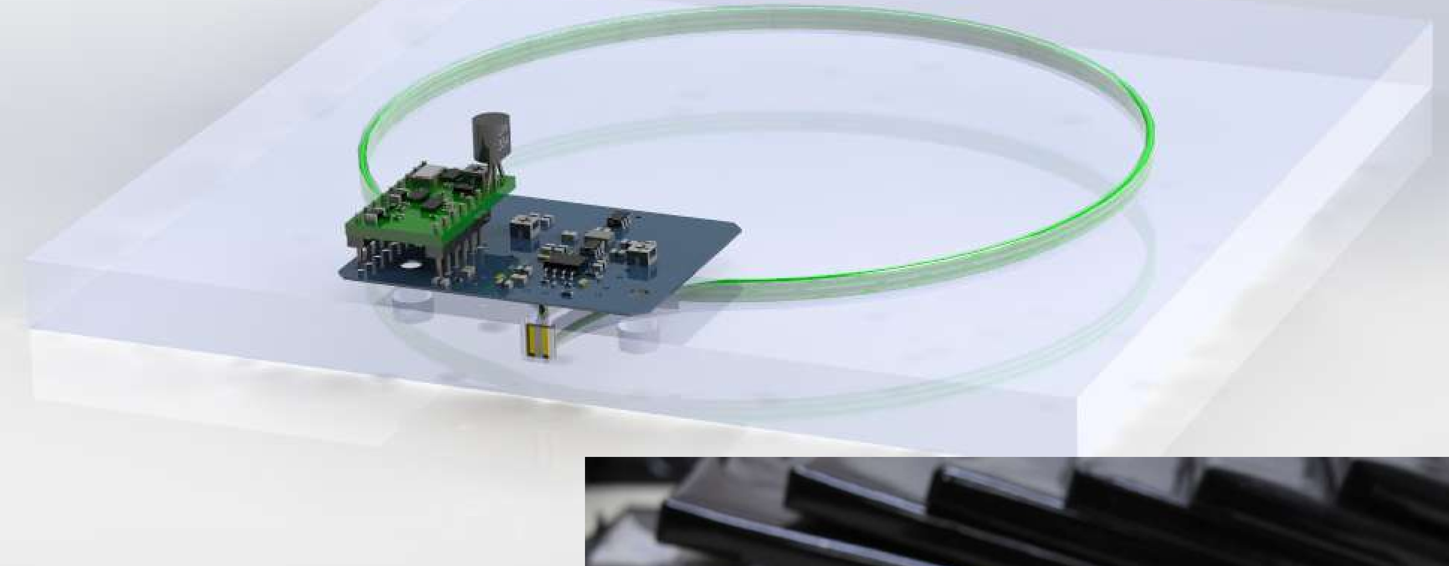
The shipment of Module0 from UTFSM to CERN

Team members in CERN: Rimsky Rojas and Gerardo Vasquez

Rooms and space at UTFSM Det.Lab before August 2018



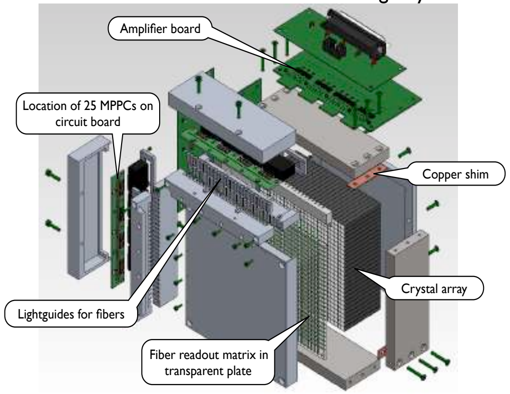
Cosmic Ray detectors: Production & Facility



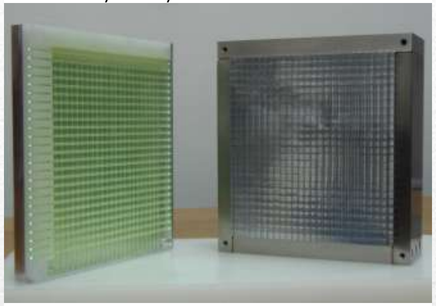
Cosmic ray test facility. 400 detectors were produced.

UTFSM Detector Laboratory activities in frame of EIC Detector R&D (BNL)

Preshower calorimeter: mechanical design layout



Crystal array with fiber readout matrix

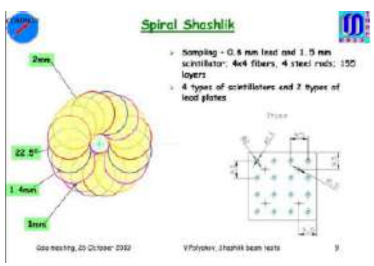


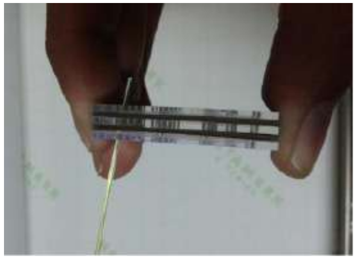
25 x 25 Kuraray Y-11 fibers embedded in transparent plate

The proposal was accepted by **EIC Detector R&D BNL in 2012.**
UTFSM bought 650 LYSO P420 (PreLude 420) pixels with 4x4x45 mm^3 size for 15600 Euro
UTFSM bought CAEN VME create, CAEN VME QDC, CAEN SY1527LC mainframe and A1519B 12 ch. 250V individual floating channels module
We got 46K $ from BNL for MPPC, fibers, components and materials.
The detector was tested and used as SRD by NA-64 in 2016, 2017 runs

https://wiki.bnl.gov/conferences/images/5/5b/RD2012-13_Progress_Report_May_2013_Brooks.pdf

W Shashlyk (Compact, 2D). UTFSM





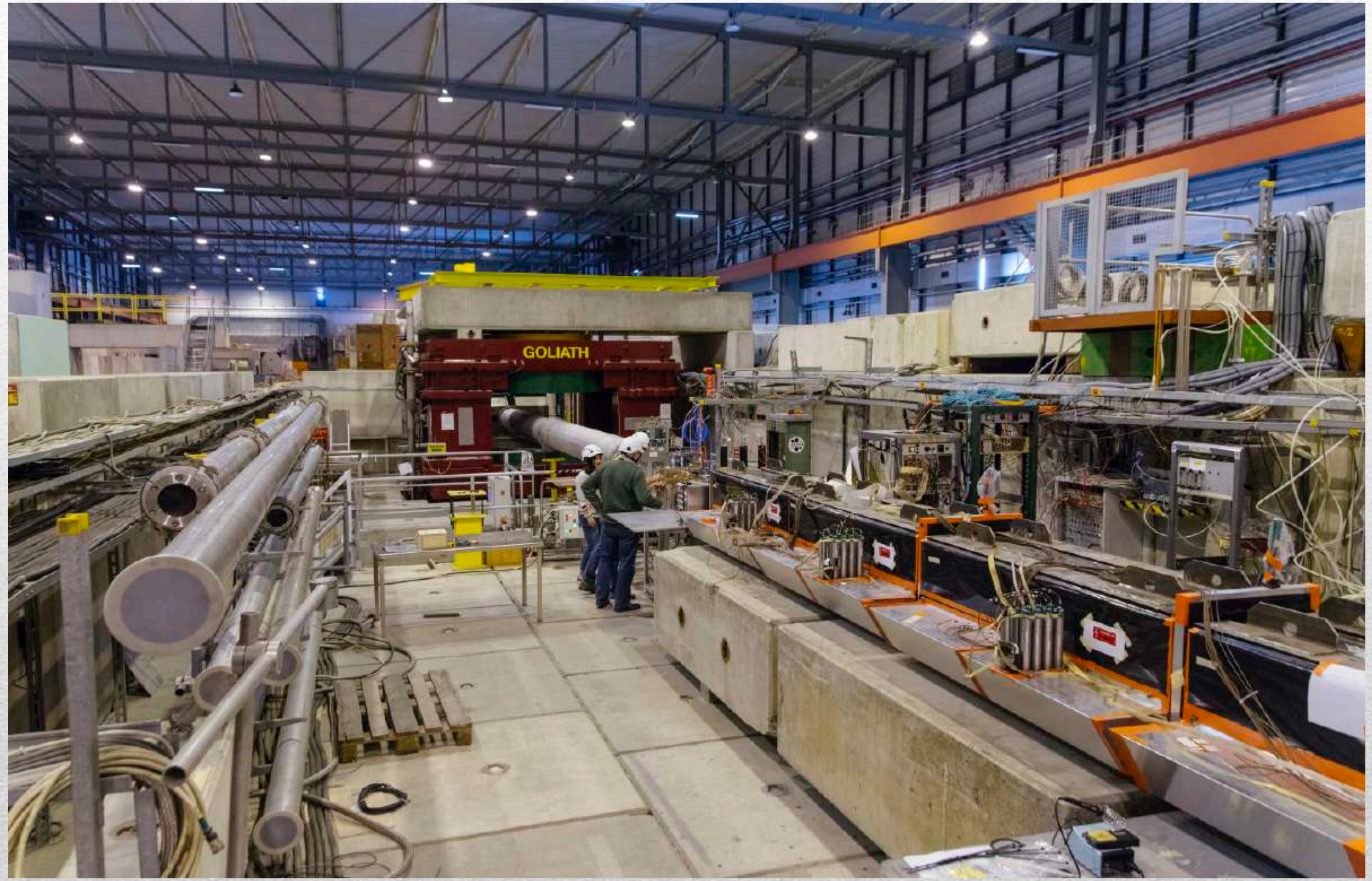
A mechanical engineer, Eliás Rozas, works on the project

https://wiki.bnl.gov/conferences/images/a/a5/EIC_R%26D_WSciFi%2BShashlik_7-26-18.pdf
https://wiki.bnl.gov/conferences/images/1/1e/Eic_r%26d_july2018_v4.2_intro.pdf

- New project for design and production of DAQ (10^3 channels) with 14 bits ADC slice sample about 2nS for NA64, new COMPASS and medical physics projects.

DAQ project

NA64, July 2016



NA64

NA64 is designed to search for new, in particular Dark Sector physics in missing energy events. Broad research program with e^-, μ, π, K, and p beams at SPC (PBC'16/17)

- e^- program approved in March 2016

-2016: test run in July (2w), physics run October(4w) 4.3×10^{10} 100 GeV invisible,

-2017: 5w run in autumn 5.4×10^{10} visible 100 GeV e

-2018:5w run, 1.94×10^{11} 100 GeV e invisible, 3.04×10^{10} 150 GeV e visible

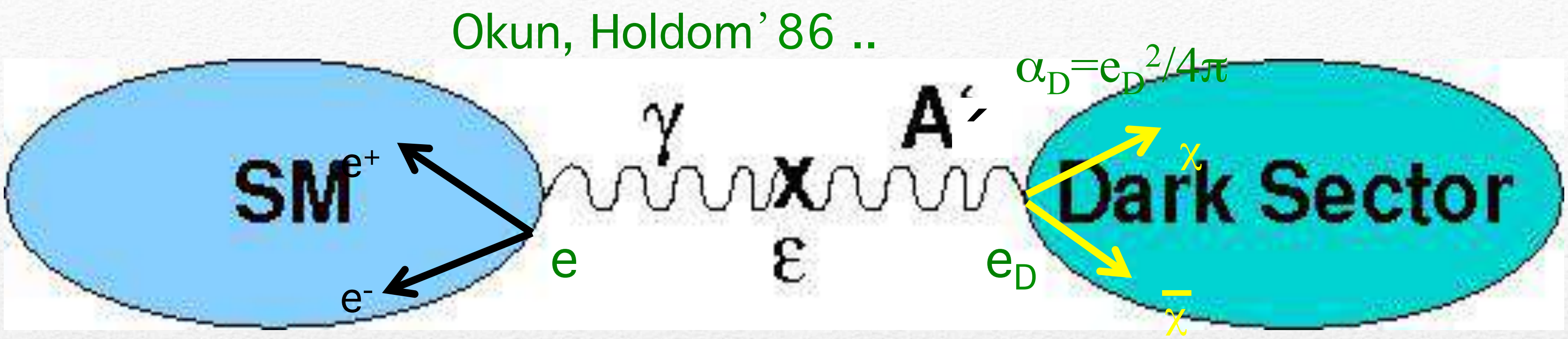
- Main goals for 2016-2018:

-Search for invisible decay of the A′, in particular in the parameter space which could explain the muon g-2 anomaly

-Feasibility of the search for the light X-boson from the ^{8}Be excess

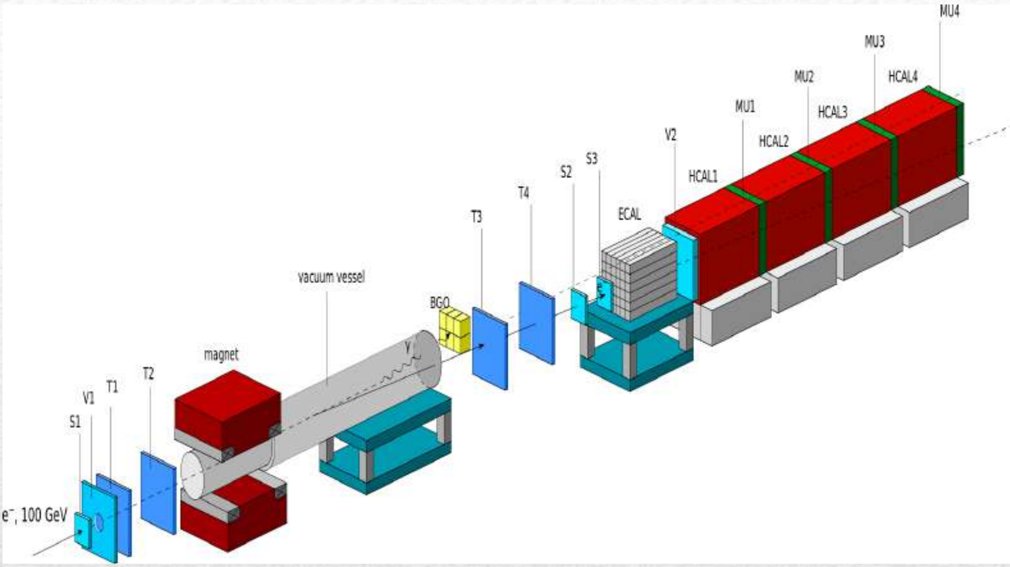
- ~ 40 participants from Chile, Germany, Greece, Russia, Switzerland and CERN

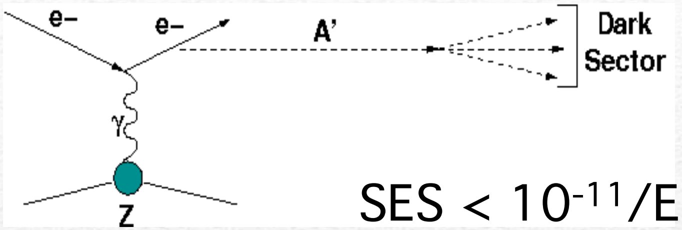
Vector portal to Dark Sector



- new massive boson A´ (dark photon) which has kinetic mixing with ordinary photon: $\Delta L = \varepsilon/2\ F^{\mu\nu} A'_{\mu\nu}$
- GUT prediction for the size of the γ-A´ mixing strength (ε<<1): 1-loop: $\varepsilon \sim 10^{-4}$ - 10^{-2} ; 2 loops: $\varepsilon \sim 10^{-5}$ - 10^{-3}, $m_{A'} \sim \varepsilon^{1/2} M_Z$
- Production: A´ - bremsstrahlung $e^- Z \rightarrow e^- Z A'$, $\sigma \sim Z^2 \varepsilon^2 / m_{A'}^2$
- Decays:
  - Visible: $A' \rightarrow e^+e^-, \mu^+\mu^-$, hadrons,..
  - Invisible: $A' \rightarrow \chi\bar{\chi}$ if $m_{A'} > 2m_\chi$ assuming $\alpha_{DM} \sim \alpha >> \varepsilon$.
    Can explain $(g-2)_\mu$, astrophys. observations
- Cross section for χ–DM annihilation: $\sigma v \sim \underbrace{[\alpha_{DM}\, \varepsilon^2 (m_\chi/m_{A'})^4]}_{y}\ \alpha/m_\chi^2$

Search for A´->invisible decays at CERN SPS





SES < 10^{-11}/EOT

S.Andreas et al., arXiv: 1312.3309
S.G., PRD(2014)

Signature:

- in: 100 GeV e- track
- out: $E_{ECAL} < E_0$ shower in ECAL
- no energy in Veto and HCAL

Main components :

- clean 100 GeV e- beam
- e- tagging system: tracker+SRD
- 4π fully hermetic ECAL+ HCAL

Background:

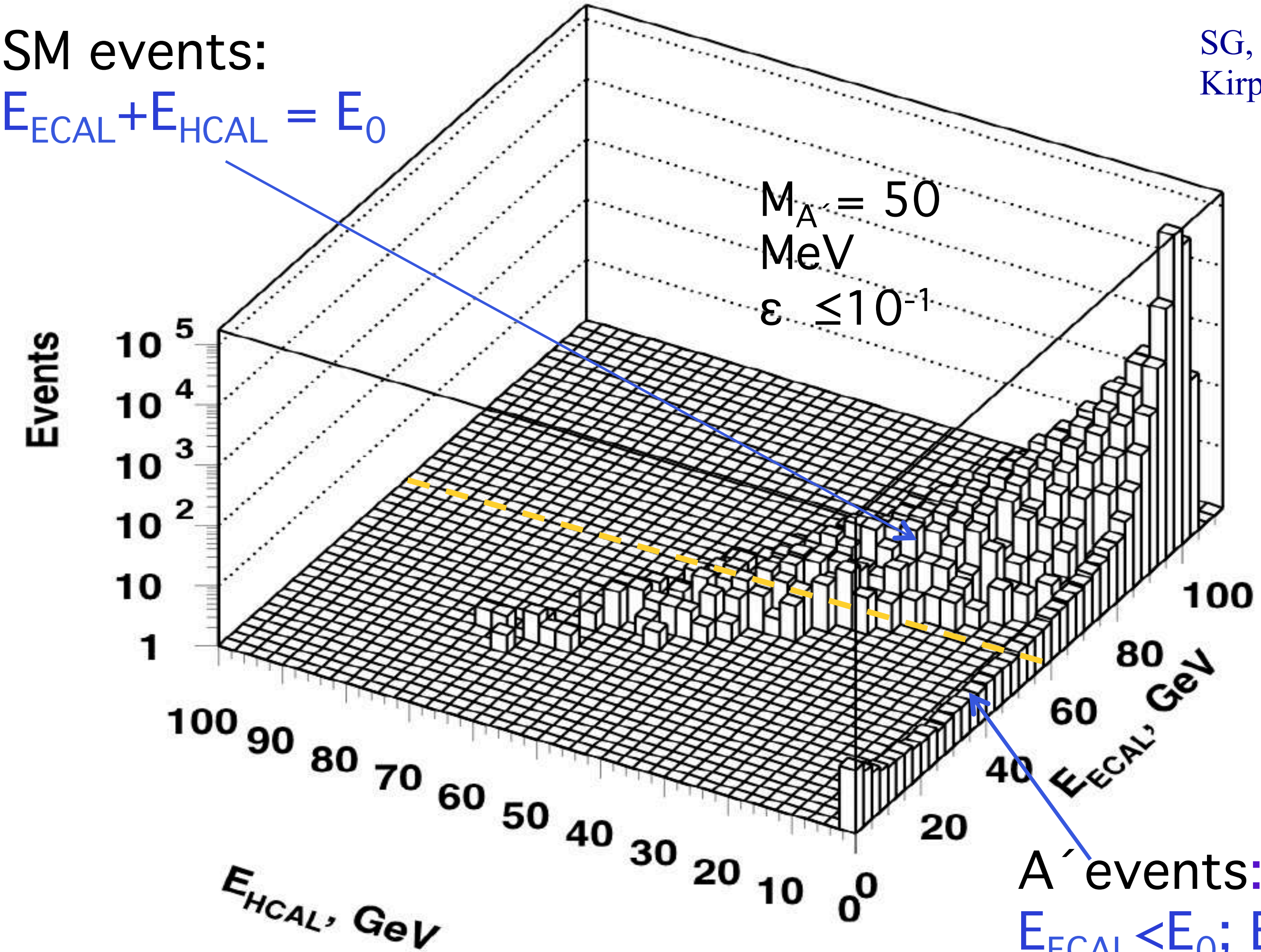
- μ, π, **K decays in flight**
- Tail < 50 GeV in the e- beam
- Energy leak from ECAL+HCAL

Signature for eZ->eZA´; A´-> invisible

GEANT4+code for A´emission in the process of e-m shower development σ(e^-Z->e^-ZA´) from Bjorken et al.`09

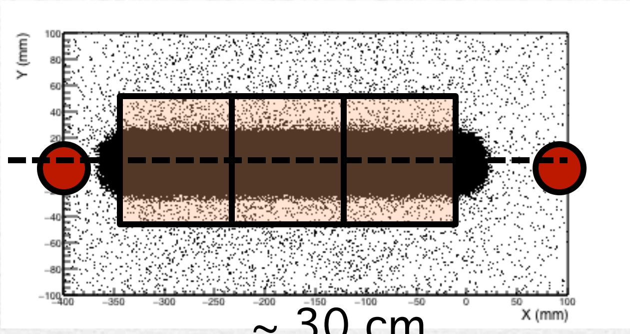
SG, Kirsanov, Krasnikov, Kirpichnikov PRD(2016)

SM events:
$E_{ECAL}+E_{HCAL} = E_0$



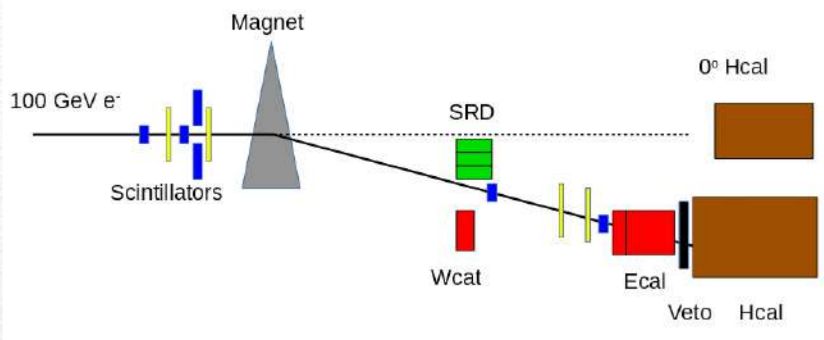
A´events:
$E_{ECAL}<E_0$; $E_{HCAL}=0$

Electron tagging with synchrotron radiation (SR)

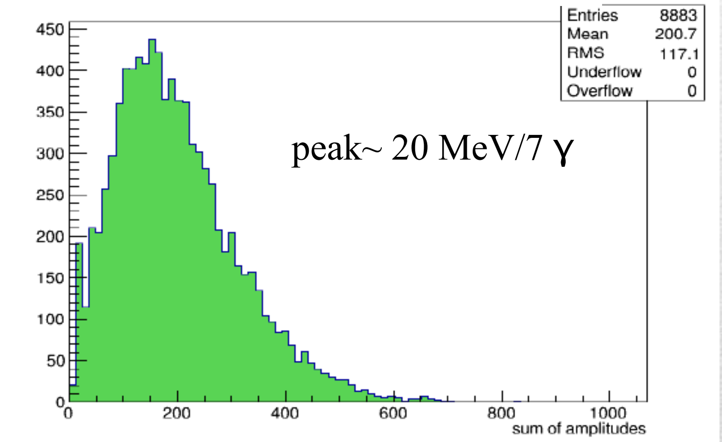


Deflected
Beam position

~ 30 cm



SRD: PbSc, 200 layers
0.08 mm Pb+1mm Sc



Amount of detected SR energy, γ's:

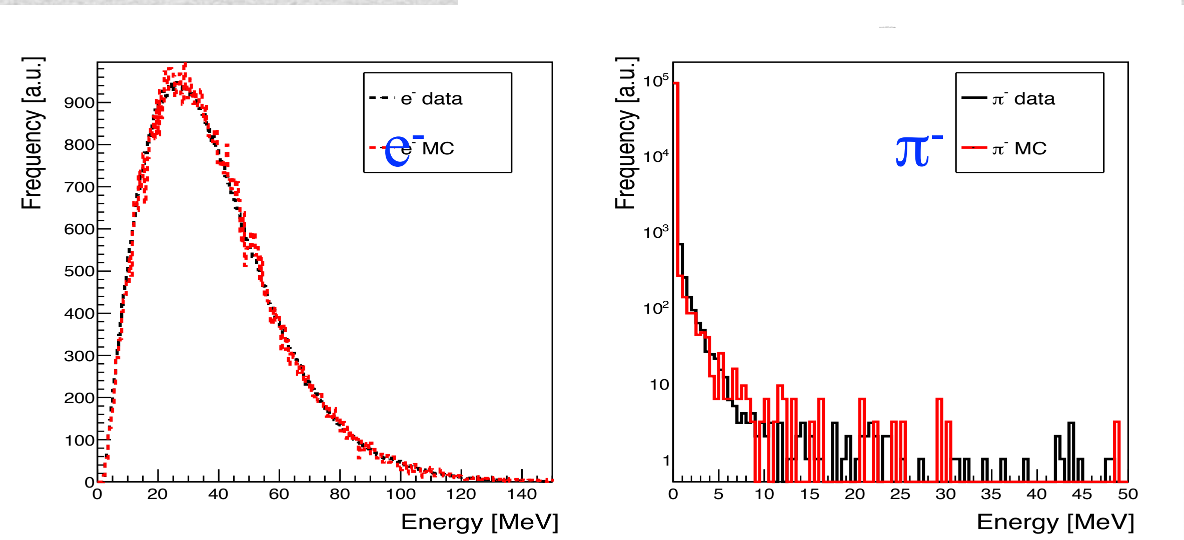
$\Delta E \sim E_0^3/m^4$, <Eγ>~ 2 MeV, <Nγ> ~ 30

July run: BGO SRD – good ΔE/E, afterglow.
Replaced with a fine segmentation
Pb-Sc SRD – fast, poor ΔE/E

October run: Pb-Sc with transv. segmentation. Tuning halo.

SRD selection cuts:

- $1 < SRD_i < 80$ MeV
- All SRD_i in time within ±2 ns
- Efficiency $\varepsilon_{SRD} > 0.95$



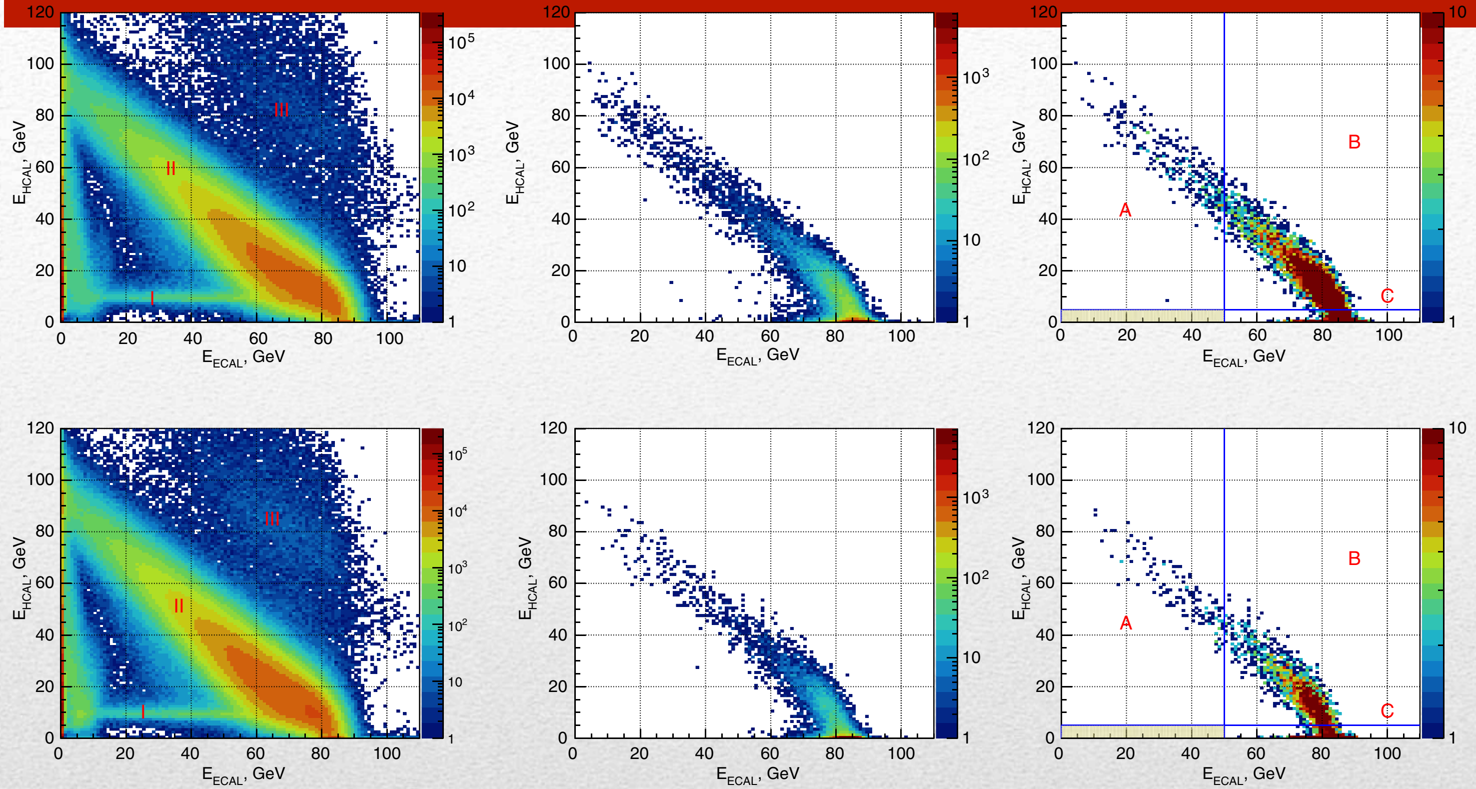


FIG. 7. Event distribution in the (E_{ECAL}; E_{HCAL}) plane from the runs II(top row) and III (bottom row) data. The left panels show the measured distribution of events at the earlier phase of the analysis. Plots in the middle show the same distribution after applying all selection criteria, but the cut against upstream interactions. The right plots present the final event distributions after all cuts applied. The dashed area is the signal box region which is open. The side bands A and C are the one used for the background estimate inside the signal box. For illustration purposes the size of the signal box along E_{HCAL}-axis is increased by a factor five.

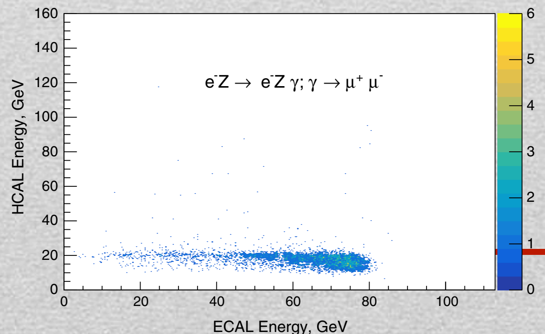


FIG. 8. Selected dimuon events in the (E_{ECAL}; E_{HCAL}) plane.

D. BANERJEE et al. PHYS. REV. D 97, 072002 (2018)

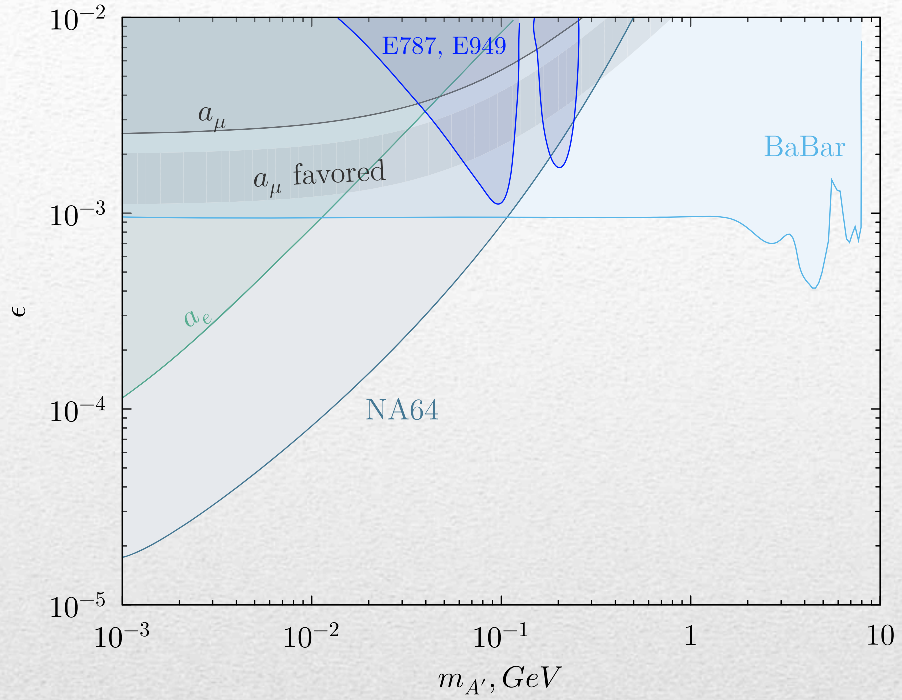


FIG. 15. The NA64 90% C.L. exclusion region in the $(m_{A'}, \epsilon)$ plane. Constraints from the *BABAR* [39], E787 and E949 experiments [34,35], as well as the muon α_μ favored area are also shown. Here, $\alpha_\mu = \frac{g_\mu - 2}{2}$. For more limits obtained from indirect searches and planned measurements see e.g., Ref. [13,14].

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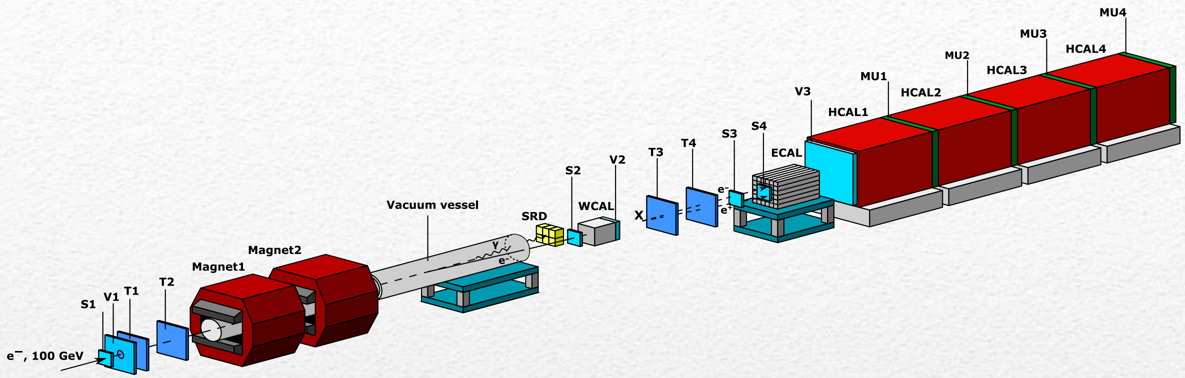

FIG. 1. Schematic illustration of the NA64 setup to search for the A', $X \to e^+e^-$ decays.

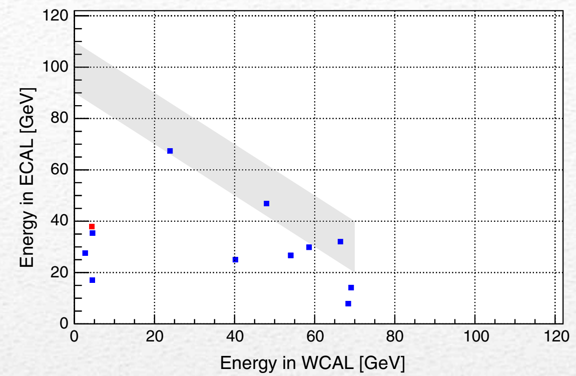

FIG. 2. Distribution of selected e.m. neutral (presumably photon) and signal events in the (E_{WCAL}; E_{ECAL}) plane from the combined 30 X_0 and 40 X_0 runs. Neutral e.m. events are shown as blue squares. The only signal-like event is shown as a red square. The dashed band represents the signal box.

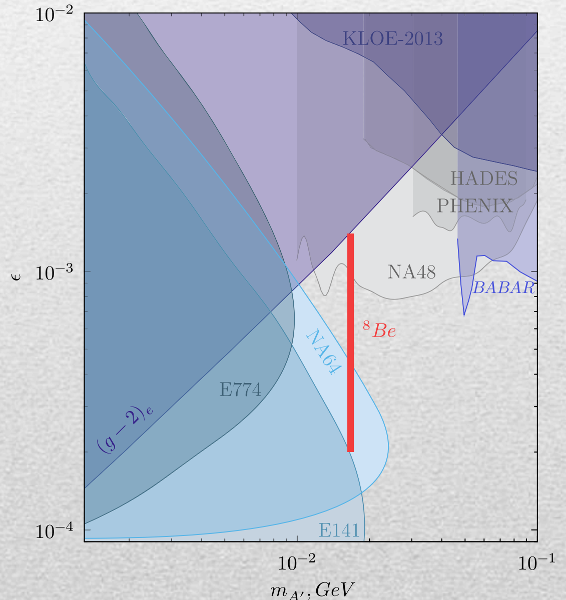

FIG. 3. The 90% C.L. exclusion areas in the (m_X; ϵ) plane from the NA64 experiment (blue area). For the mass of 16.7 MeV, the $X - e^-$ coupling region excluded by NA64 is $1.3 \times 10^{-4} < \epsilon_e < 4.2 \times 10^{-4}$. The allowed range of ϵ_e explaining the ^{8}Be anomaly (red area) [2,3], constraints on the mixing ϵ from the experiments E141 [22], E774 [25], *BABAR* [40], KLOE [45], HADES [47], PHENIX [48], NA48 [50], and bounds from the electron anomalous magnetic moment $(g-2)_e$ [71] are also shown.

Search for a Hypothetical 16.7 MeV Gauge Boson and Dark Photons in the NA64 Experiment at CERN

PHYSICAL REVIEW LETTERS 120, 231802 (2018)