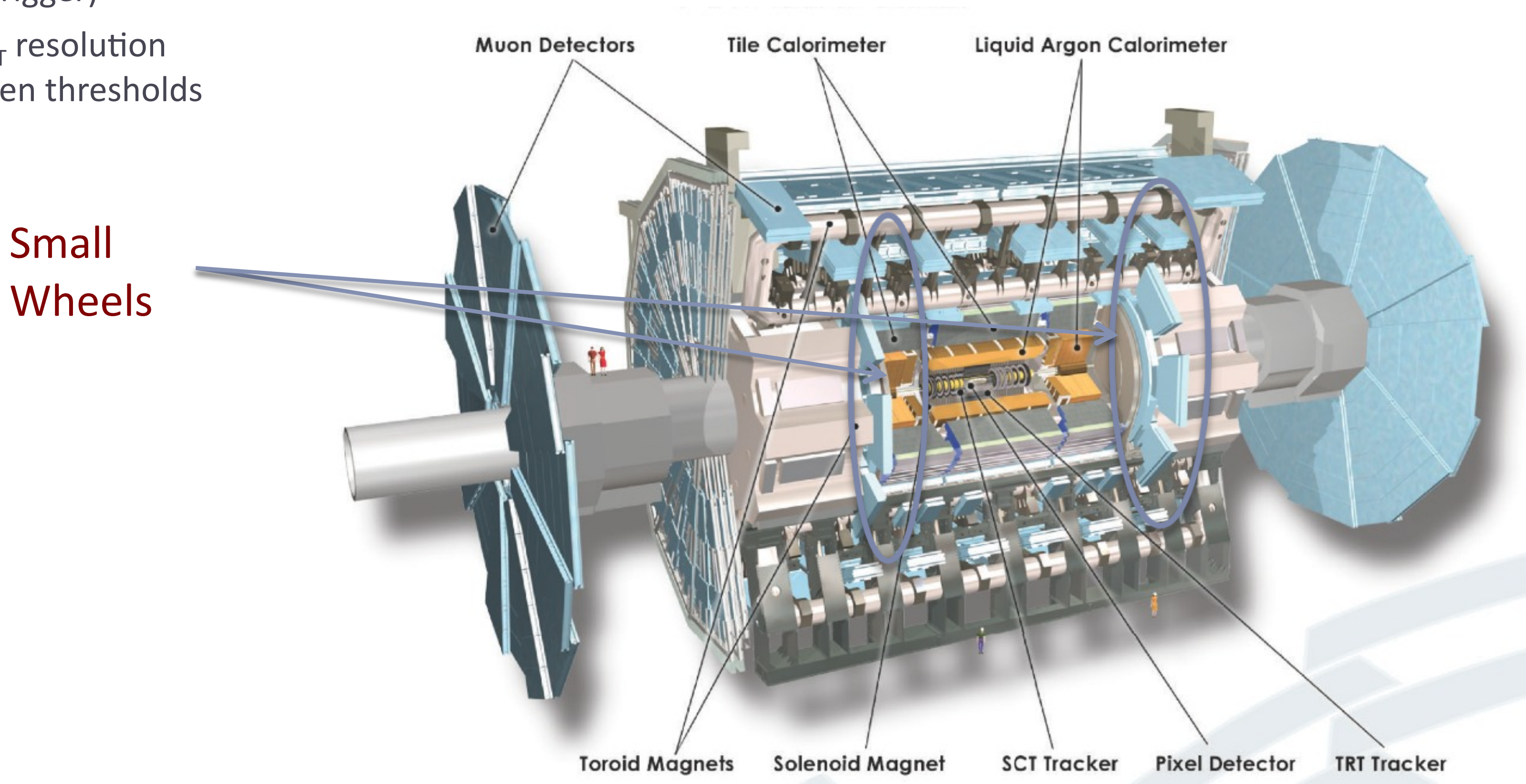
Atlas New Small Wheel Upgrade

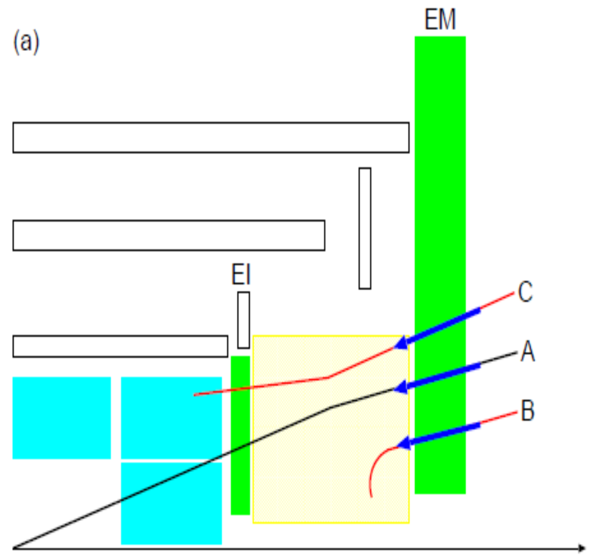
Introduction

- Small Wheel muon chambers need to be upgraded (in phase I)
  - Measured rate higher than estimate (rate limit at ~5×10^{34} $cm^{-2}s^{-1}$)
  - Reduce the fake rate at p_T>20GeV (at present small wheel not used in LVL1 trigger)
  - Improve p_T resolution to sharpen thresholds

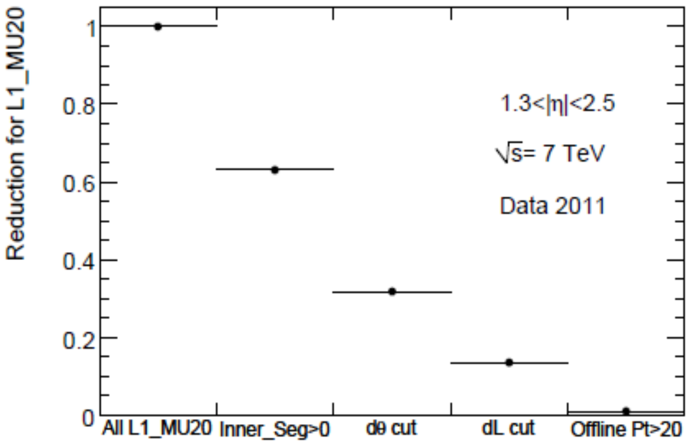


Motivation for NSW: reduction of fake rates

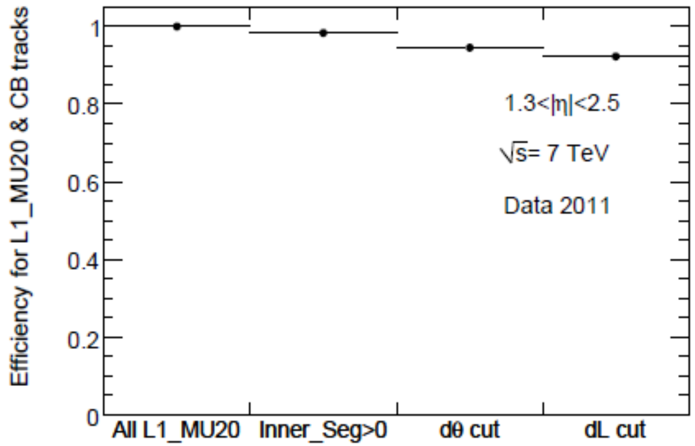
- Reduction of fake rates with NSW:
  - 0. w/o NSW
  - 1. requiring the presence of a segment in NSW
  - 2. requiring NSW segment pointing to IP (ϑ<1mrad)
  - 3. requiring NSW segment matching in (η,ϕ) the EM muon chamber trigger segment



Reduction of L1_MU20 trigger rate



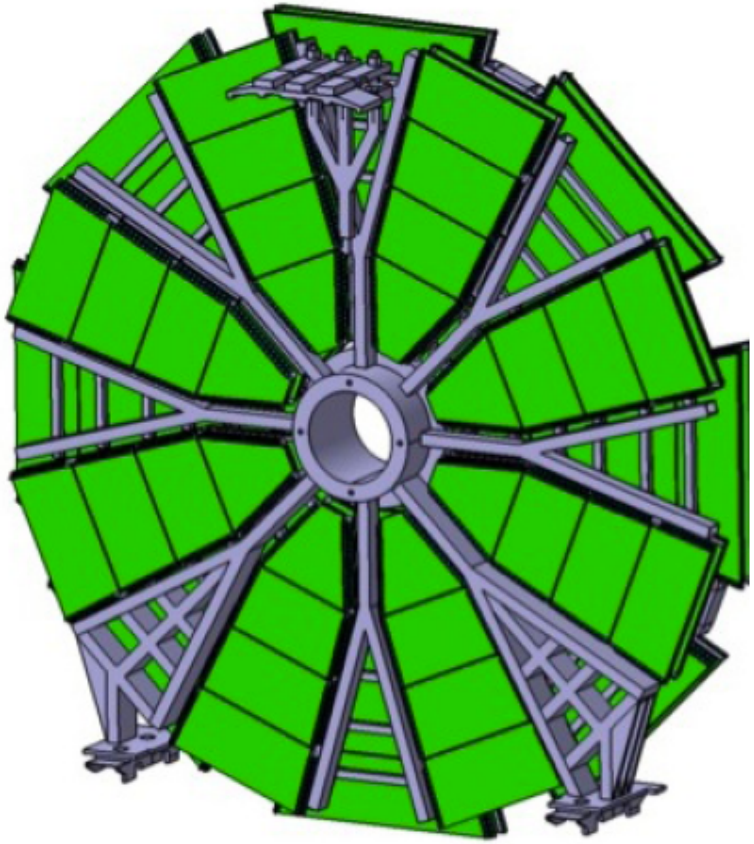
Efficiency of L1_MU20 trigger



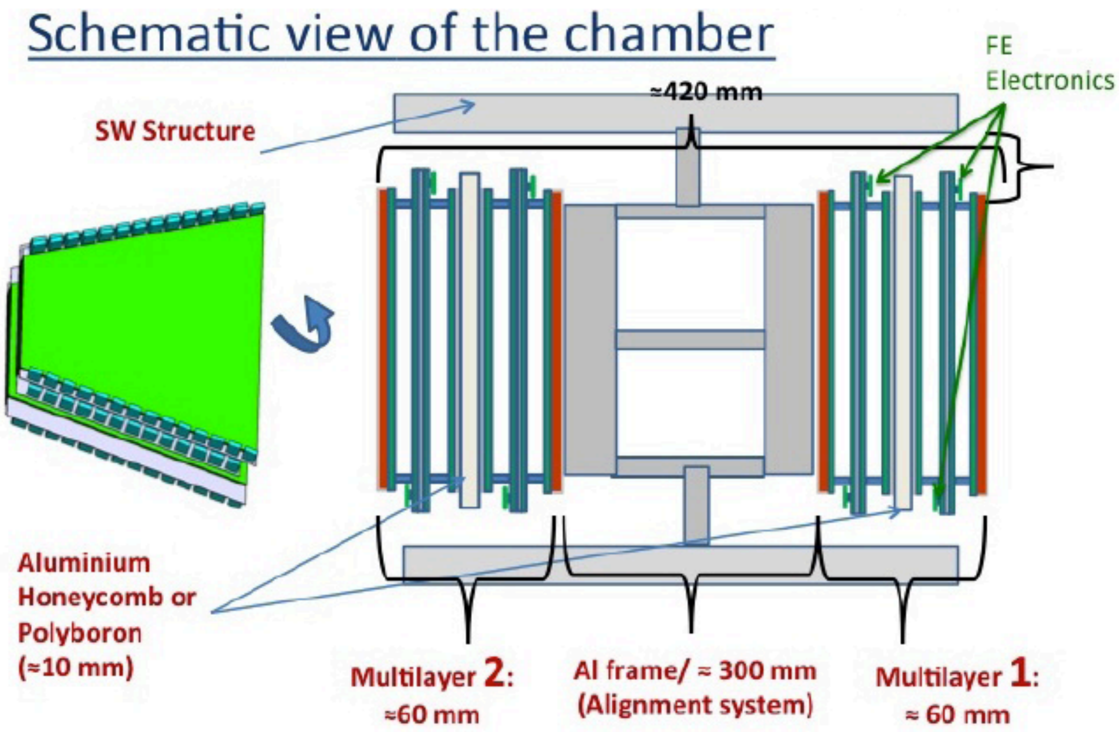
NSW selection of technology

- Three proposals
  - TGC+sMDT
  - TGC+sRPC
  - Micromegas
- Options reduced to (early 2012)
  - TGC+MM
  - TGC+MM+MDT
- Selected option:
  - TGC+MM
    - With milestones
  - Approved by ATLAS
  - 17-18 Jan. 2013 NSW meeting to evaluate milestones accomplishment

NSW layout

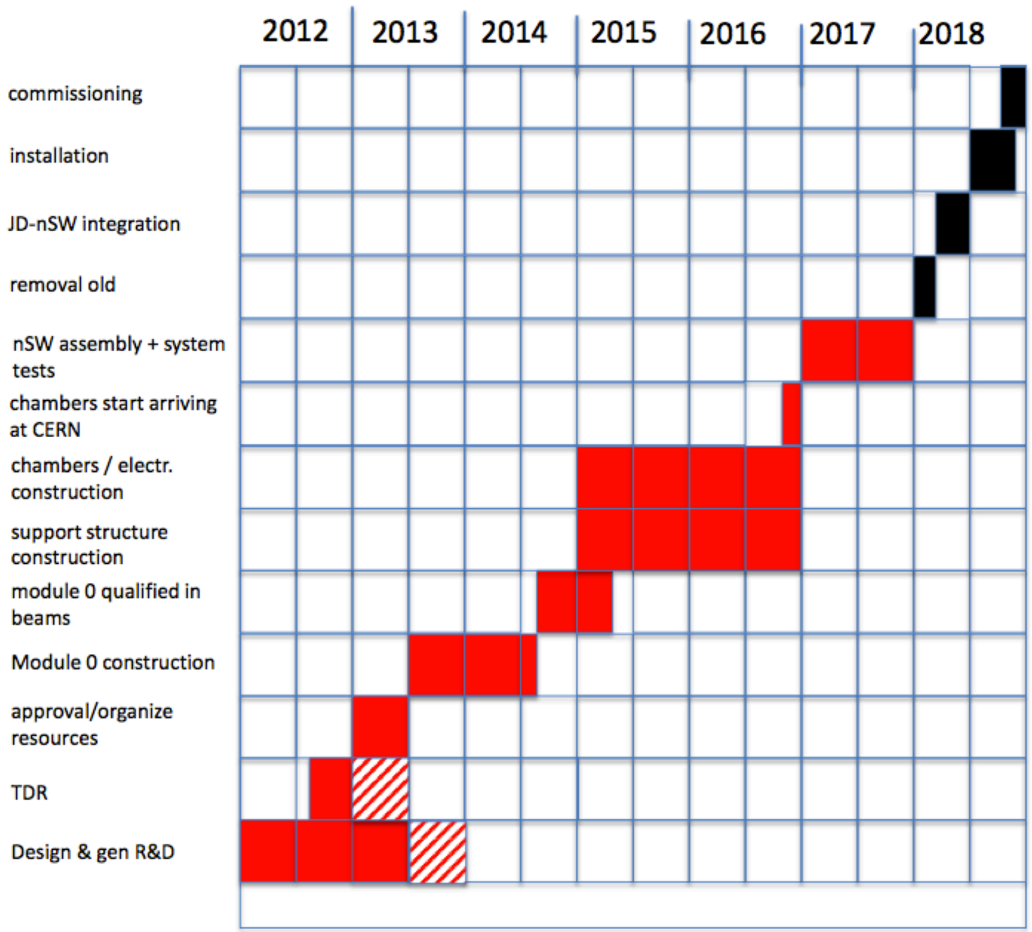


A tentative Layout of the New Small Wheels and a sketch of an 8-layer chamber built of two multilayers, of four active layers each, separated by an instrumented Al spacer for monitoring the internal chamber deformations

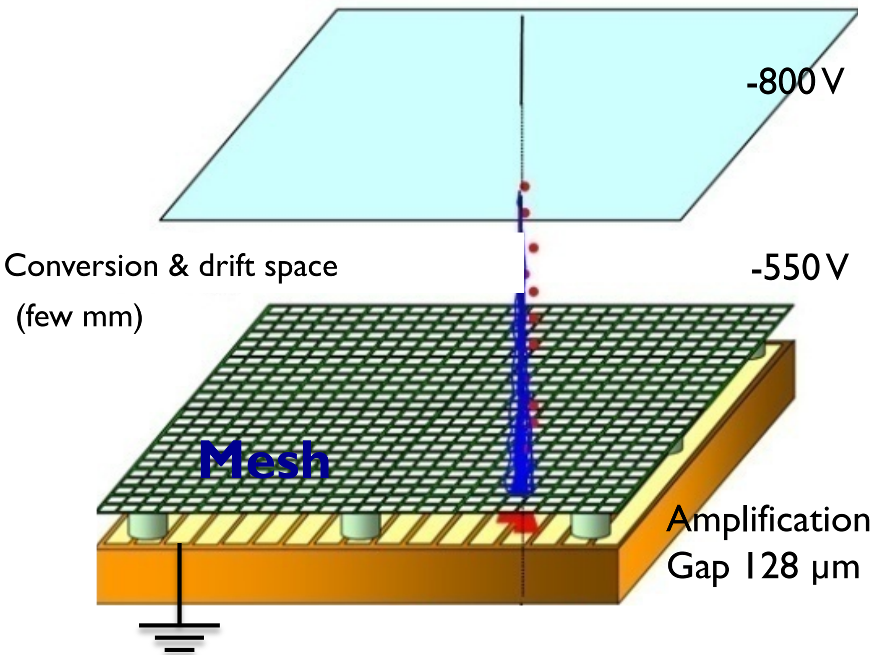


NSW Institutes & timescale

- 51 participating Institutes (interests expressed in kick-off meeting in Aug. 2012) in Micromegas, TGC, trigger, services
- 20 Institutes involved in Micromegas
  - INFN: 7 (MM/ MM+trigger) + 2 (trigger)
- Main milestones:
  - Resolution O(100um) at impact angle 0<theta<30deg
  - Performance in magnetic field
  - Spark suppression
  - Ageing properties
  - Demonstration of large chamber construction O(1m2)
  - Progress in industrial production

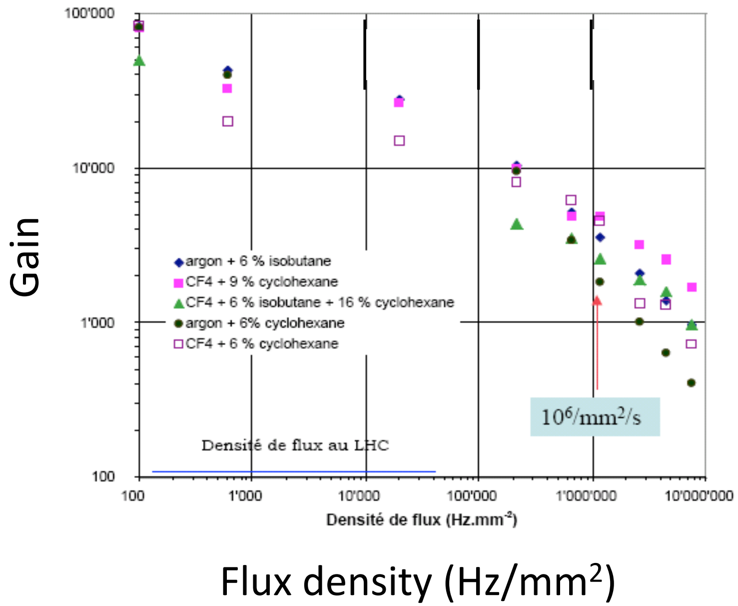


Micromegas operating principle



- Micromegas (I. Giomataris, G. Charpak et al., NIM A 376 (1996) 29) are parallel-plate chambers where the amplification takes place in a thin gap, separated from the conversion region by a fine metallic mesh
- The thin amplification gap (short drift times and fast absorption of the positive ions) makes it particularly suited for high-rate applications

No space charge effect
Reduced ballistic deficit (only for fast electronics <20 ns)
Intrinsic rate limit ~200 MHz/cm²

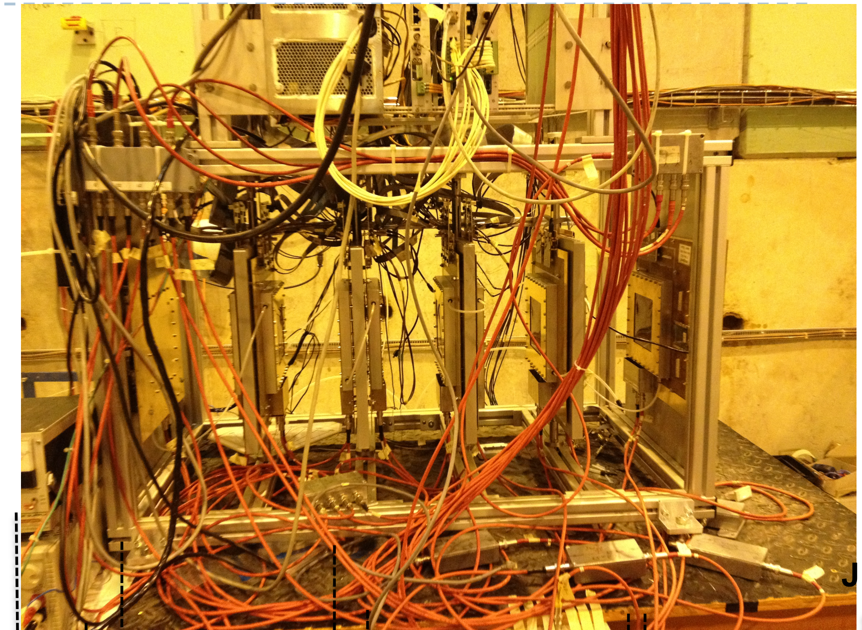


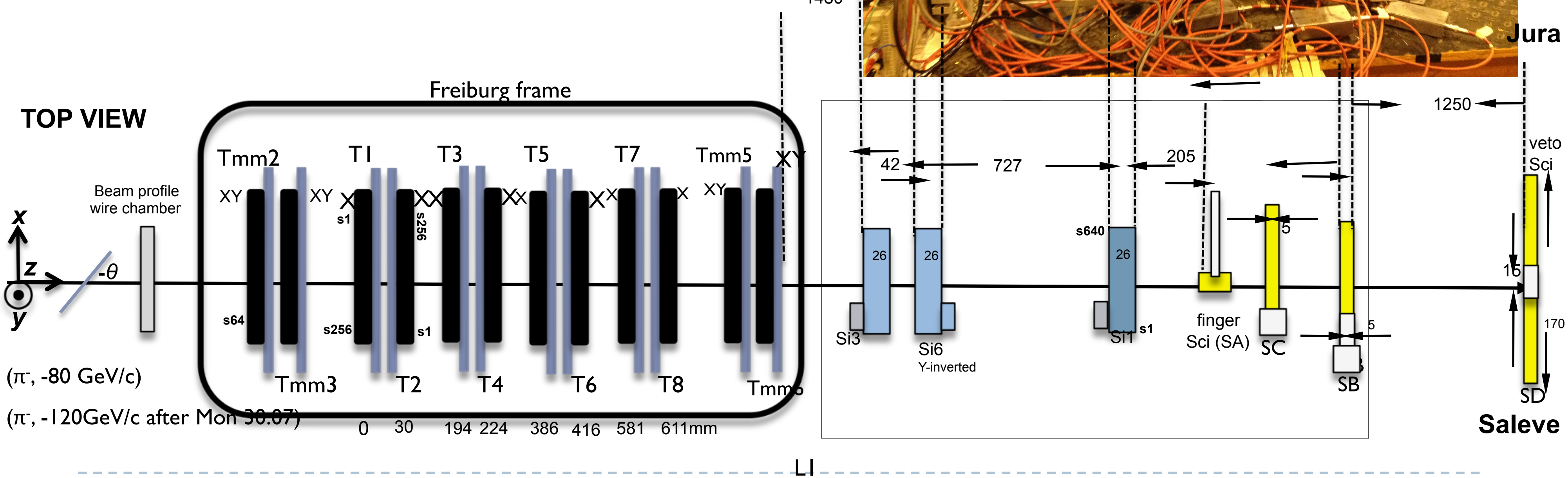
Test beams

- Huge effort of Micromegas community to run almost continuous beam tests in 2012:
  - CERN:
    - 1 week in June (H2 at CERN SPS)
    - 2 weeks in July/August (H6 at CERN SPS)
    - 2 weeks in September (H6 at CERN SPS)
    - 2 more weeks in October/November (H6 at CERN SPS)
  - Frascati:
    - 1 week in July
    - 1 week in November
  - Saclay
    - Several tests on irradiation
  - Micromegas installed in ATLAS

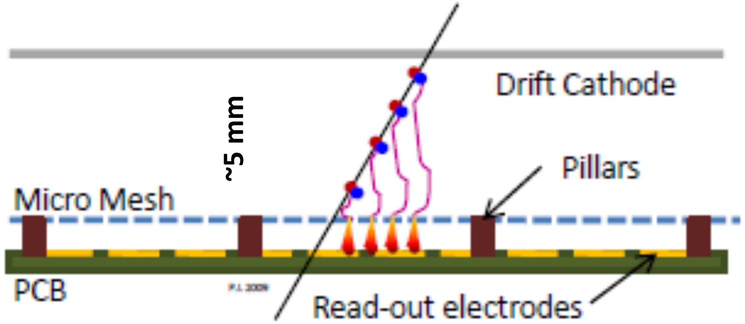
Performance of small chambers

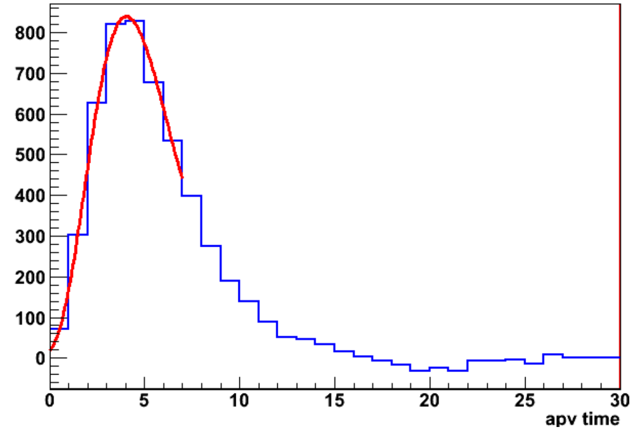
- 10x10 cm^2
- Ar:CO2 93:7
- APV25 readout (SRS system)
- 400 um strip pitch
- 5 mm drift gap
- Gain ~10^4



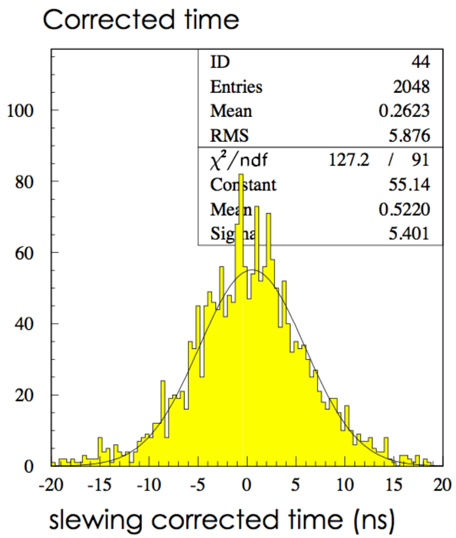


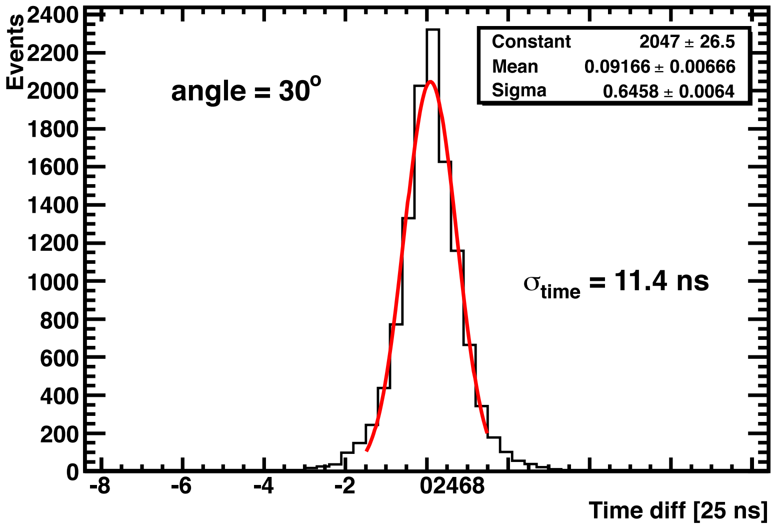
Space resolution: uTPC operation



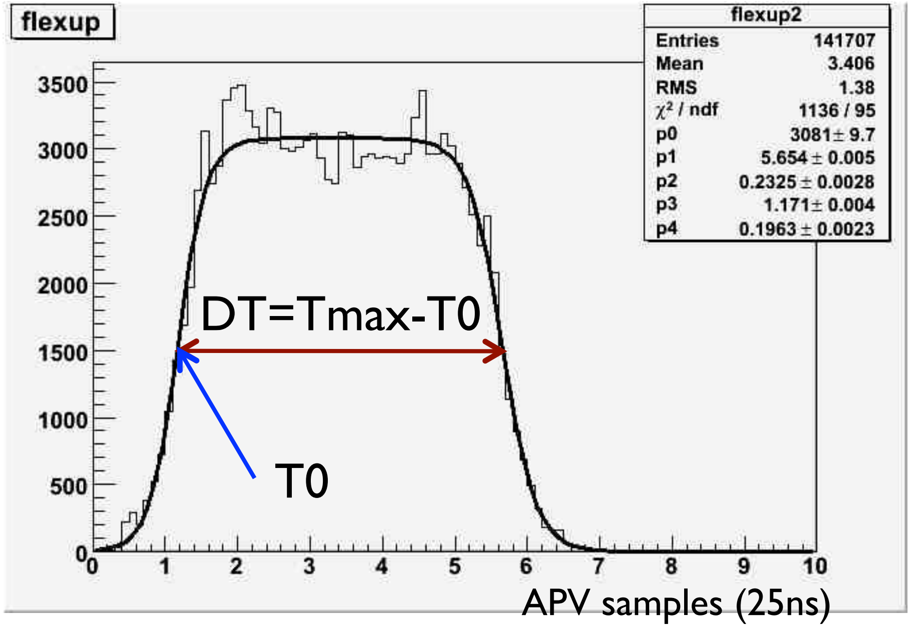


- For the uTPC mode operation a good time resolution on single hit O(<10ns) is
- APV samples signal at 25ns
- Time extracted by fitting the binned signal shape
- Intrinsically MM can do much better
  - TB in Frascati: σt = 6 ns



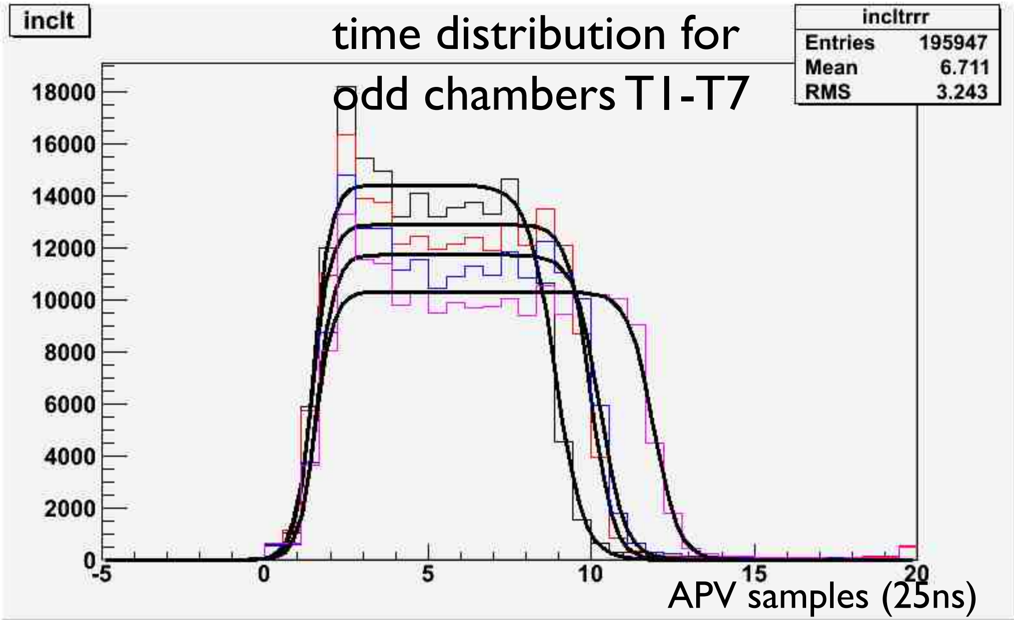


Time distributions



- From the ti distribution the T0 and y-t relation (V_{drift}) can be extracted
- Bi-FermiDirac fit
- V_{drift} = Drift gap/DT = 4.46 cm/us
- V_{drift} not the same for all chambers

- In what follows Vd is not optimized (calibrated) chamber by chamber. A unique value from simulation (Garfield) V_d=4.7 cm/us is used
- Optimization will improve the spatial resolution (work in progress)



Spatial resolution

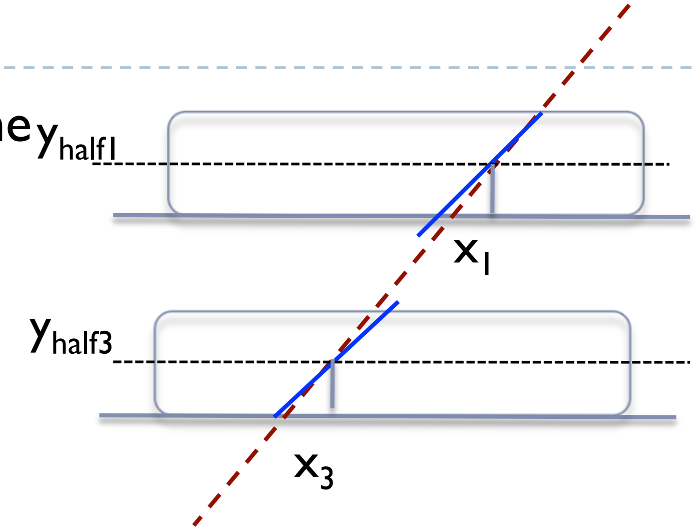
- First method: comparison of homologous (same orientation) chambers
  - Time jitter equal in the two chambers: difference X_1-X_3 removes the jitter
  - Resolution computed as

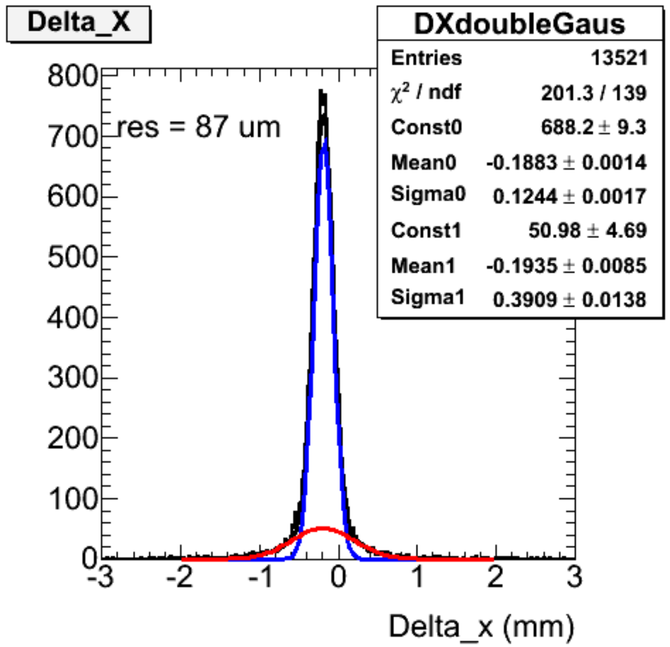
$$\sigma(X) = \frac{\sigma(X_1 - X_3)}{\sqrt{2}}$$

  Resolution equal for both chambers

  Beam divergency (measured to be ~24 um) negligible

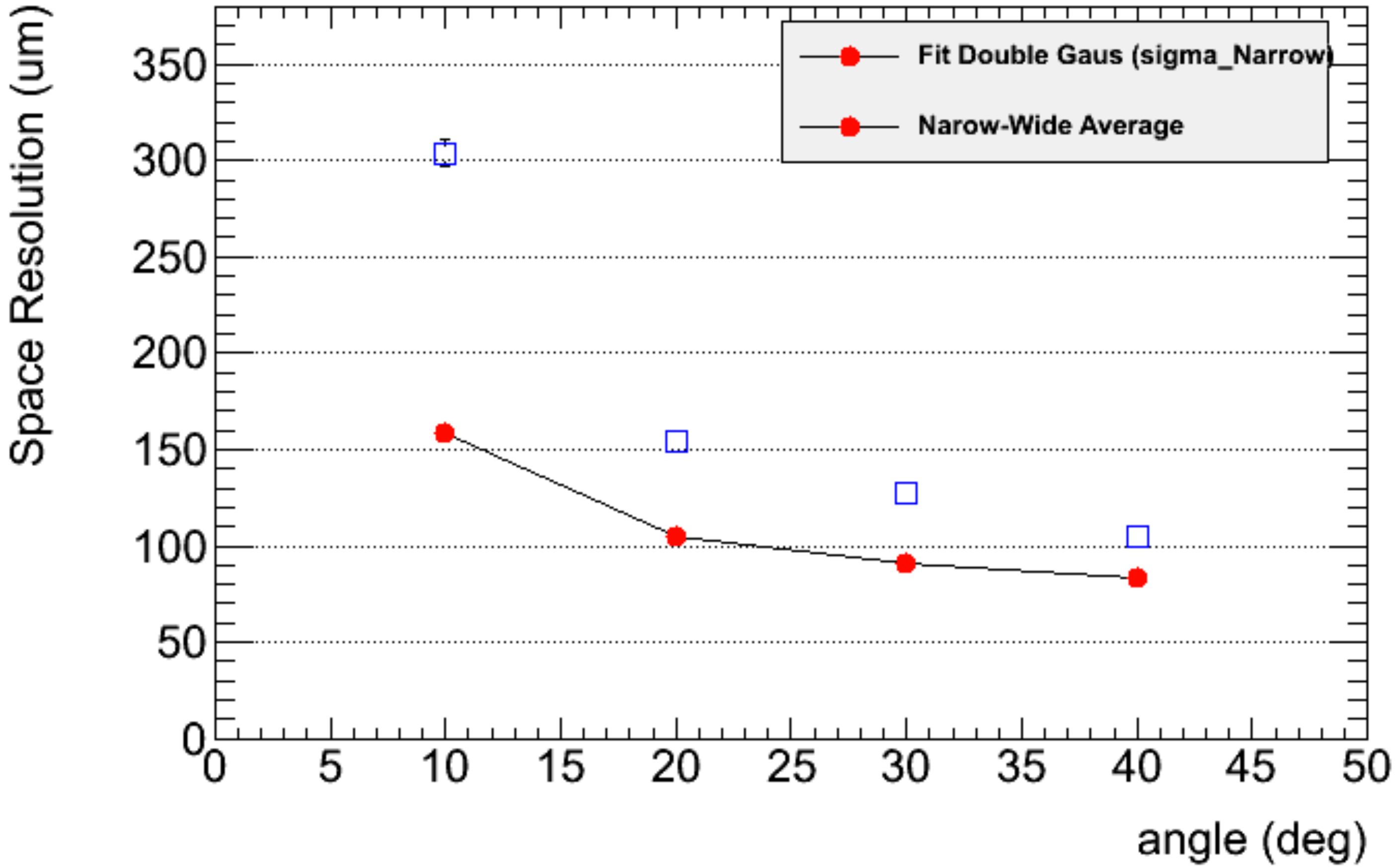
- Distributions show tails → fit with double gaussian
- Resolutions quoted either as sigma of the 'core' gaussian or as weighted average of two gaussians





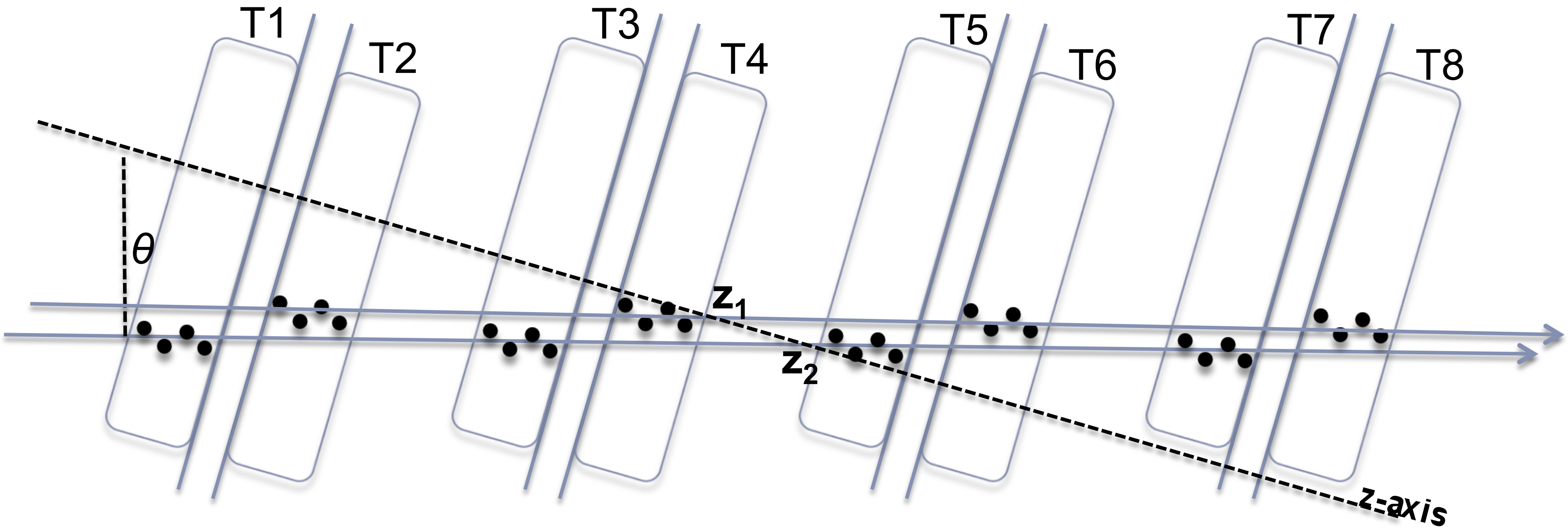
uTPC single chamber resolution

- First method



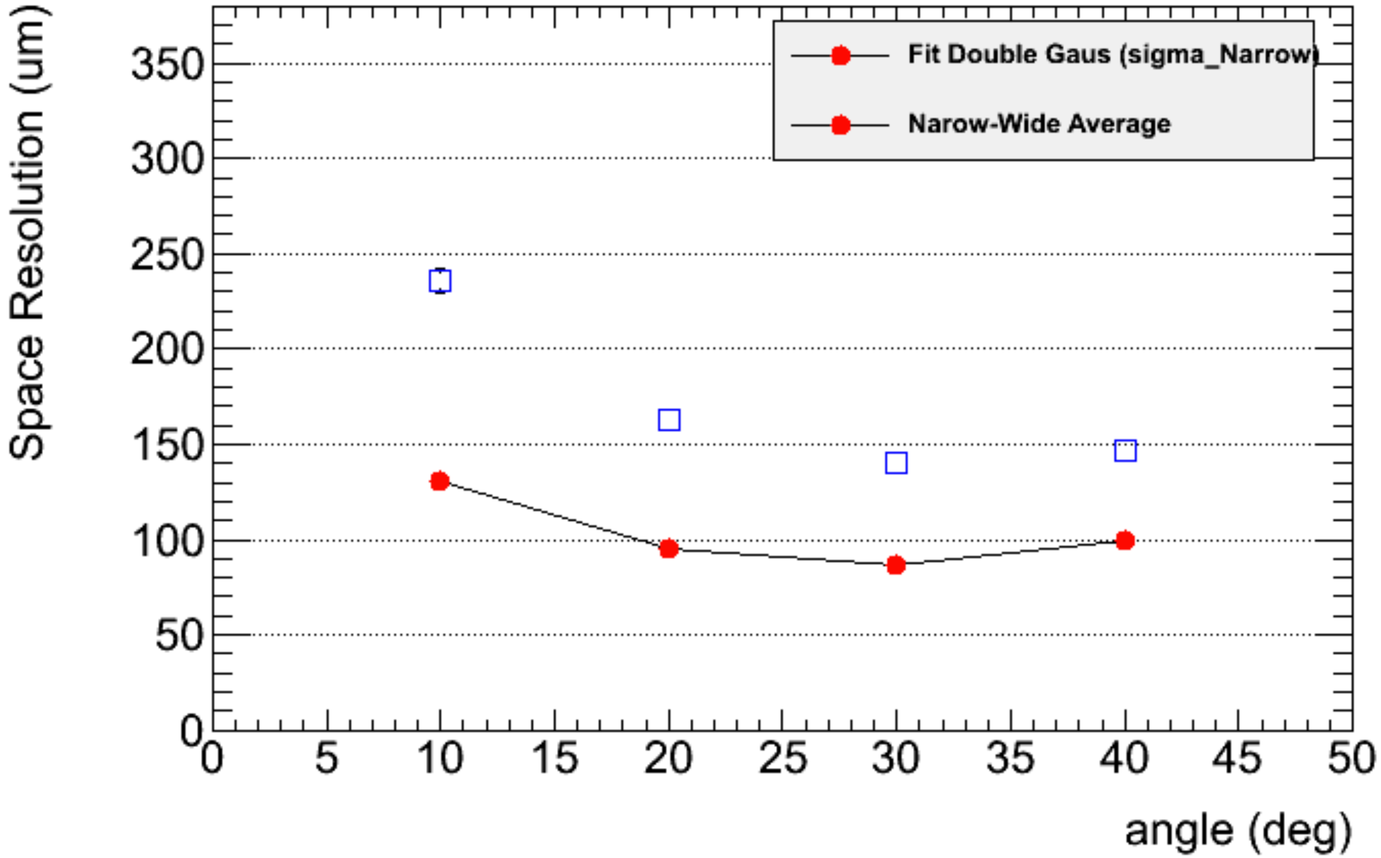
Spatial resolution

- Second method: global fit
  - Time jitter is corrected by reconstructing global tracks from uTPC hits separately for even and odd chambers
  - A global fit is then applied to the uTPC hits of all chambers but the one under study
  - Standard uTPC tracklet is reconstructed for the chamber under study
  - X_{half} comparison between global and local track



uTPC single chamber resolution

- Second method

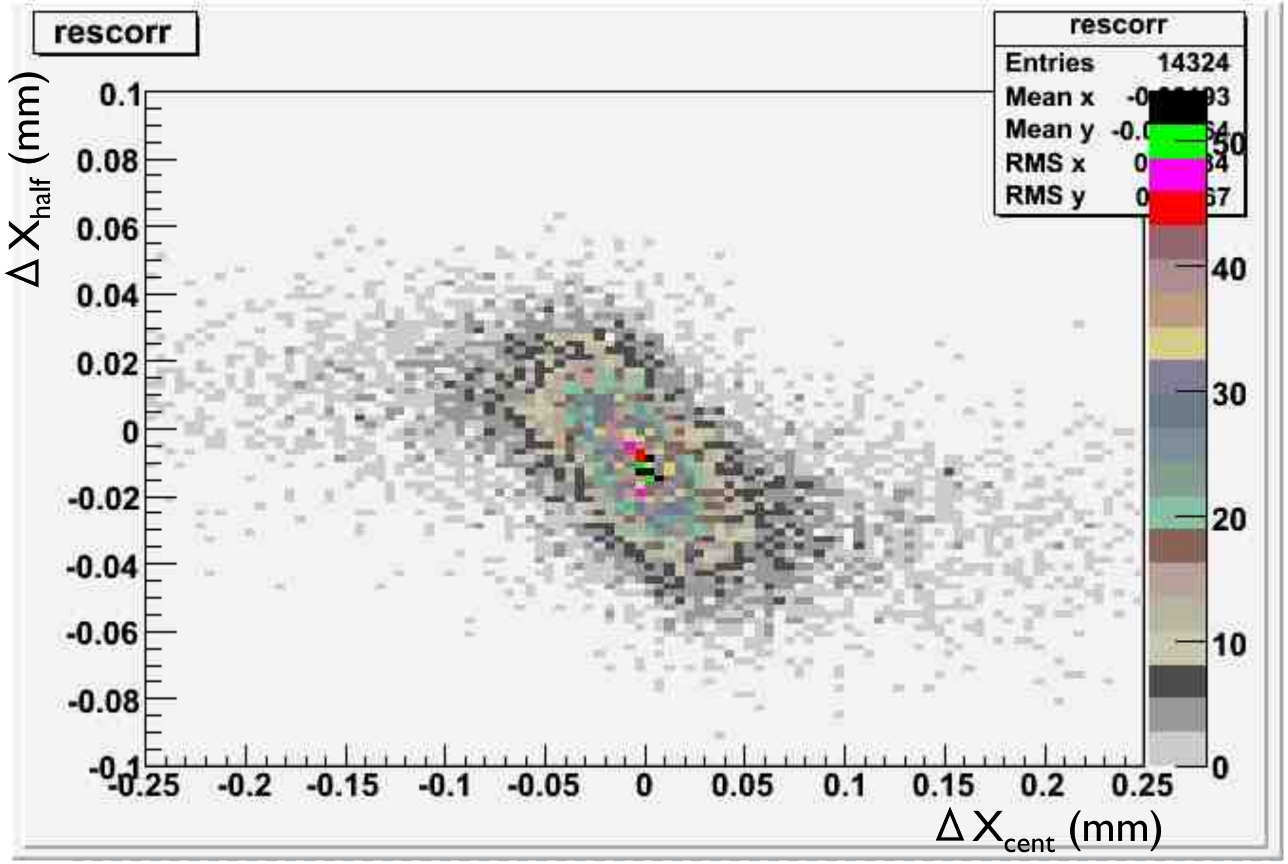


Correlation with centroid

- Resolution in uTPC and with the centroid method are anticorrelated → can be used to improve the resolution:

$x_{comb} = (x_{half} + x_{cent}) / 2$

$$x_{comb} = \frac{w_{half} x_{half} + w_{cent} x_{cent}}{w_{half} + w_{cent}}$$

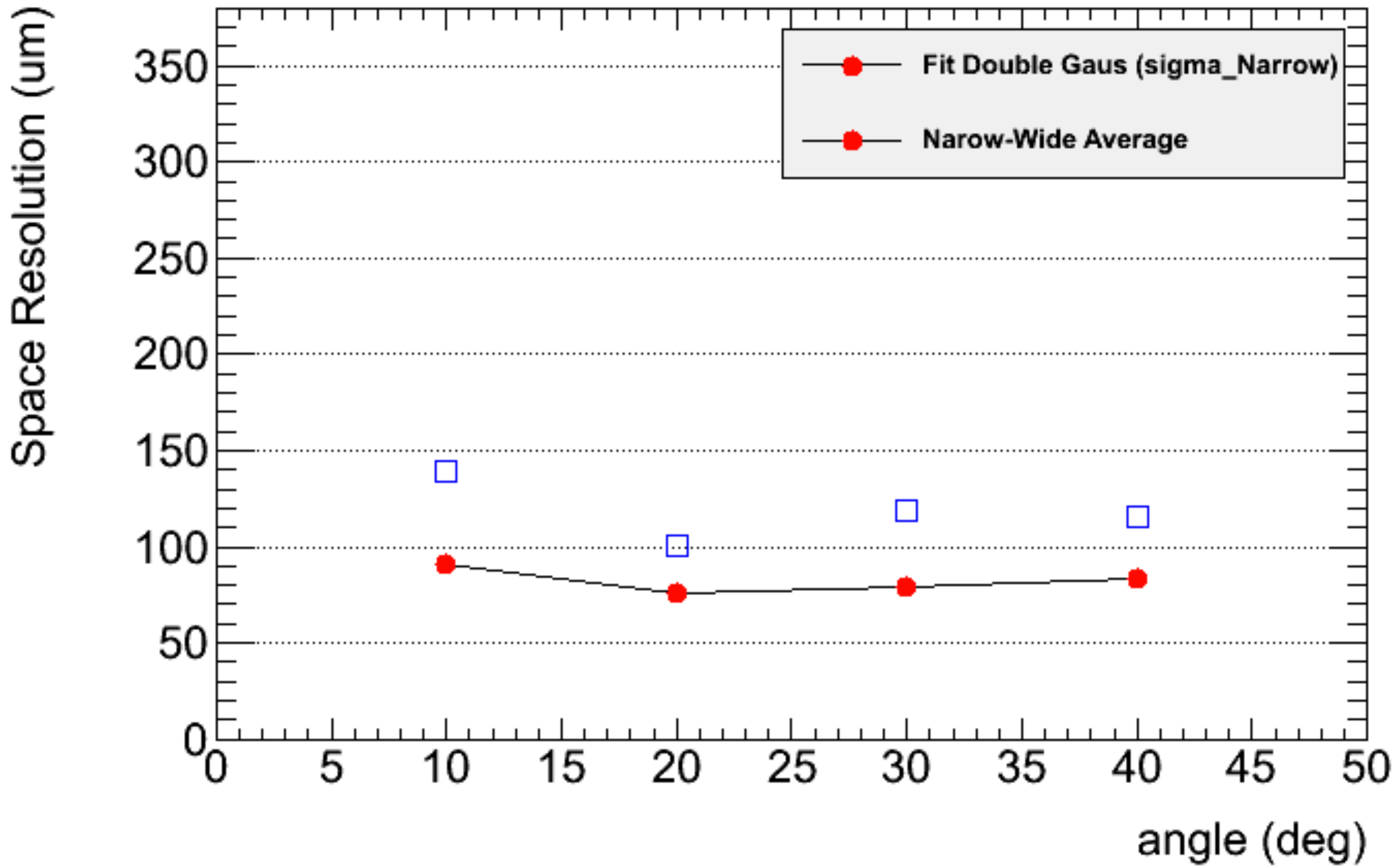


$$w_{half} = \left(\frac{N_{strip}}{N_{cut}} \right)^2$$

$$w_{cent} = \left(\frac{N_{cut}}{N_{strip}} \right)^2$$

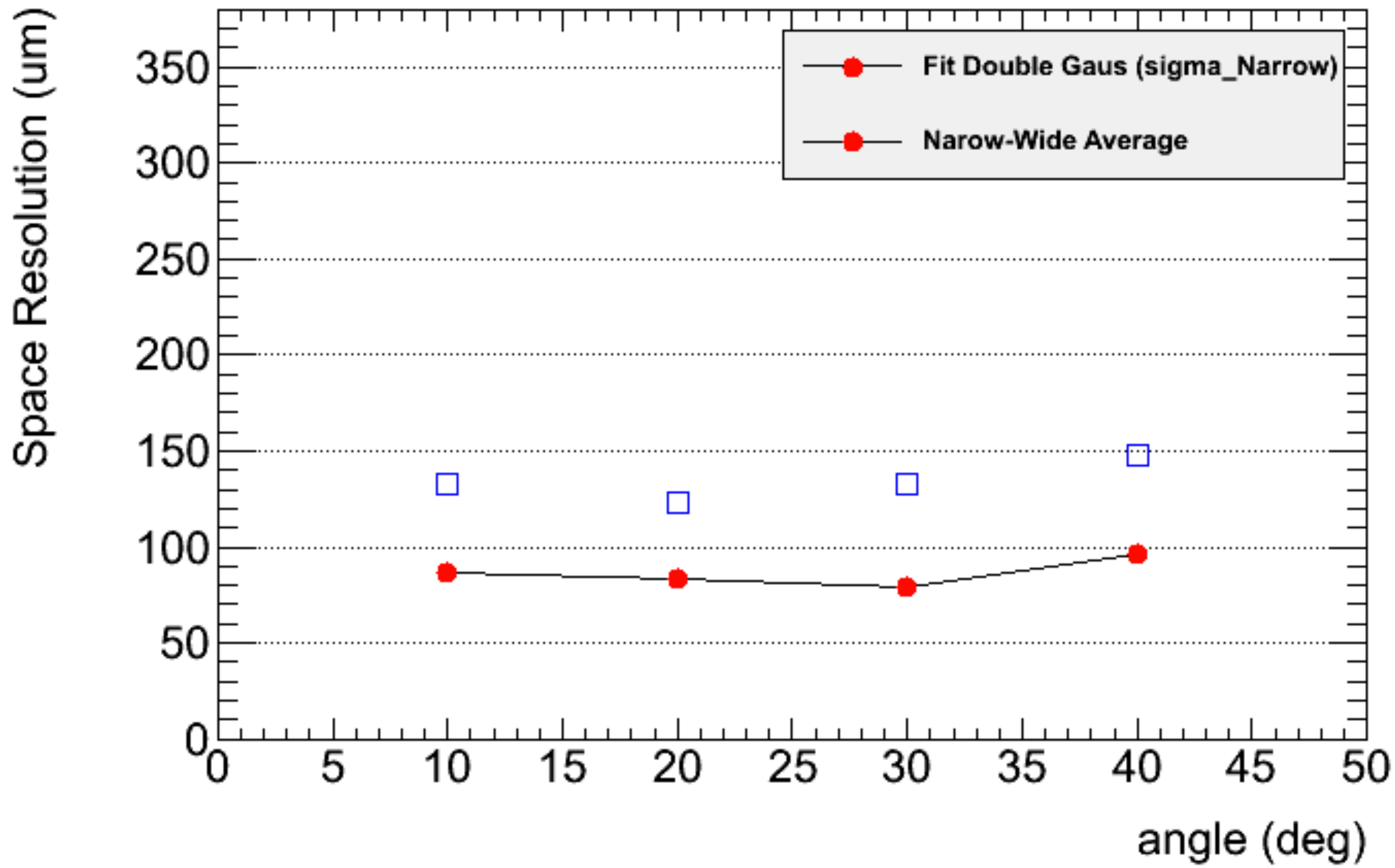
Micromegas single plane spatial resolution

- Combined uTPC and centroid – first method (MM difference)

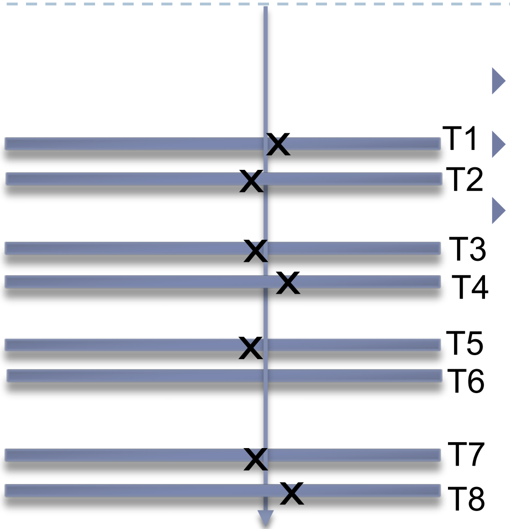


Micromegas single plane spatial resolution

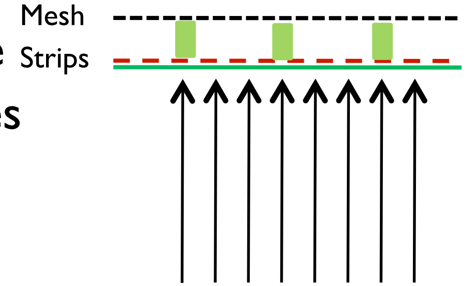
- Combined uTPC and centroid – second method (global fit)



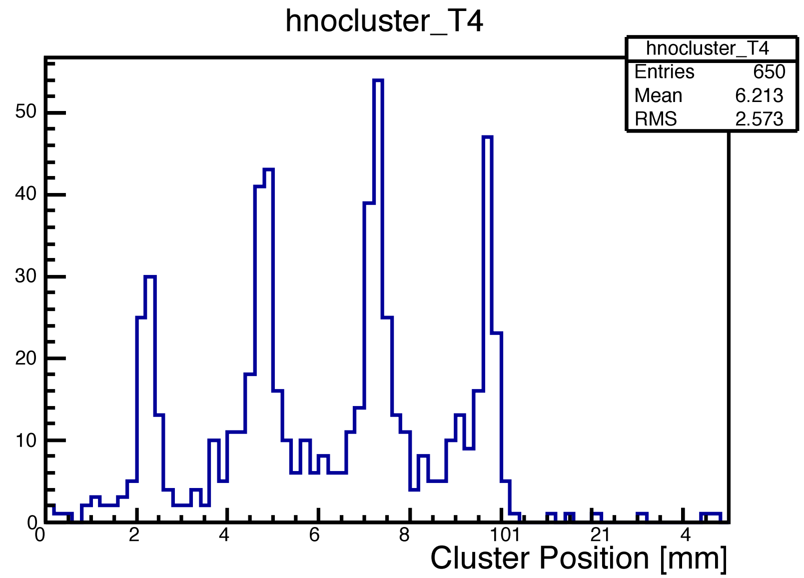
Efficiency

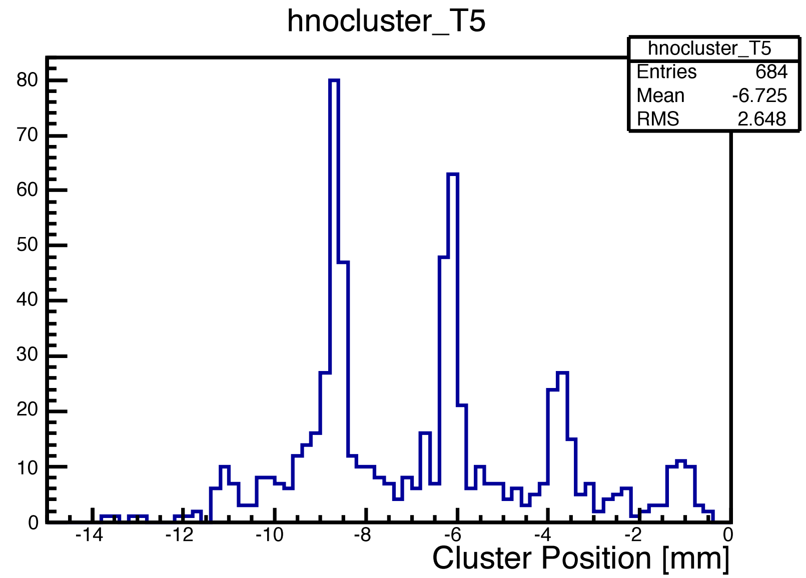


- Inefficiency distribution on MM strip plane
- Track reconstructed with other MM planes
- Inefficiency due to pillars expected 1.1%

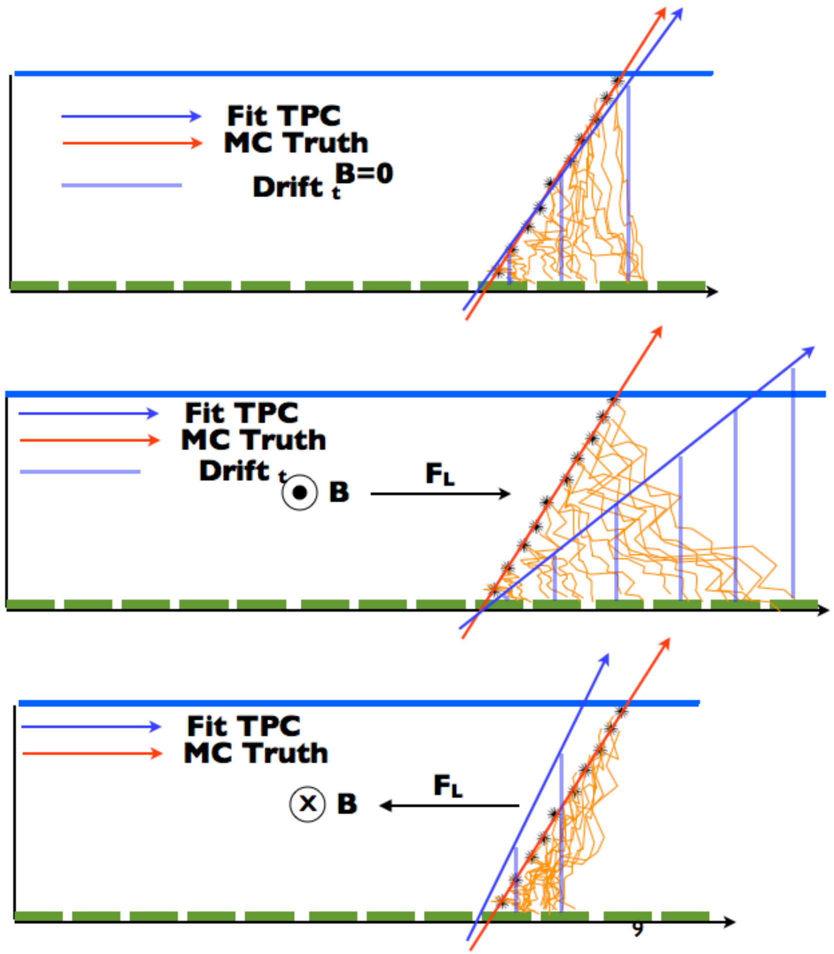


Chamber	T1	T2	T3	T4	T5	T6	T7	T8
Inefficiency (%)	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

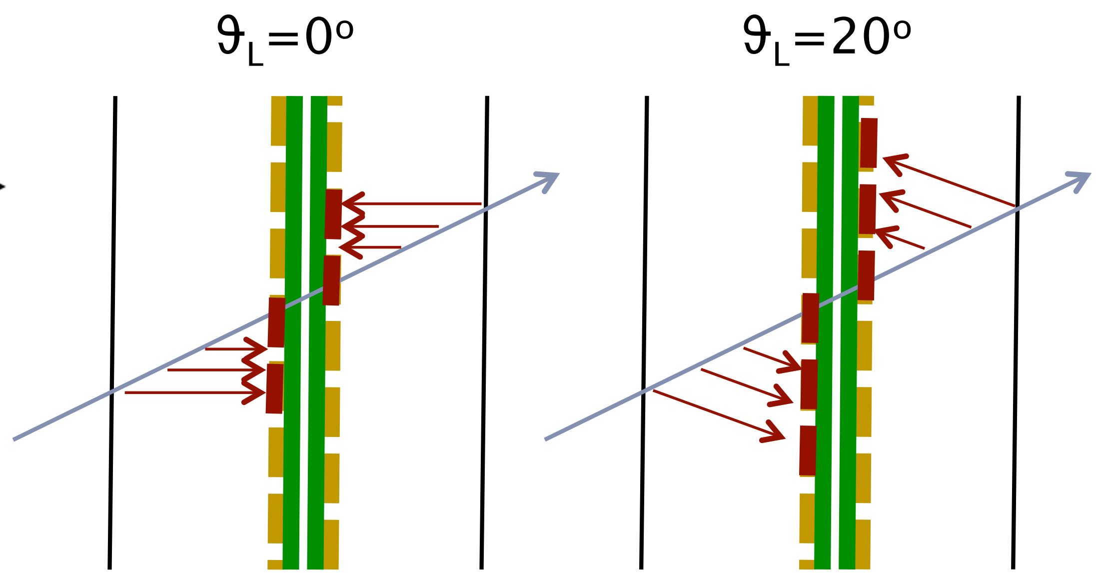




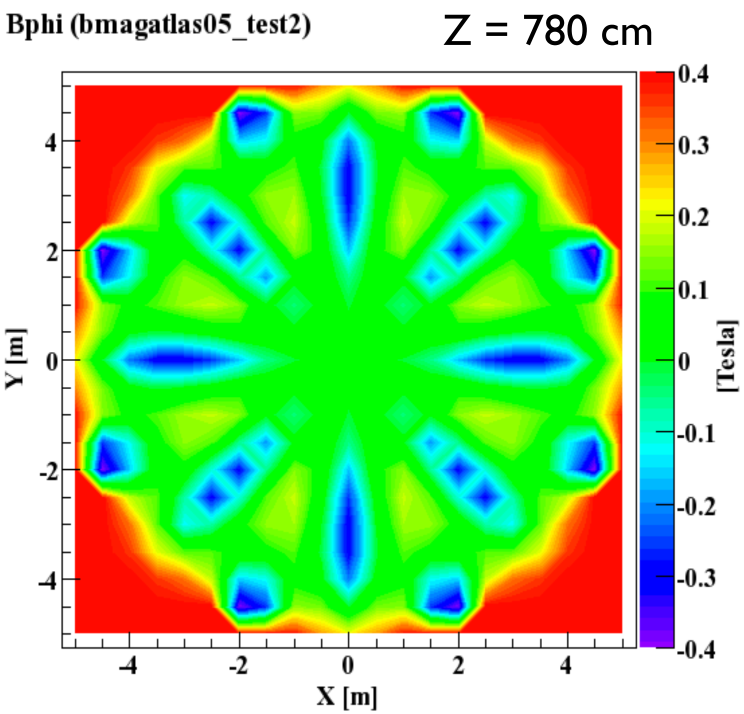
Test with magnetic field

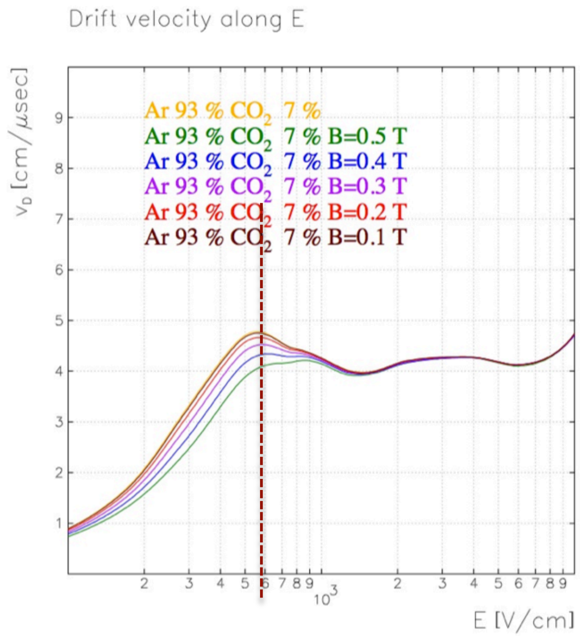


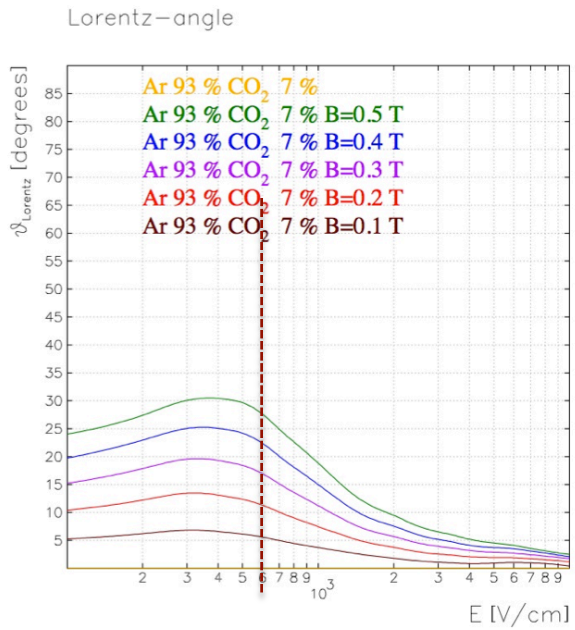
- Lorentz angle changes the footprint
- The effect depends on $E_{drift}xB$
- Is opposite in a back-to-back configuration



Garfield simulation

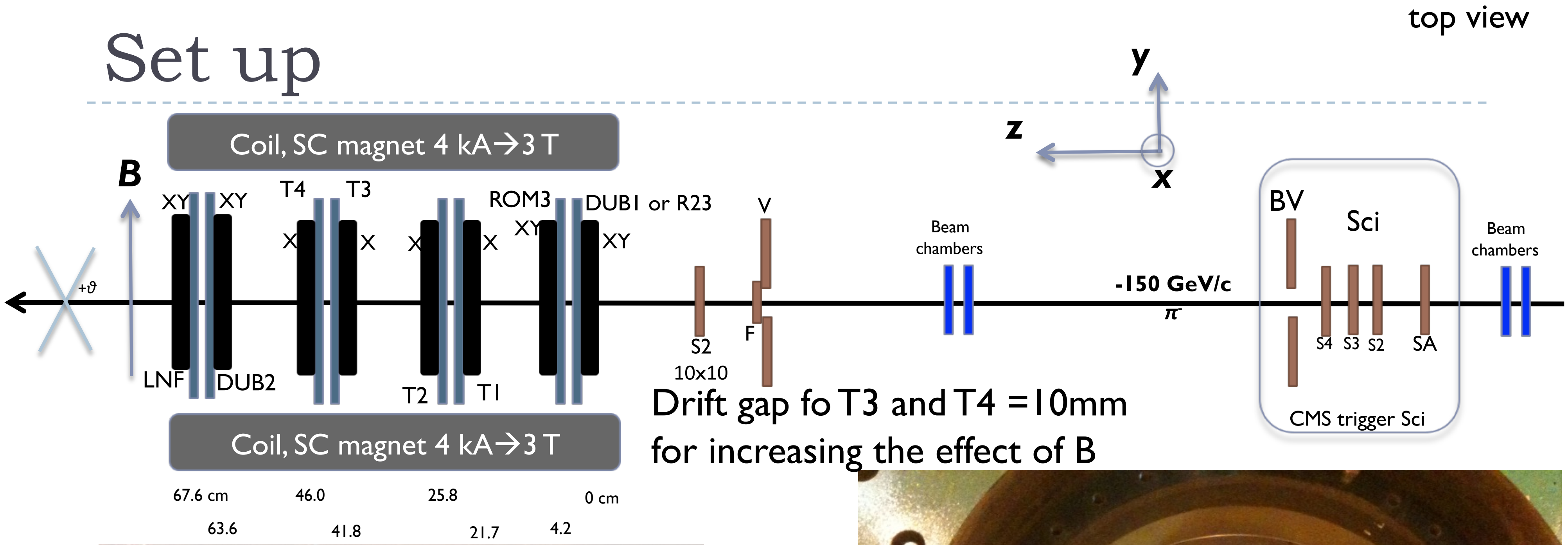




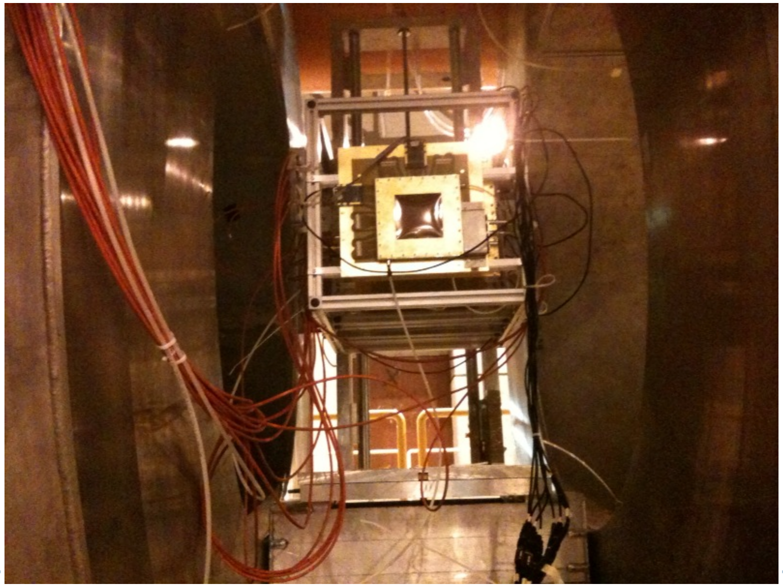


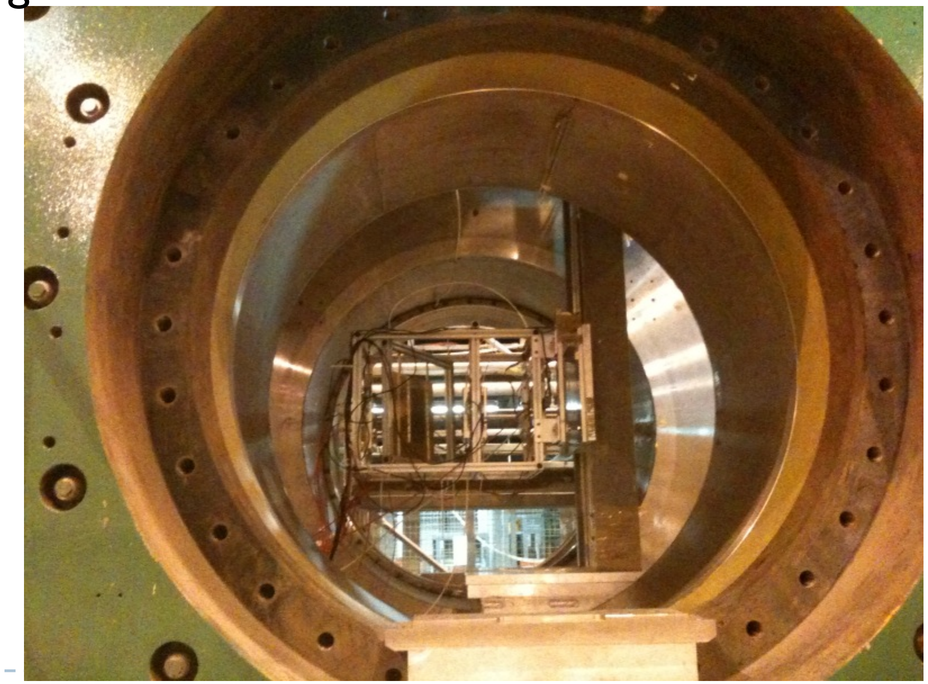
- Maximum field in SW ~0.4T
- Maximum Lorentz angle ~20° (depends on the drift field)

Set up



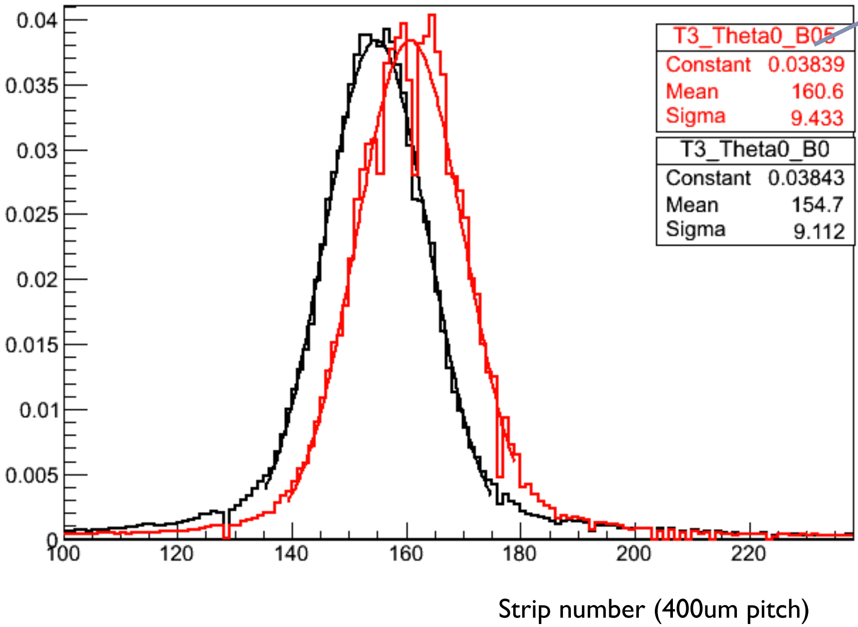
Drift gap fo T3 and T4 =10mm
for increasing the effect of B



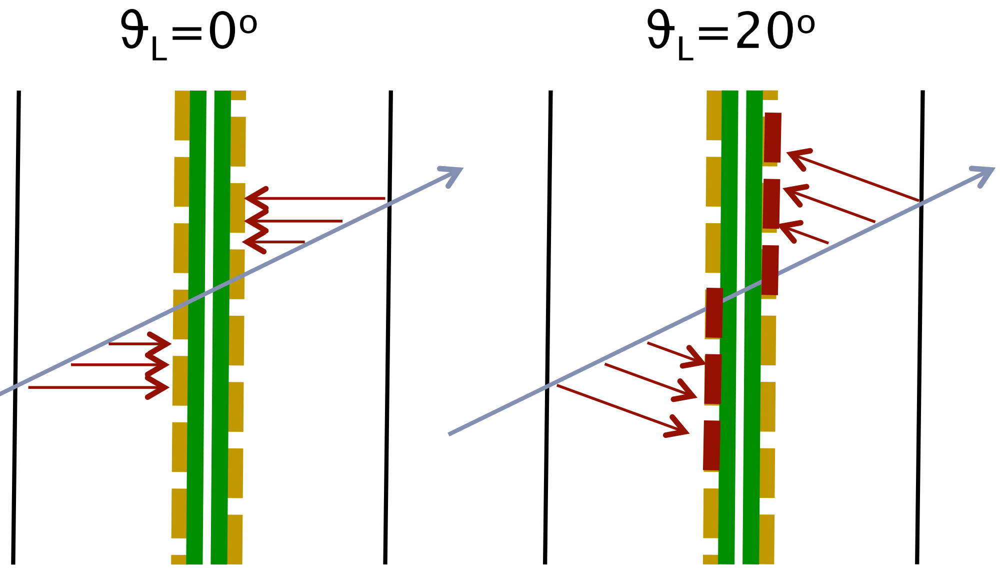


Beam profile

- MM beam profile (E_{drift}=1kV/cm) online plot – no cut applied
  - B = 0T → $\vartheta_L = 0^o$
  - B = 0.5T → $\vartheta_L = 20^o$



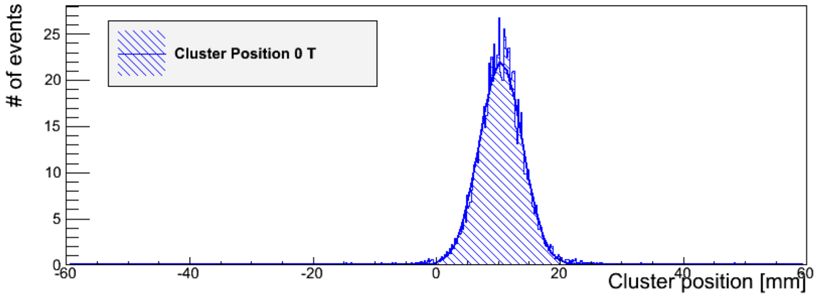
mm

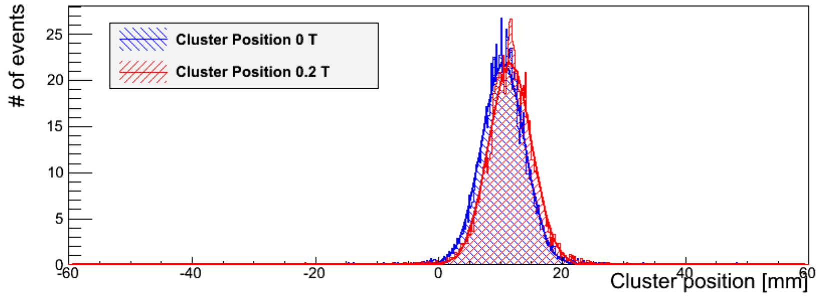


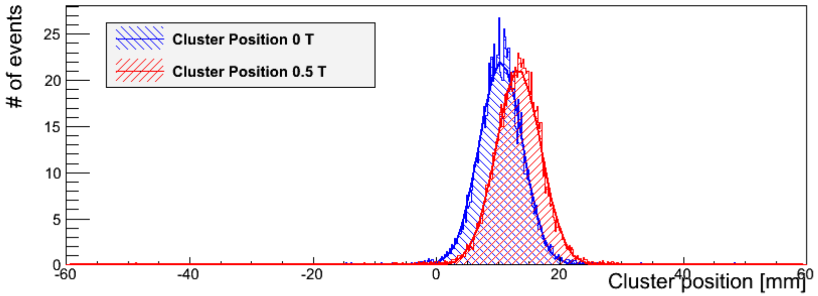
- From displacement of cluster position the Lorentz angle can be extracted

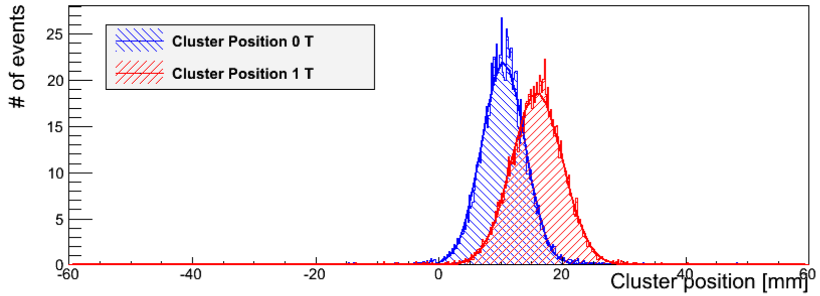
Data – cluster position vs B

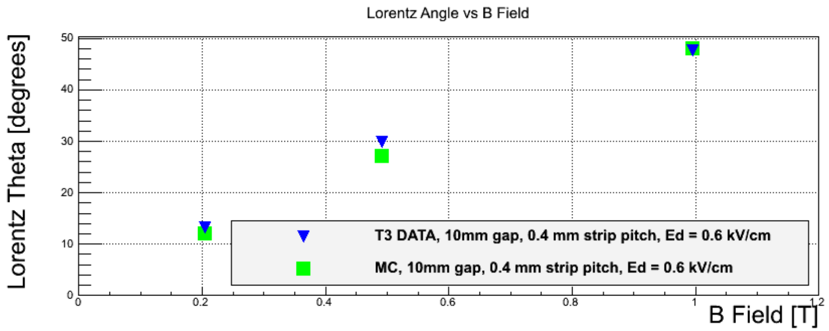
Normal tracks

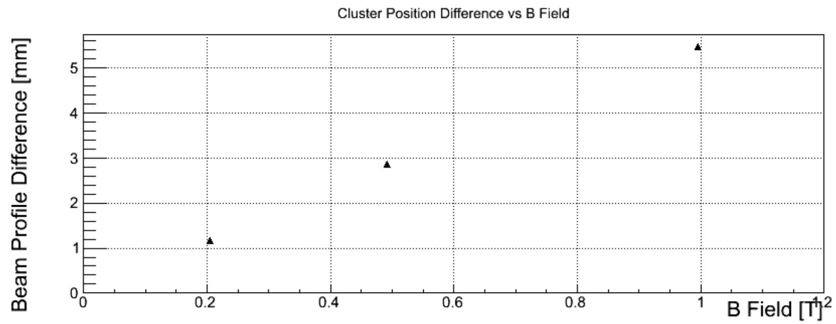






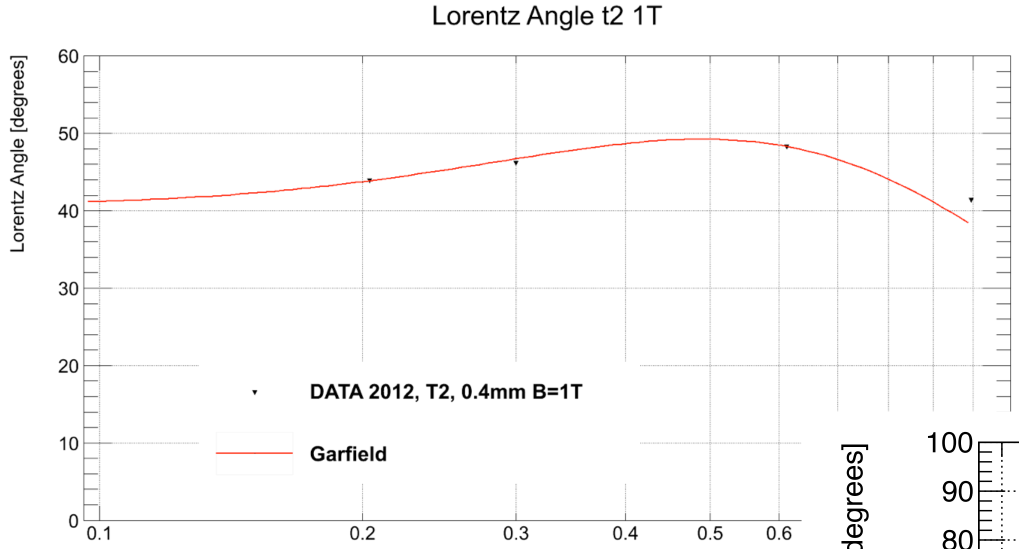






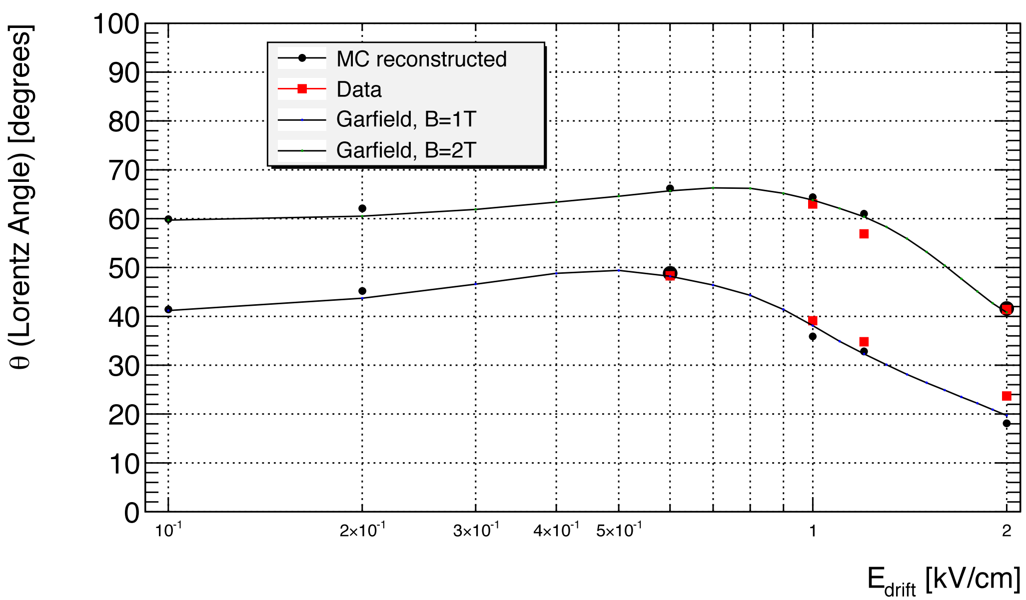
Data-MC comparison

- Lorentz Angle vs drift field; cluster size method



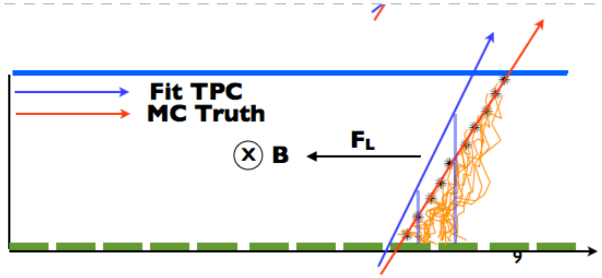
- T2, 5mm Gap
- B = 1T

- T3, 10mm Gap
- B = 1 T
- B = 2 T

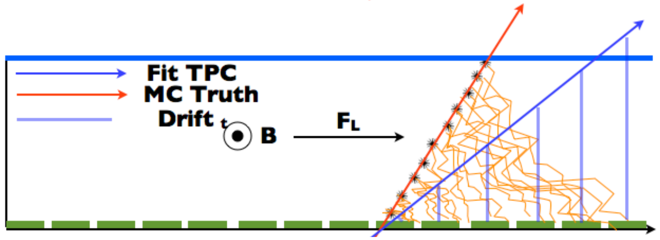


Space resolution with B: work in progress

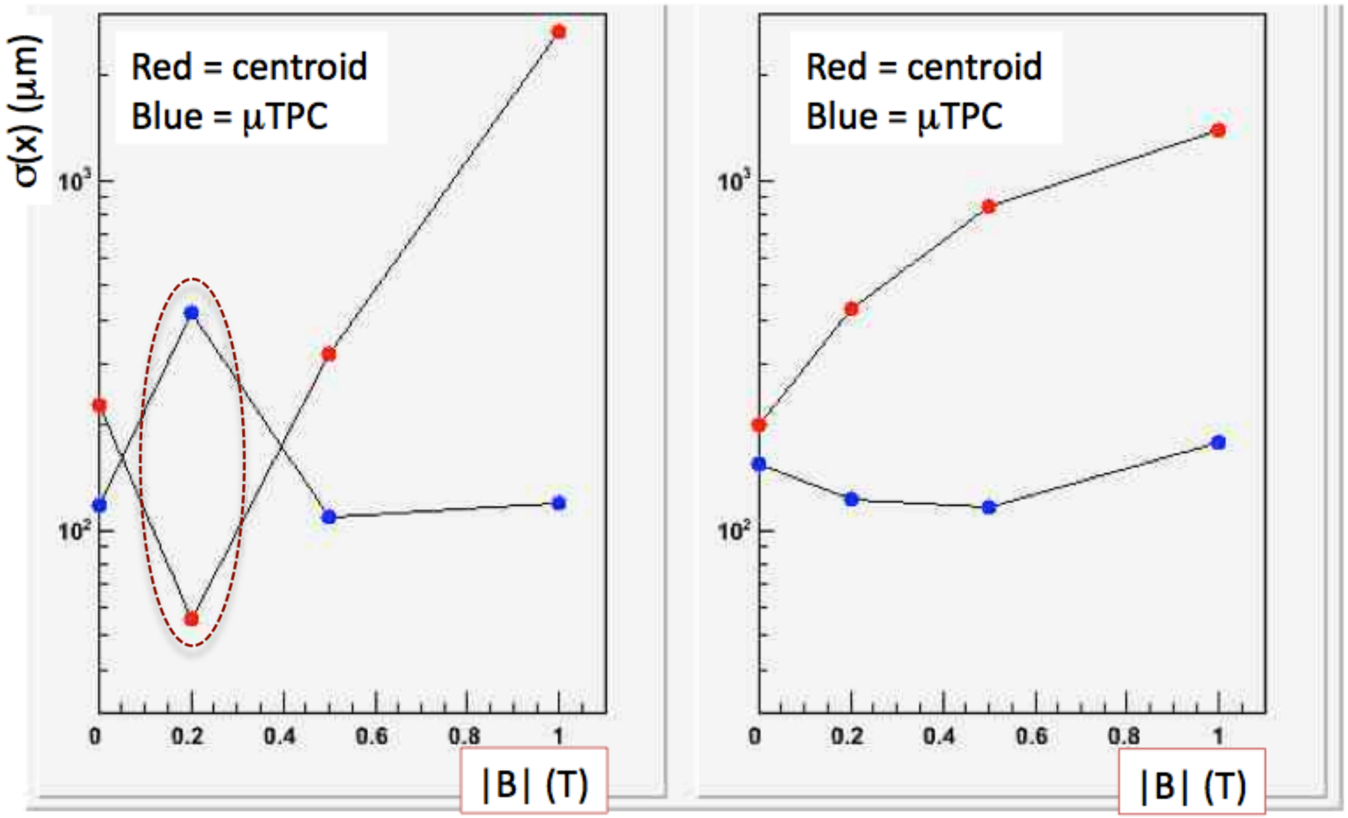
- Focusing



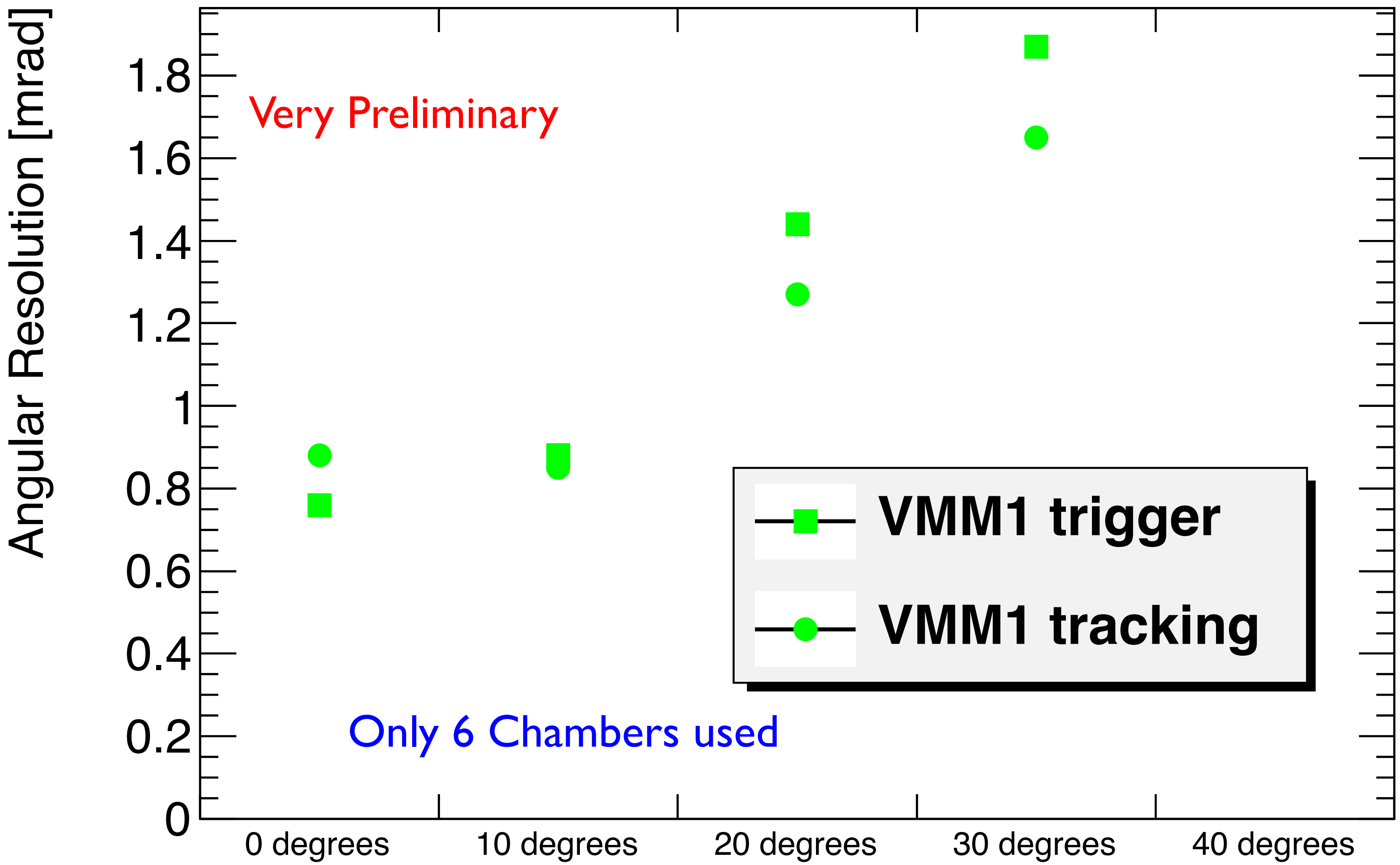
- De-focusing



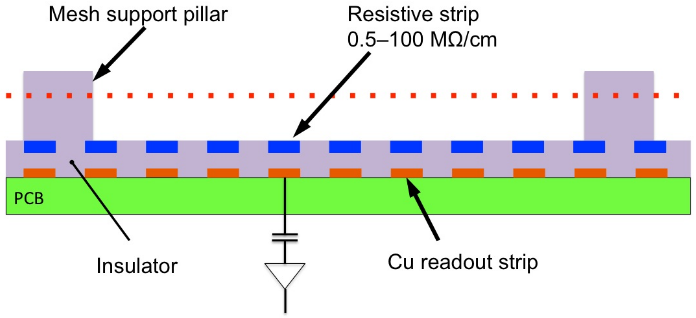
'singularity'



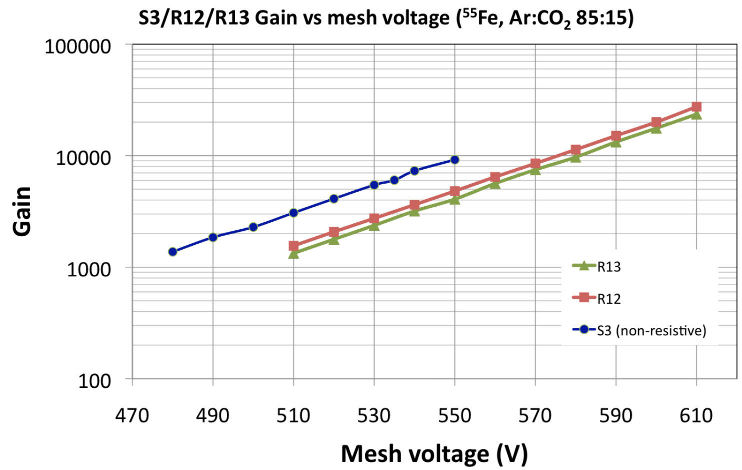
VMM1: preliminary track slope resolution

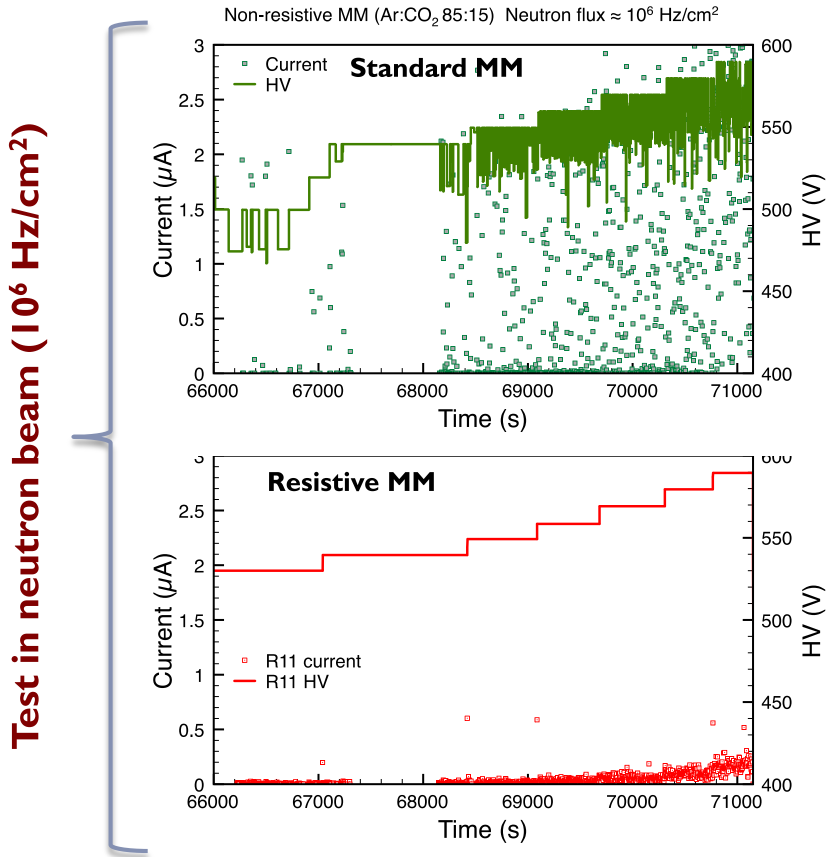


Sparks: problem and solution



- Sparks can be drastically reduced by adding a resistive layer on the r/o strips
- Specific R&D to optimize the resistive protection
- Excellent results





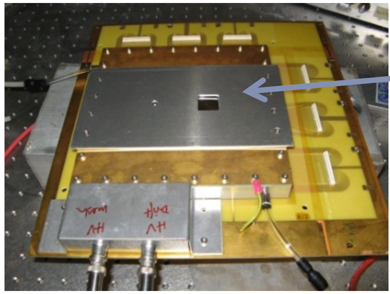
- Additional stability observed in 'reversed' operation mode: HV applied to resistive strips, mesh grounded

X-ray irradiation

Detector operated in data taking conditions

Gas mixture : Argon + 10% CO2
Gas Flow = 0.5 l/h
Gain 3000
HVm = 540V
HVd =790 V

X-ray generator set-up at 10 kV 5 mA



X-ray exposure in a small active area region of 4 cm².

Equivalent charge generated during 5 years HL-LHC

Wi (Argon + 10% CO_2) = 26.7 eV
Gain = 5000
MIP deposit in 0.5 cm drift = 1248.5 eV

Charge per iteration = 37.4 fC

Expected rate at the HL-LHC : 10kHz/cm²

5 years of HL-LHC operation (200days X year)

Total detector charge generated during HL-LHC operation is estimated to be 32.5 mC/cm²

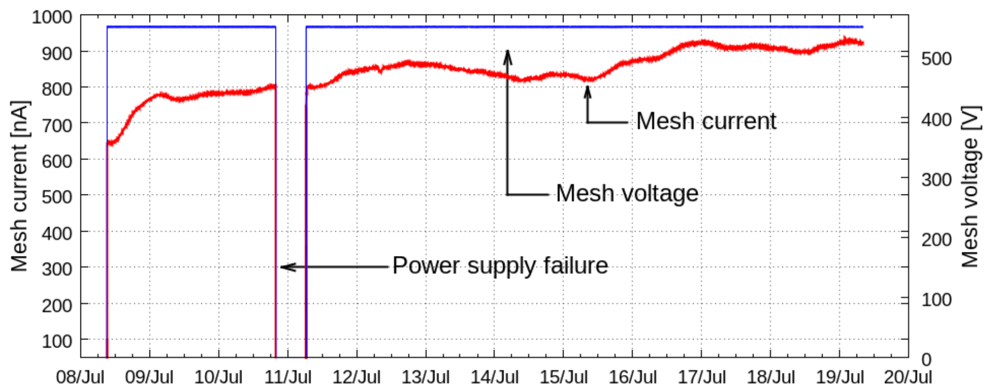
During the X-ray ageing test it was generated a total charge of

Q_{ageing} = 765mC in 4cm²,

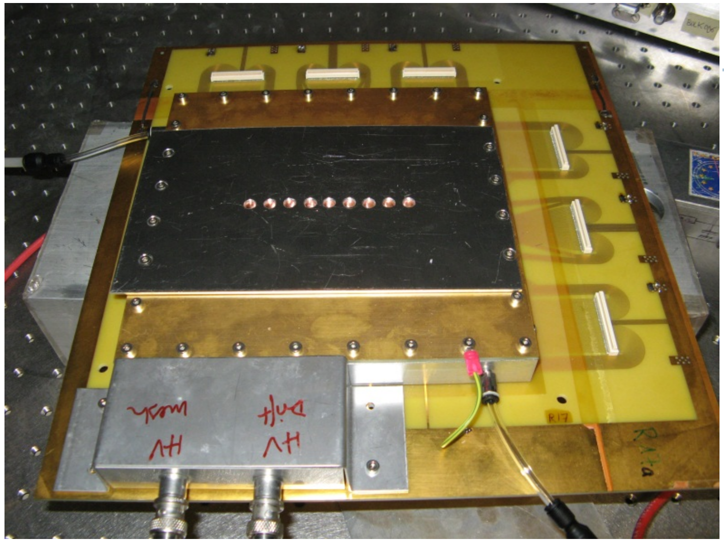
during a total exposure time of

$T_{exposure}$ = 11days 21 hours

And therefore, the total charge to be generated at the HL-LHC during 5 years with more than a factor 5 of security factor.



X-ray irradiation

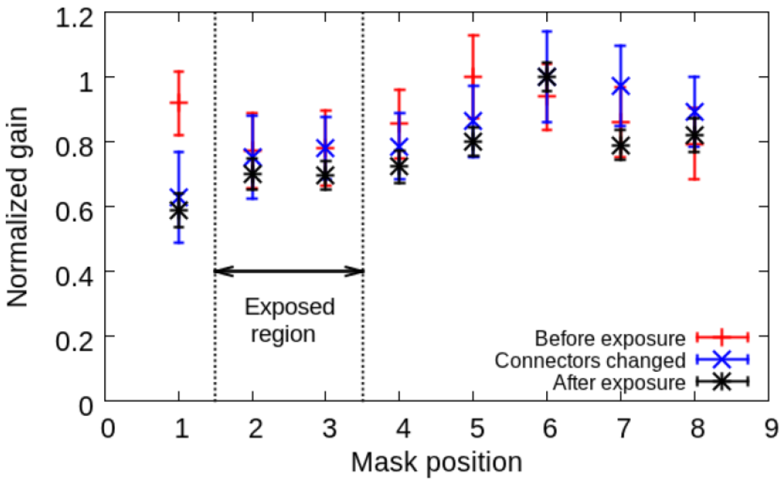


Measurements at different position were performed by using a mask with several equi-distant holes over the active region of the detector.

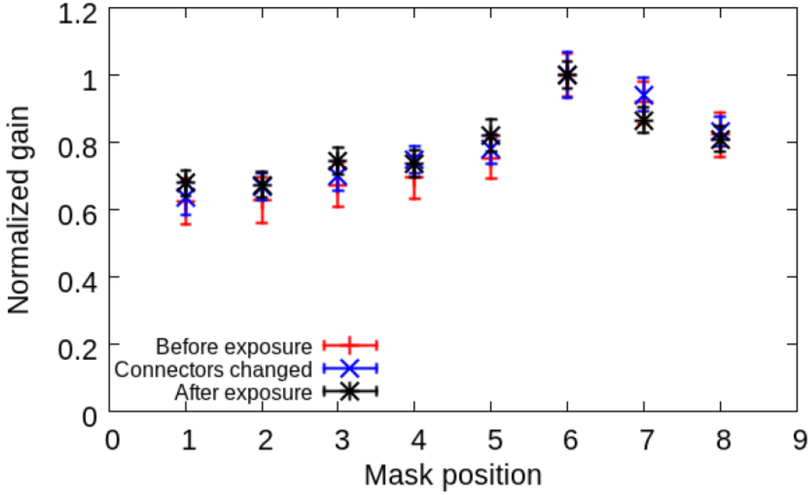
Normalized gain measurements show the relative compatibility with position.

The exposed region does not show a considerable change respect to the non-exposed regions.

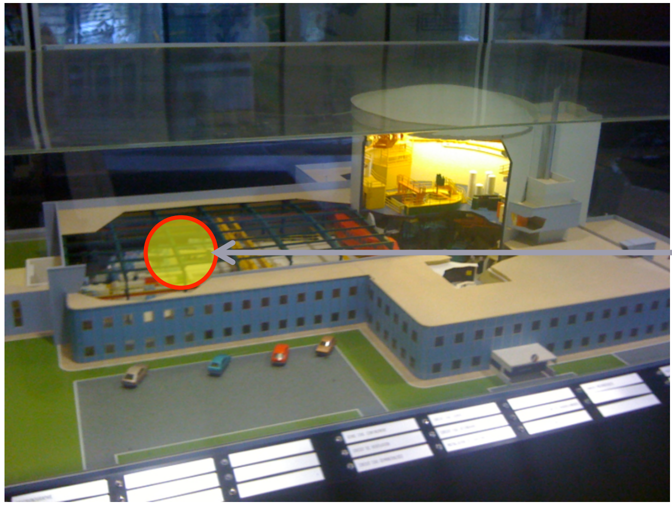
Exposed detector R17a



NON Exposed detector R17b



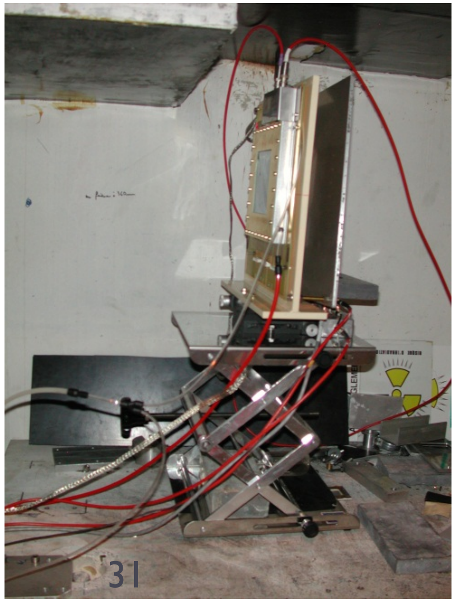
Neutron exposure

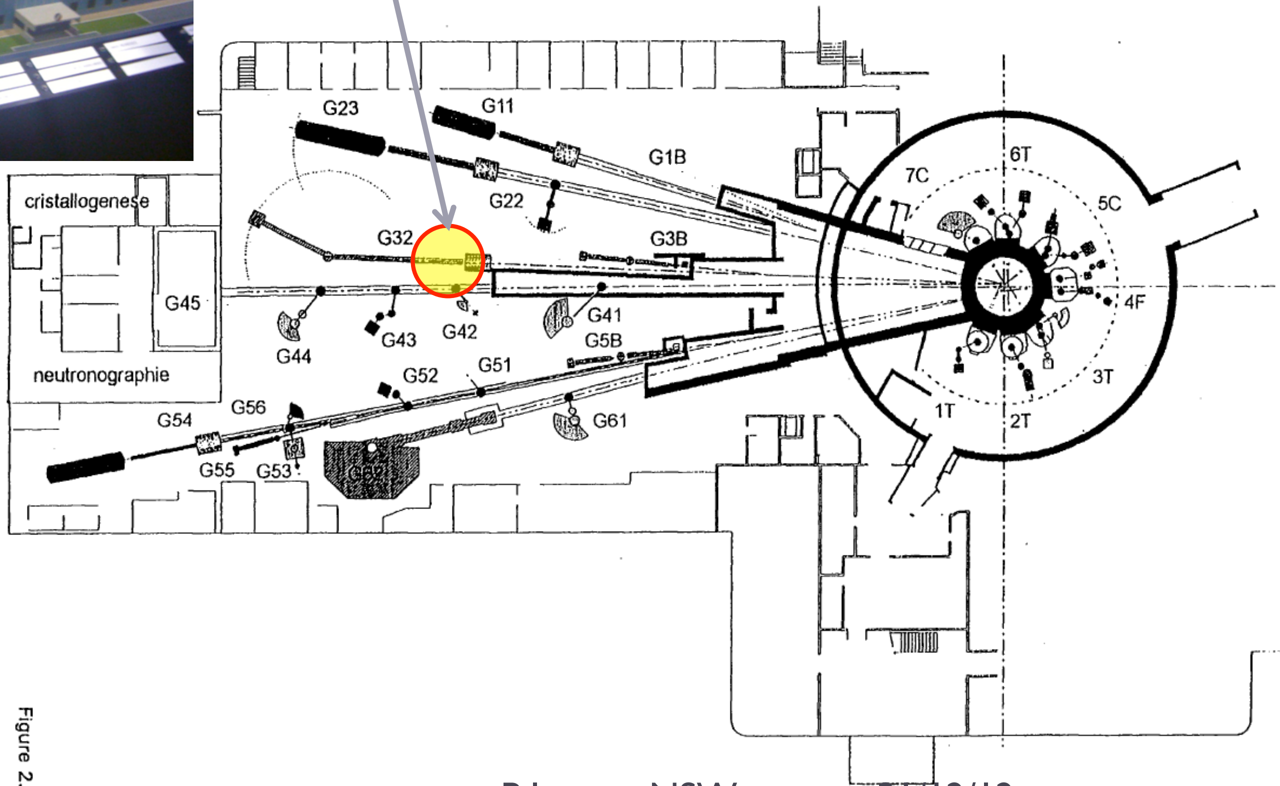


Detector emplacement at Orphee reactor Neutron guide

Neutron flux : ~8.10^8 n/cm2/sec

Neutron energy : 5 to 10 meV





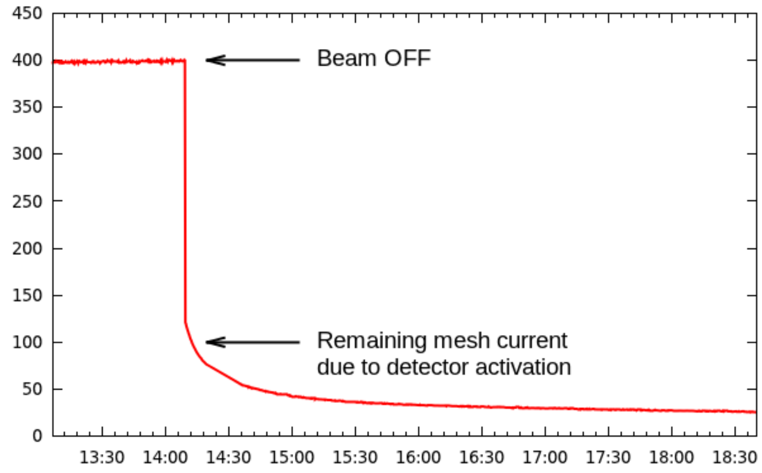
Neutron exposure

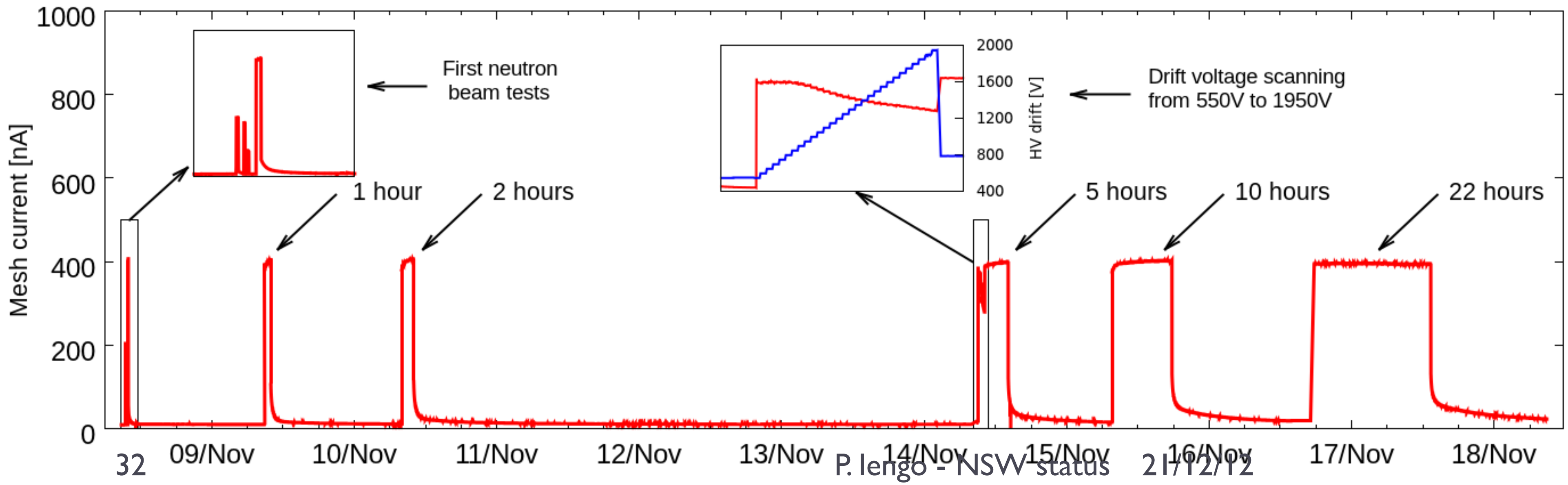
Neutron flux at the level of CSC in ATLAS ~3.10^4 neutrons/cm2/s

10 years at HL-LHC (=> x10.10^7 sec) with a security factor x3

At the HL-LHC, we will accumulate 1,5.10^{13} n/cm2

At Orphee we have ~8.10^8 n/cm2/sec so in 1 hour we have : 8.10^8 x 3600 ~ 3.10^{12} n/cm2/hour which is about 2 HL-LHC years (200 days year).





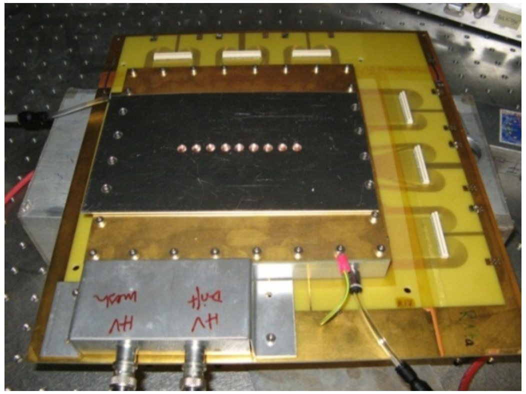
Gamma irradiation

Source de Cobalt 60 placed at 50cm from the source :

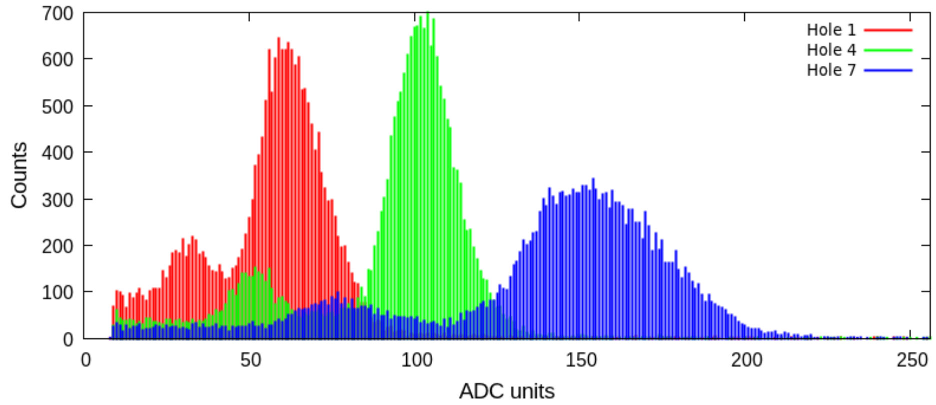
- 20 days ~ 10 y-LHC equivalent
- Total exposure time: 480 h
- Total integrated charge: 1484 mC
- Mean mesh current: 858 nA

Measurements at different position were performed by using a mask with several equidistant holes over the active region of the detector (Same mask used along all the aging tests).

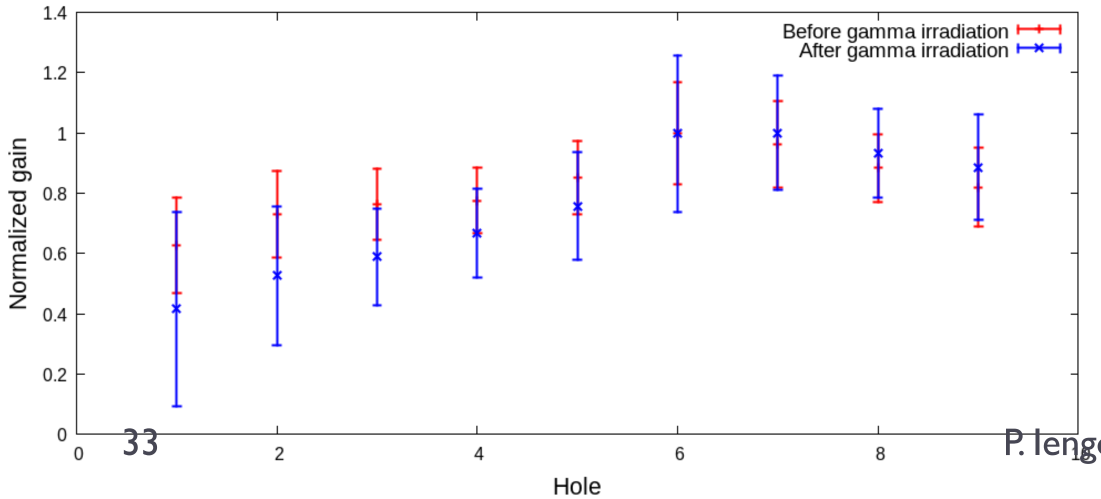
9 Holes mask



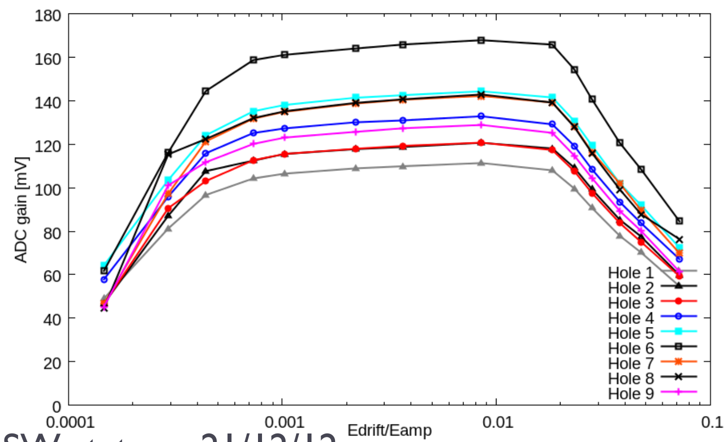
Fe55 source calibrations at different hole positions



Gain profile measured at the 9 reference points



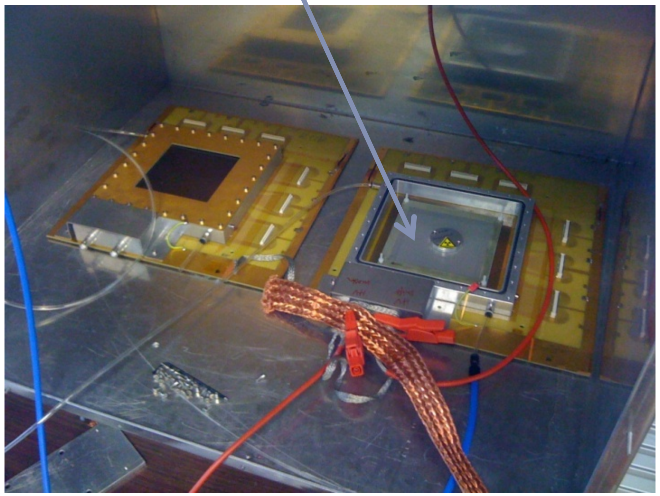
Detector transparency



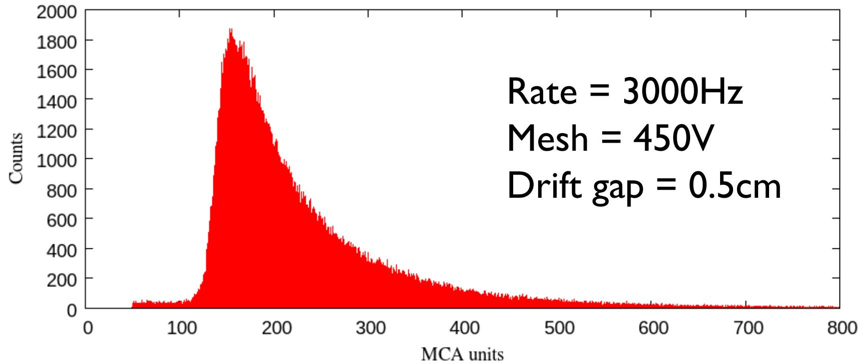
Alpha irradiation

Alpha source installed inside the chamber and centered just on top of the drift grid.

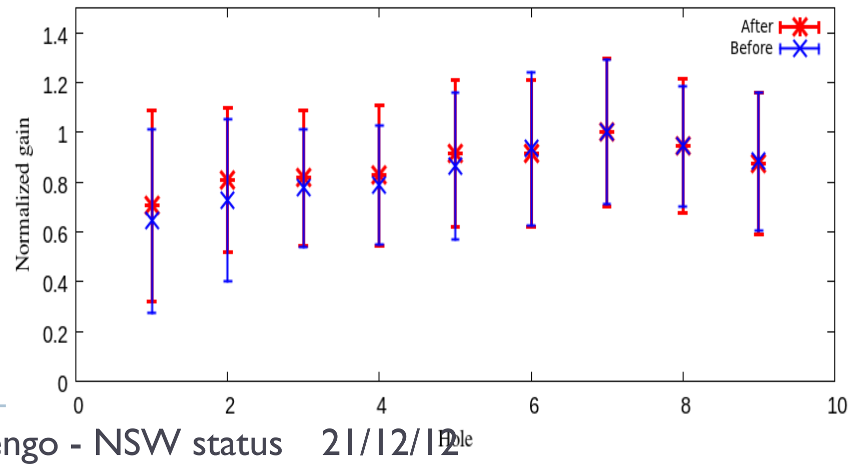
R17a detector irradiated with an alpha



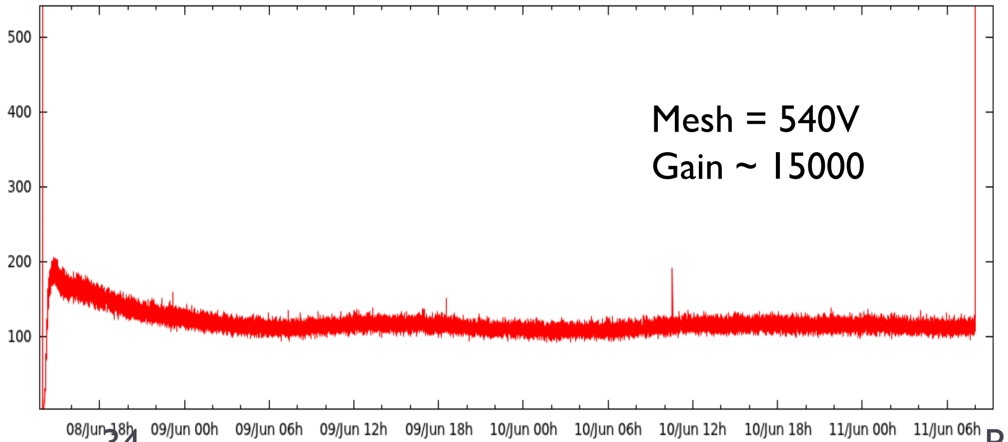
Alpha spectrum



Gain profile before and after irradiation

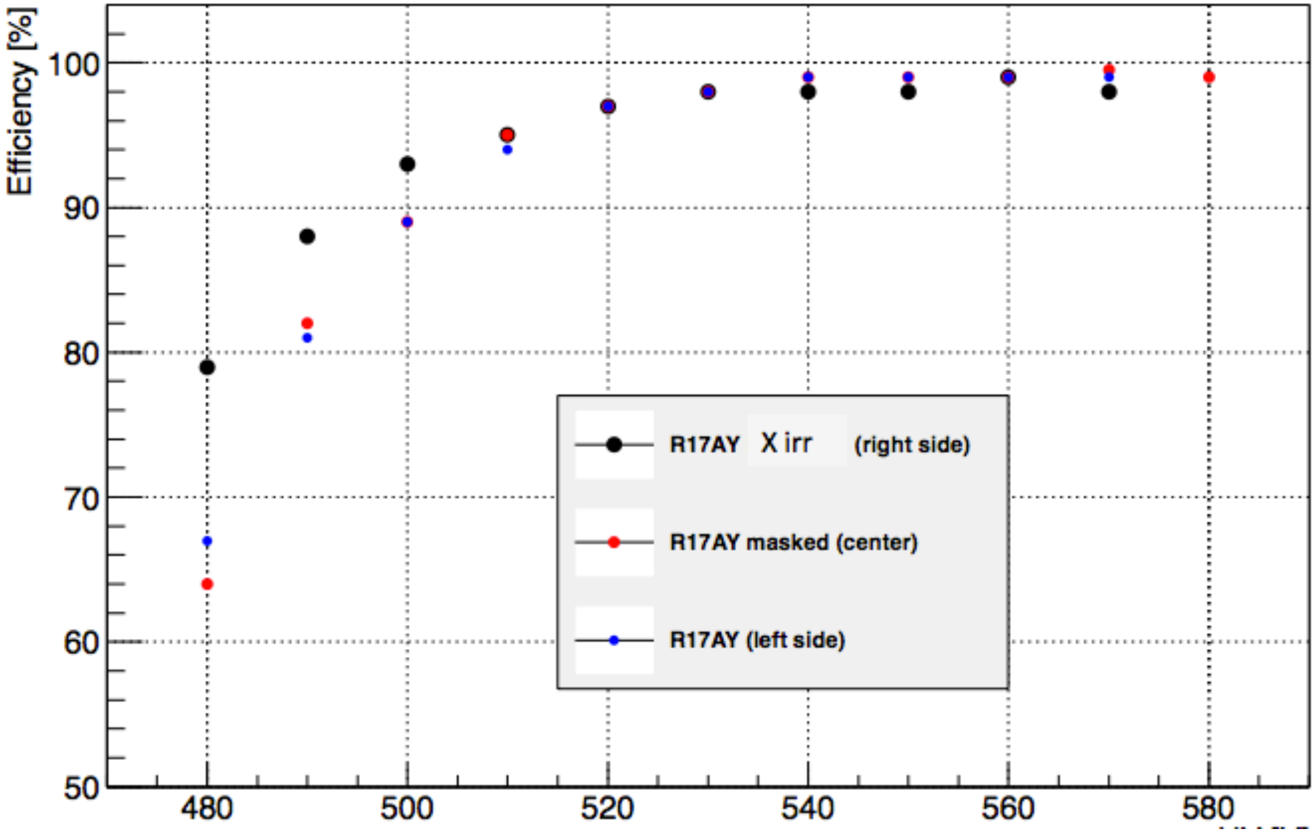


Mesh current during alpha irradiation



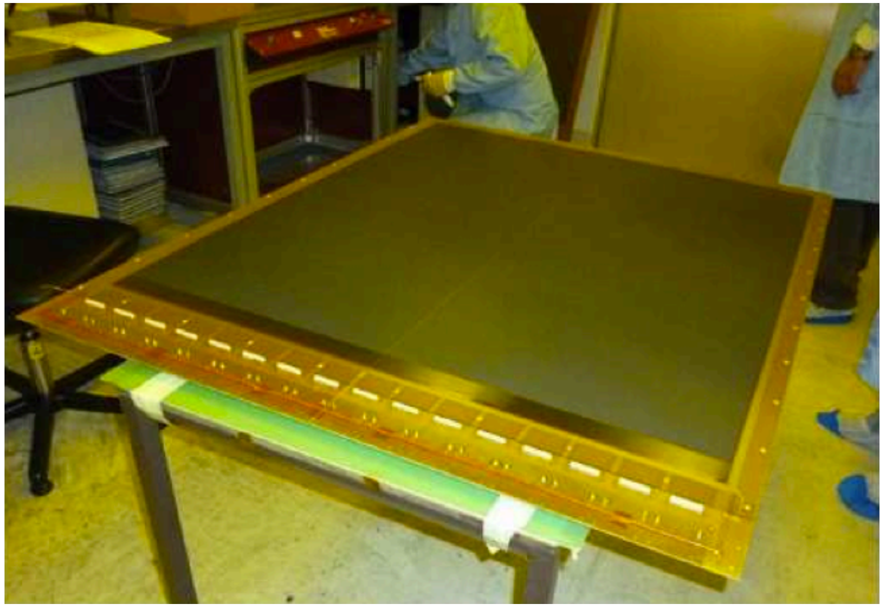
Irradiated chamber tested on beam

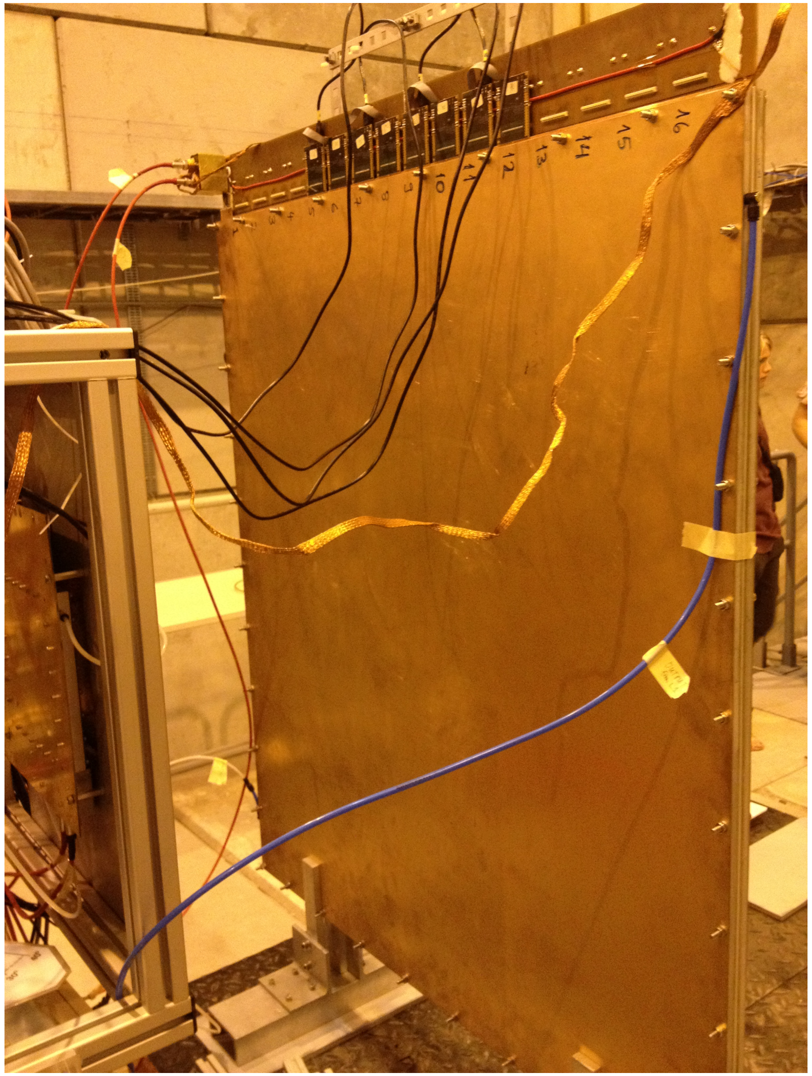
- No efficiency reduction observed



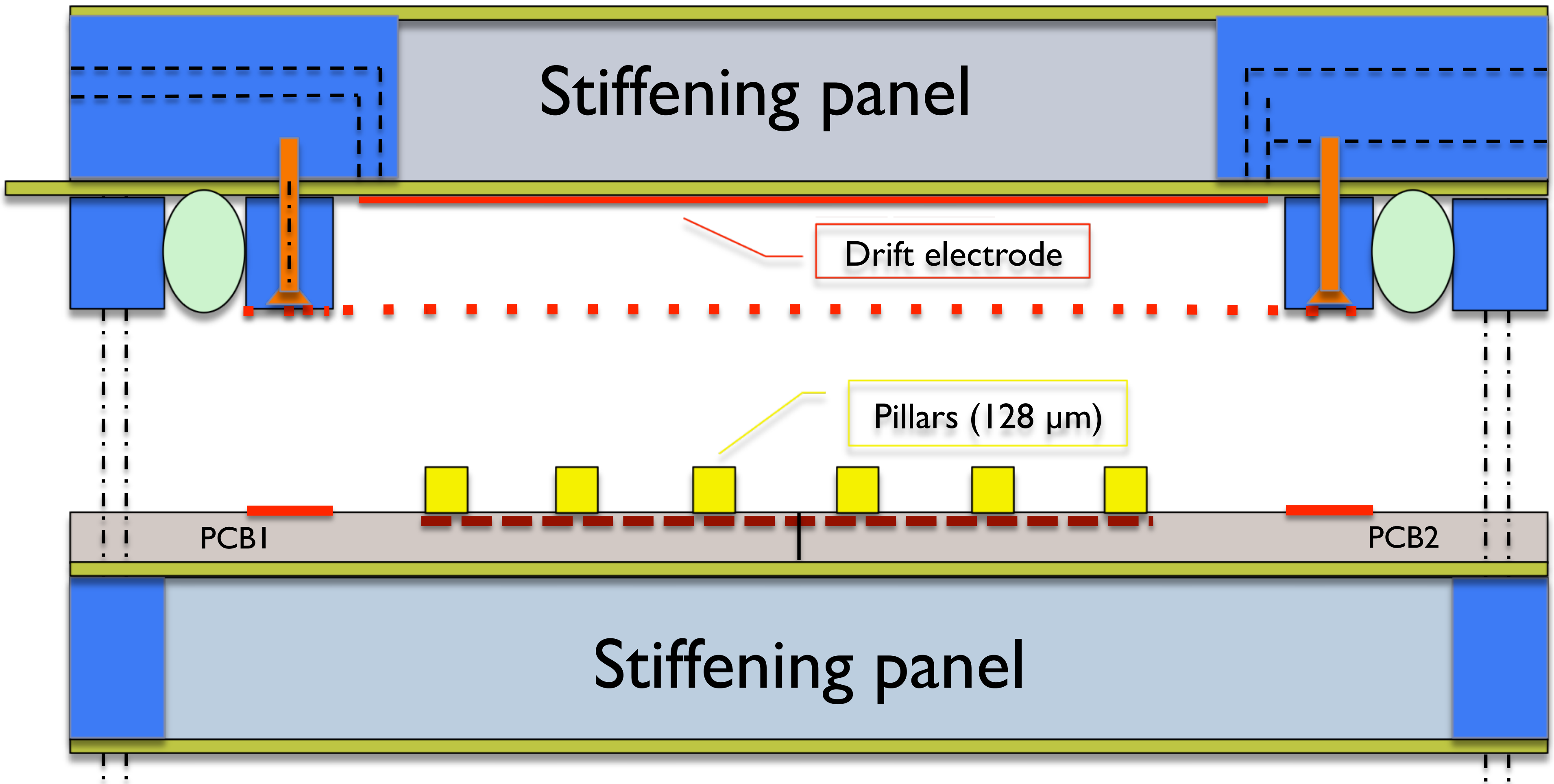
Test on L1 chamber (1x1 m^2)

- 1m2 chamber obtained with 2 1x0.5 PCBs on Al support
- Floating mesh
- 450 um strip pitch

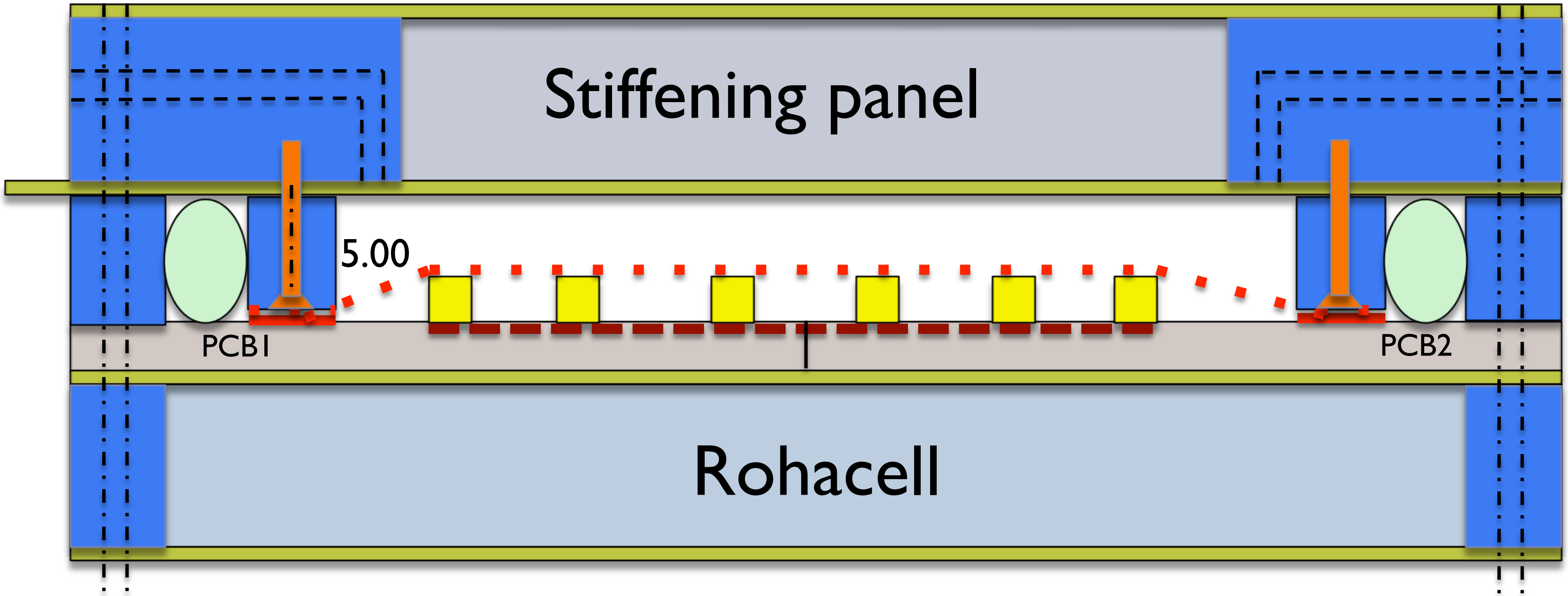




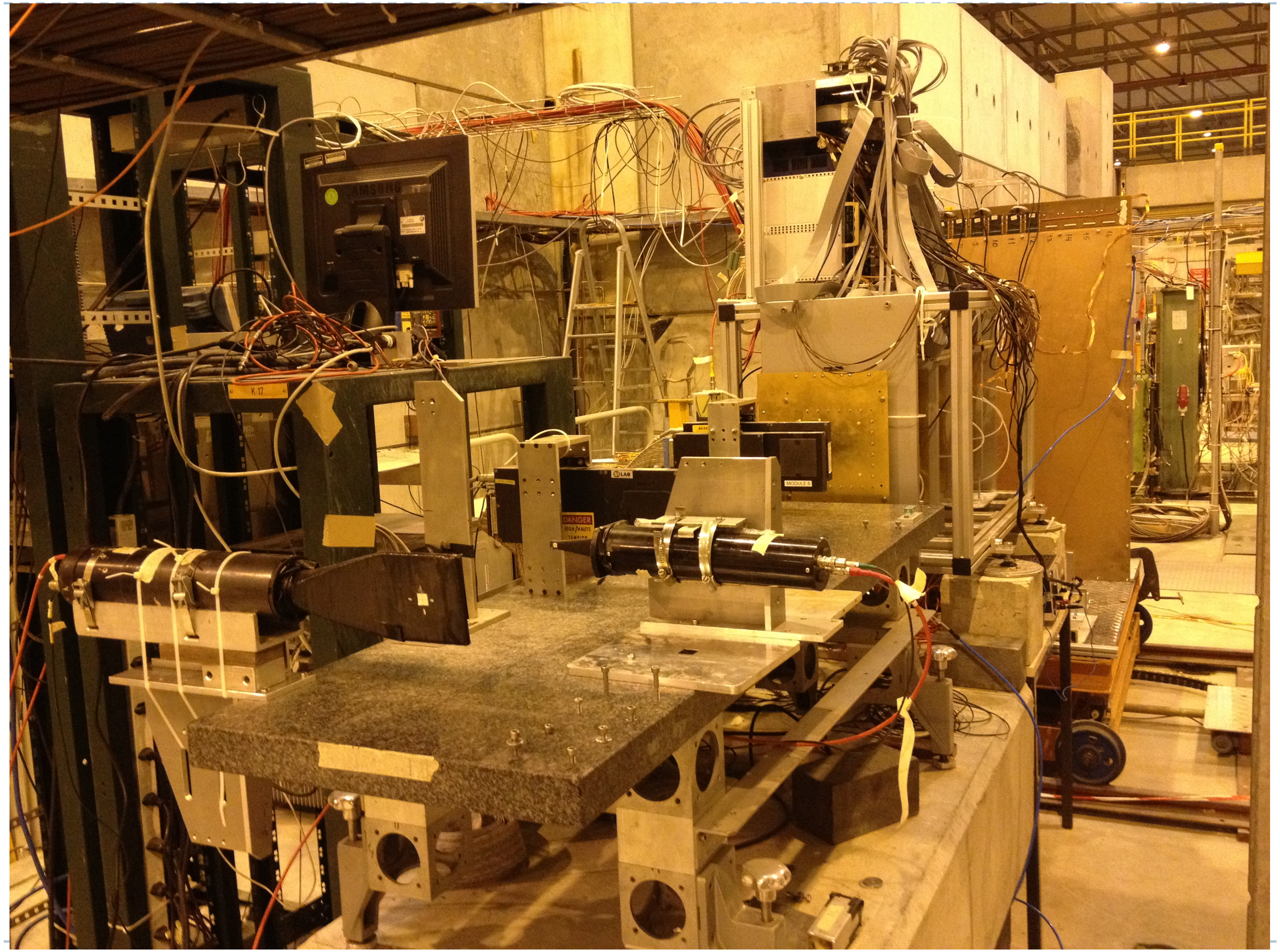
1 x 1 m² sketch (not to scale)



1 x 1 m² sketch (closed)

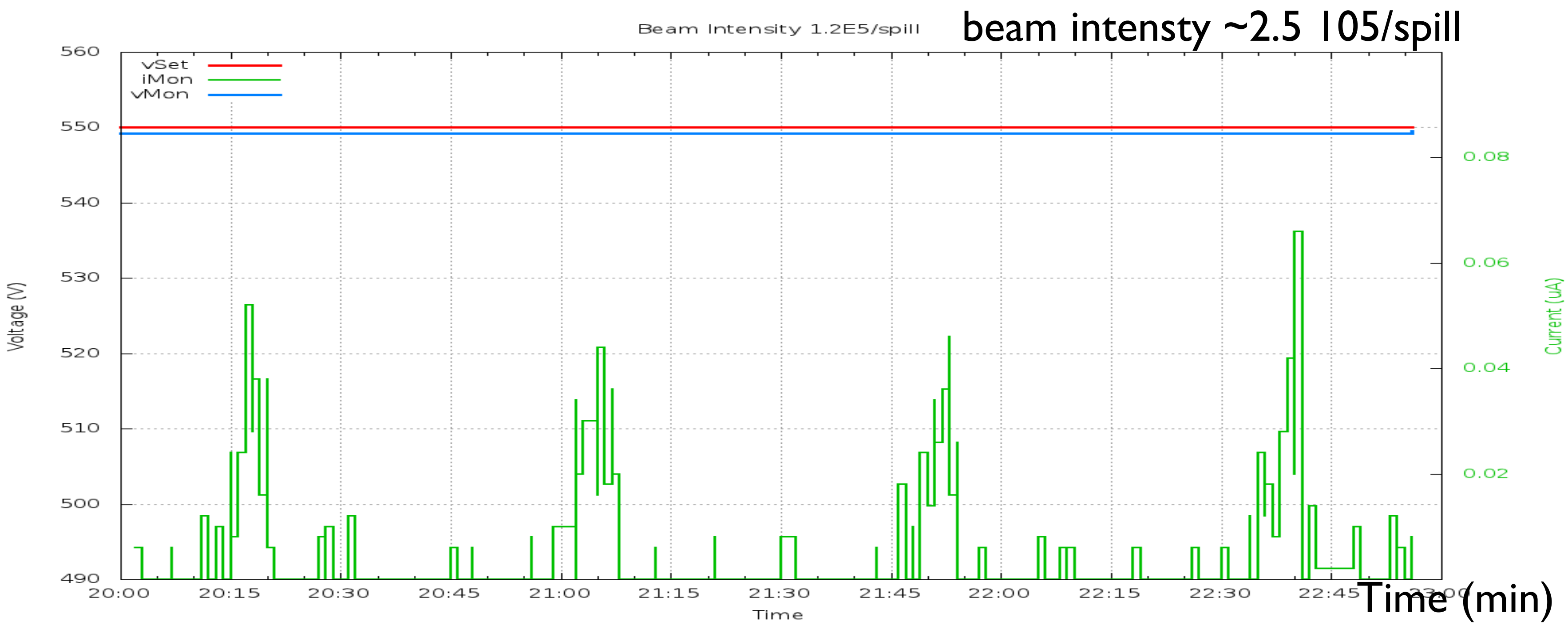


Test of L1



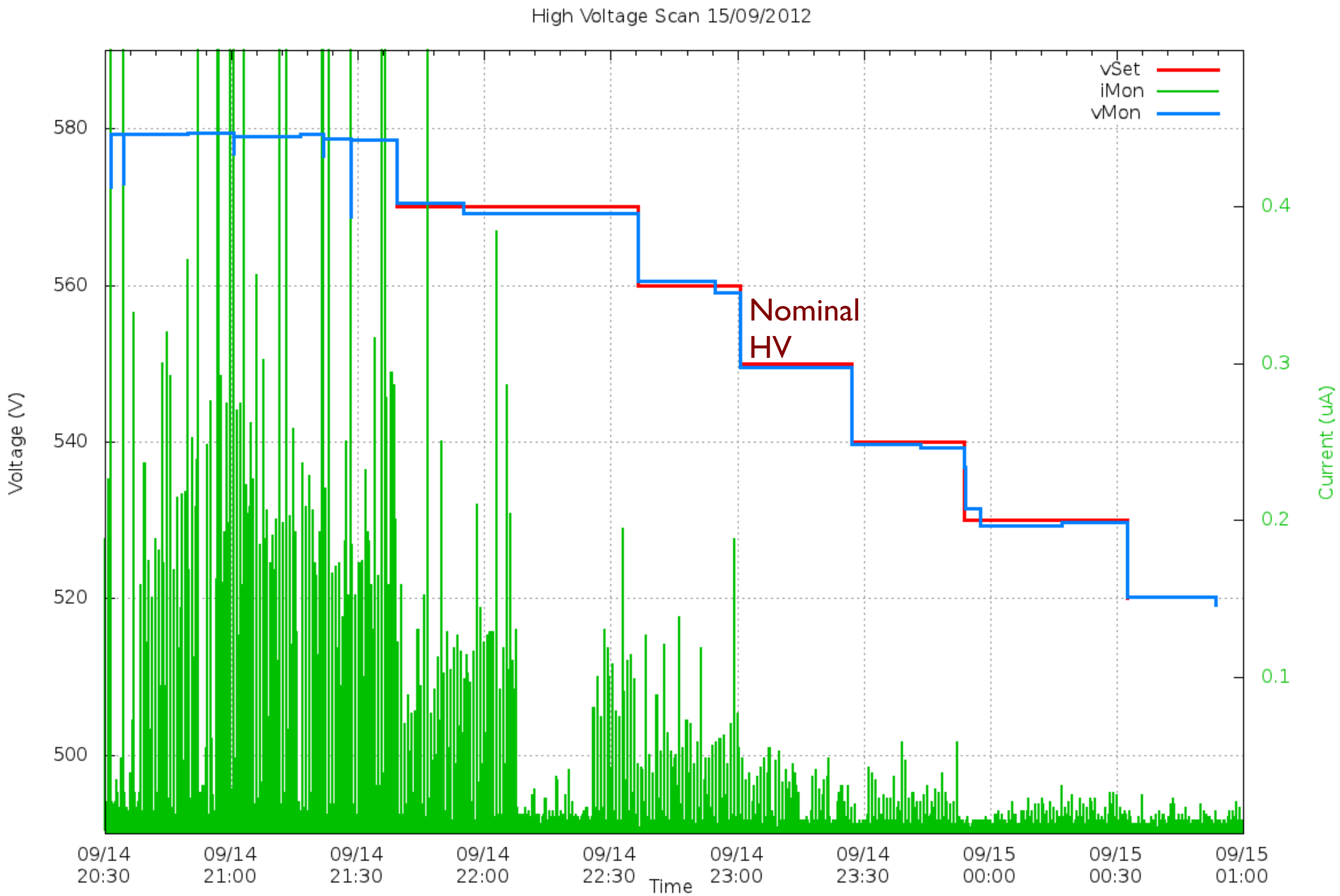
Test on L1: current

- Stable operation during 2 months at the H6 beam line
- Working point ~550V (wrt 500V for TX chambers)
- Current during spills <100nA (beam intensity ~2.5x10^5/spill); few nA in between spills

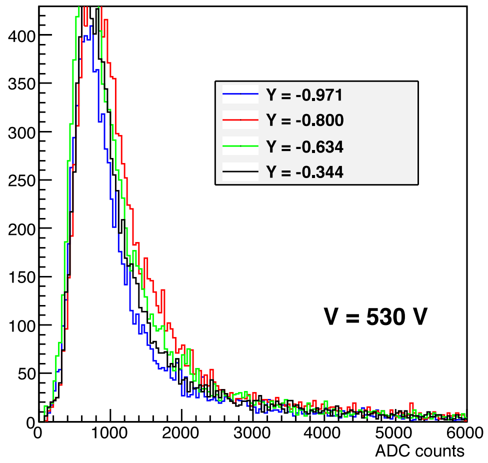


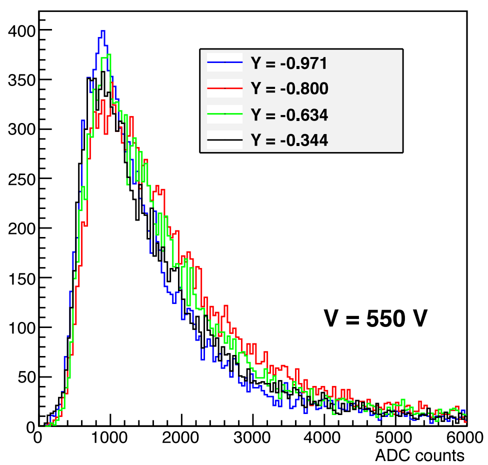
L1 current

- HV Scan (beam intensty ~1.5 10^5/spill)

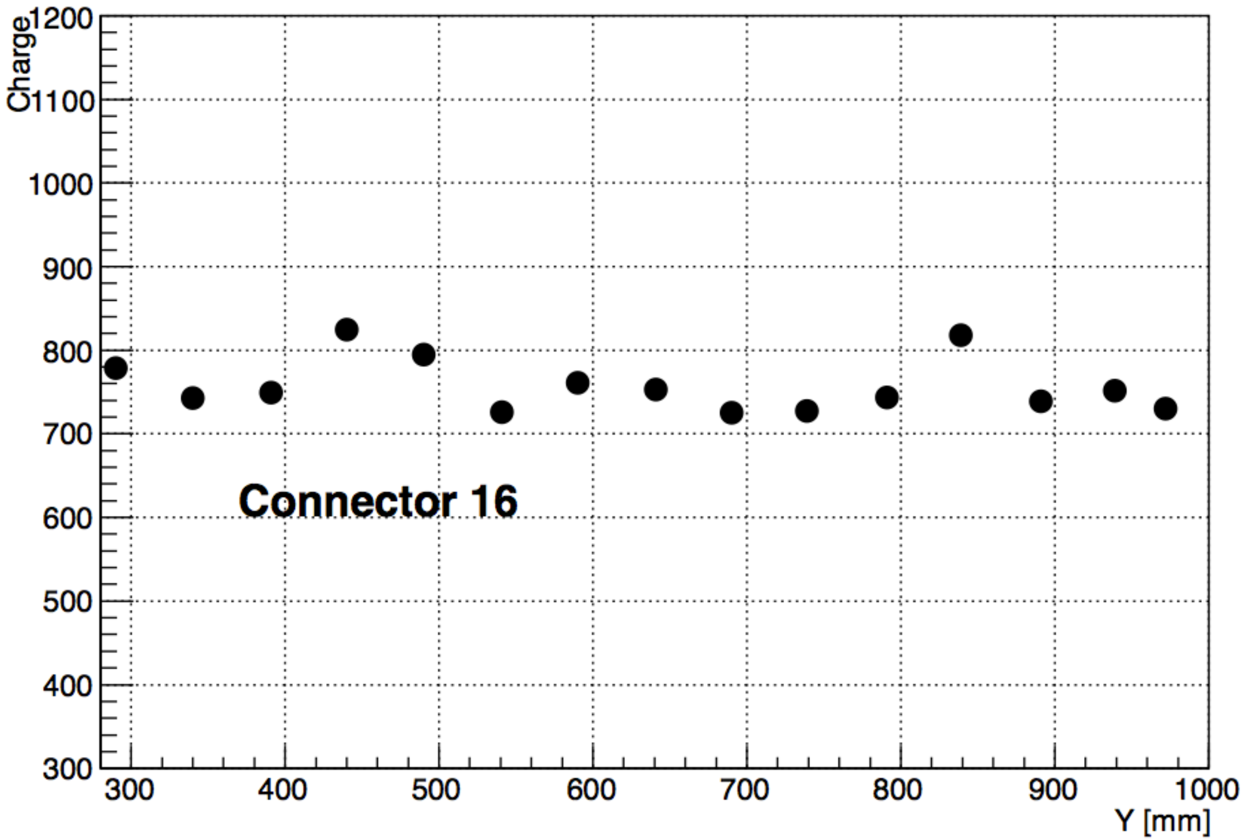


L1: Charge uniformity along the strip



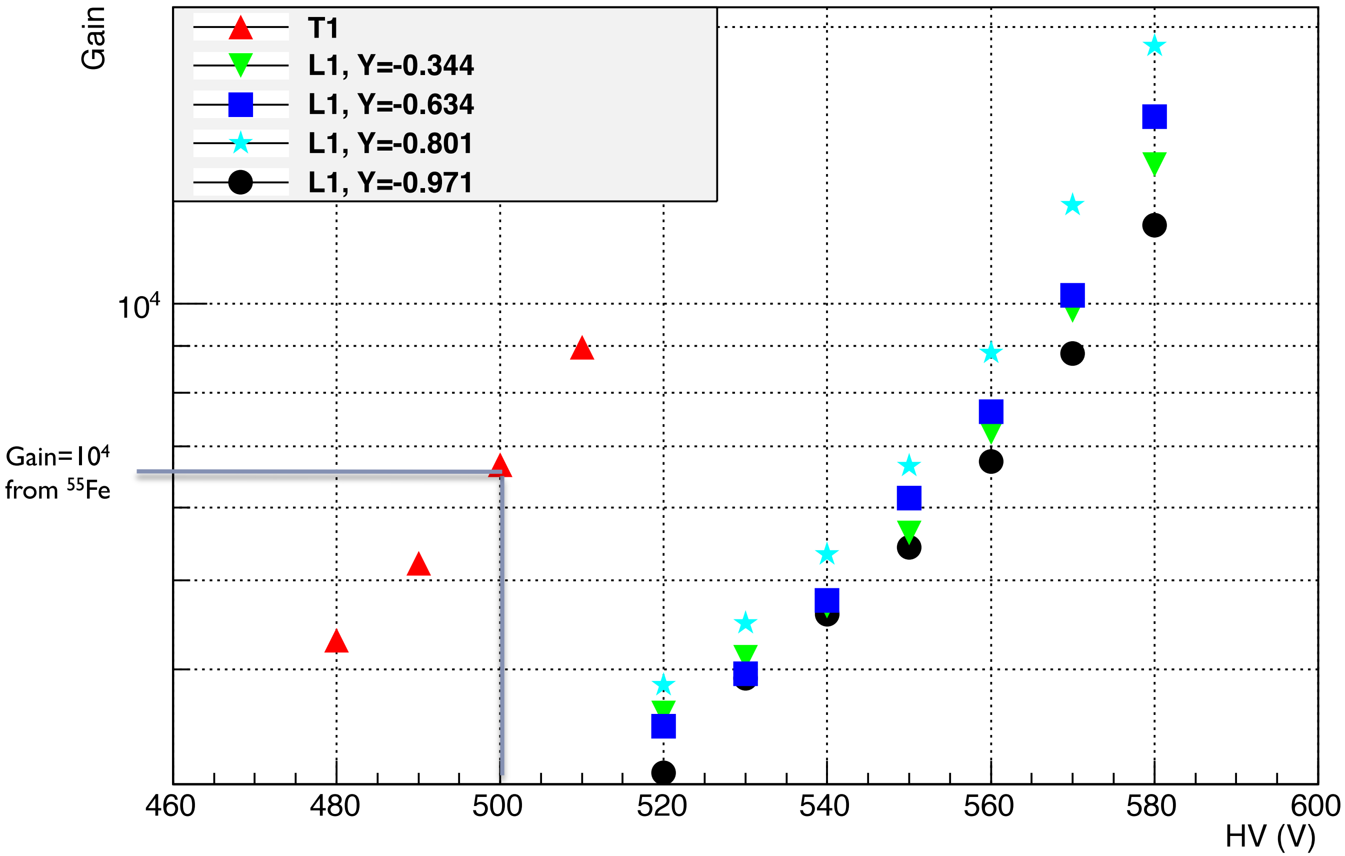


- Max charge (ADC counts) along Y strips for connctor 16 (right edge of L1)



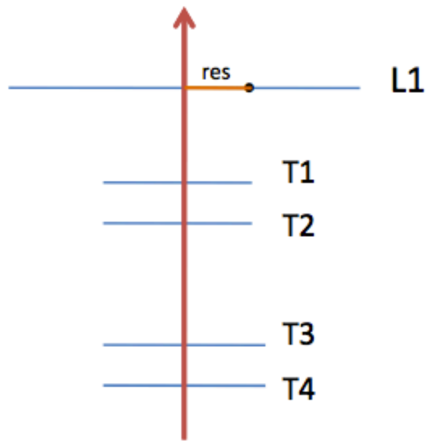
L1: Gain

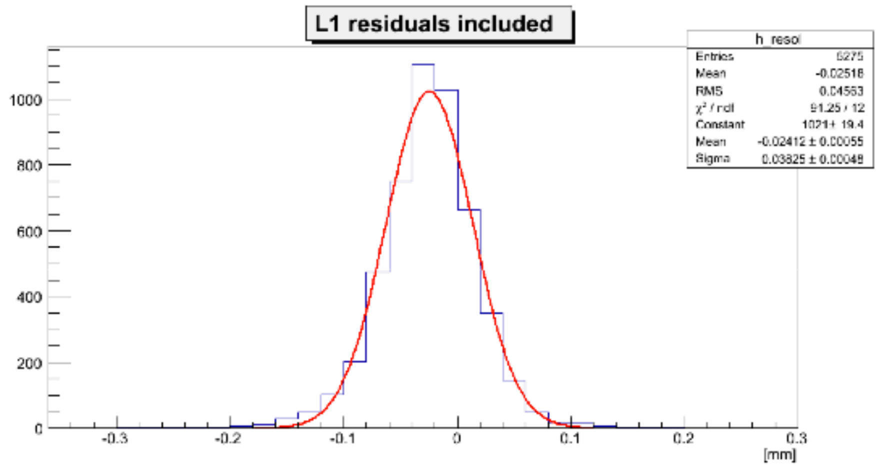
- Gain at different Y positions



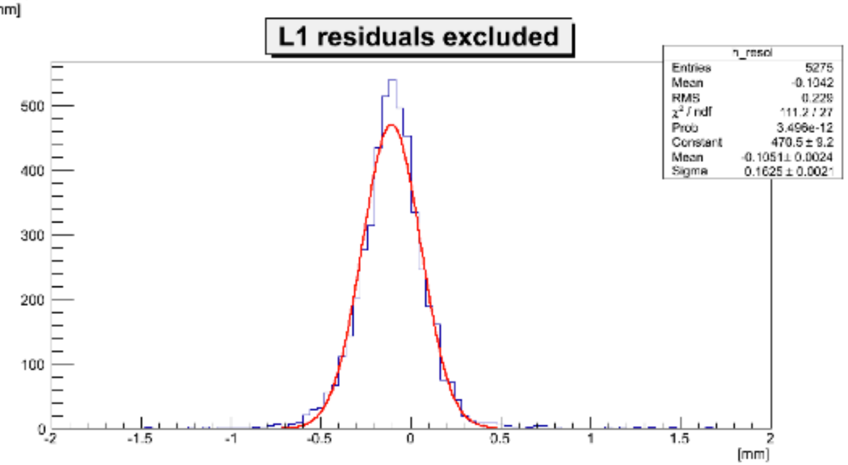
L1: resolution for normal tracks

- Use test chambers to define a track
- Extrapolate to L1
- Compute residuals biased (L1 included in the track) and unbiased (L1 excluded from track)



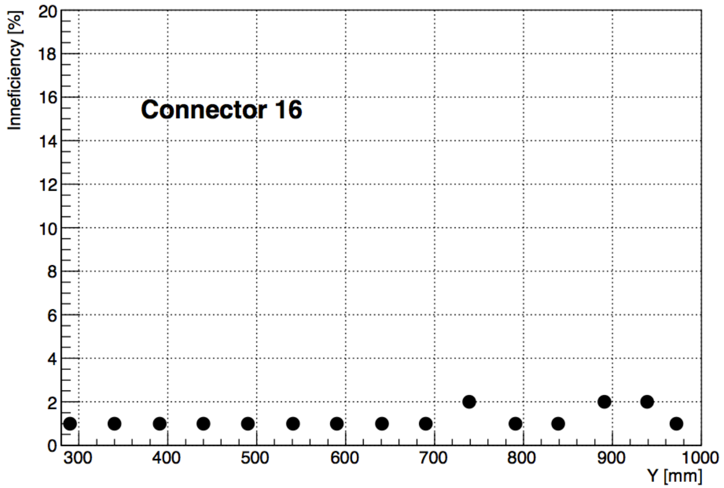


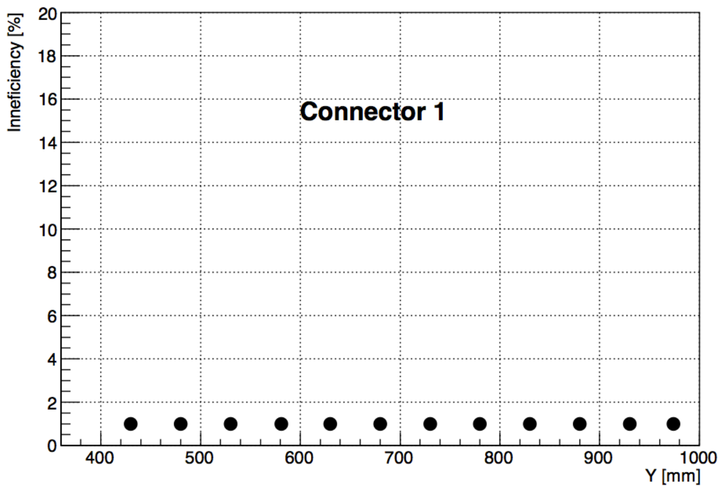
$$\sigma = \sqrt{\sigma_{exc} \cdot \sigma_{inc}} \approx 78\mu m$$

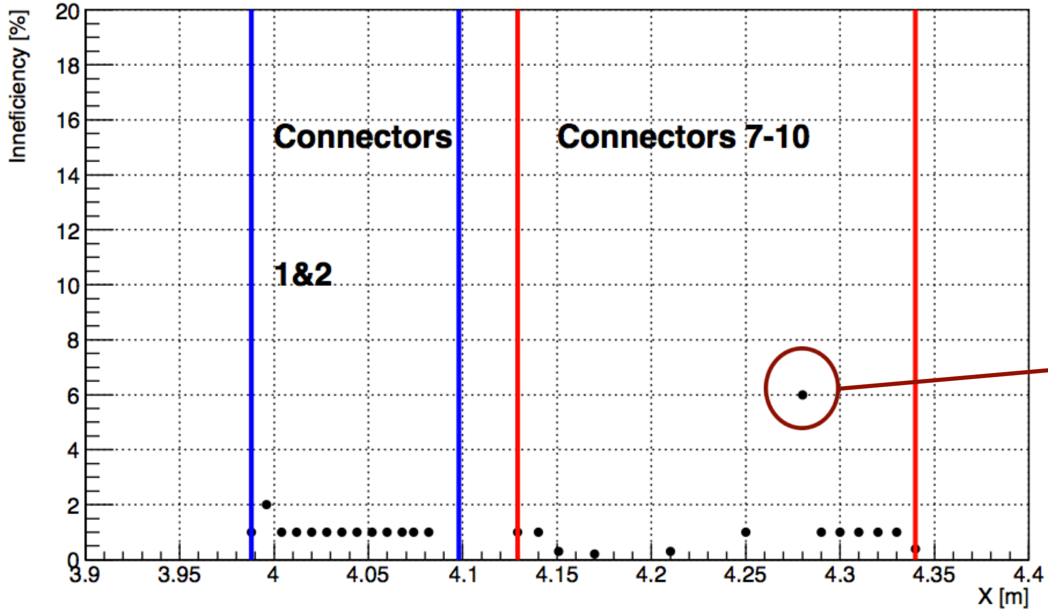


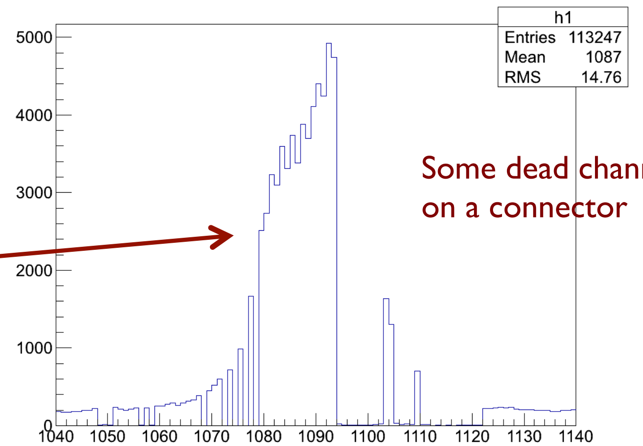
L1: Inefficiency

- Track reconstructed with Tmm reference chambers and extrapolated to L1







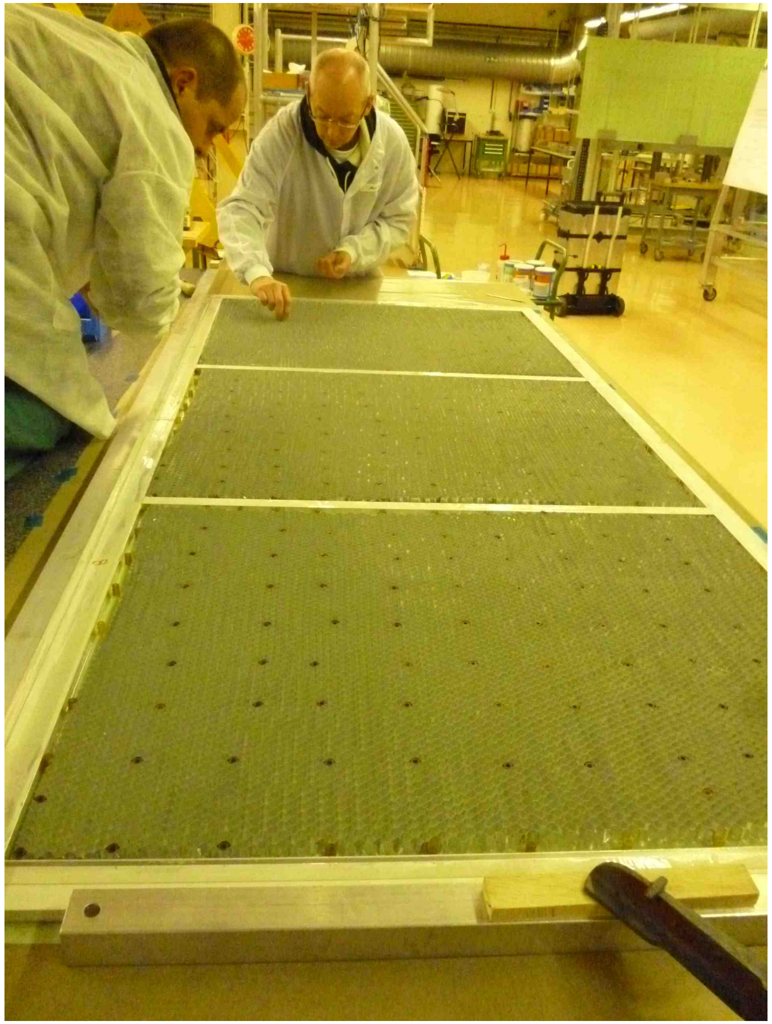


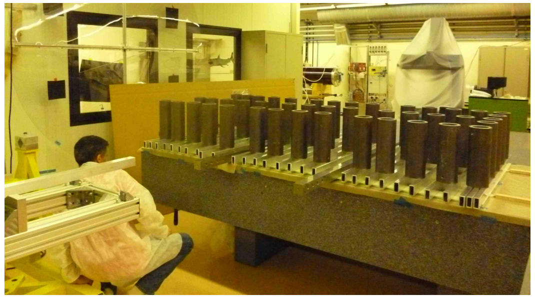
Some dead channels on a connector

The 2 x 1 m^2 MM (milestone)

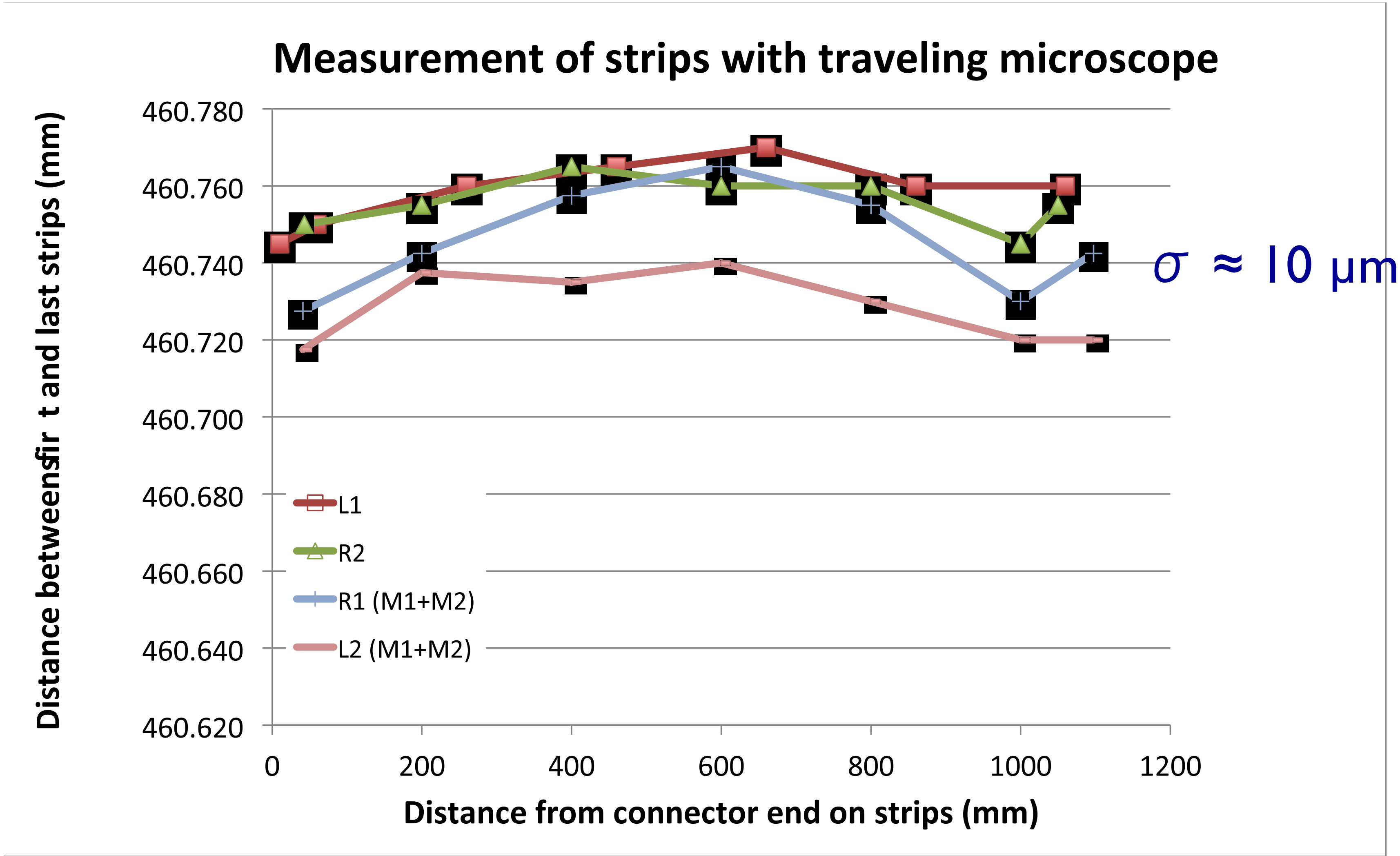
- Parameters:
  - Chamber dimensions 1 x 2.4 m^2 (overall, 0.92 x 2.12 m^2 active area)
  - 2 x 2048 strips (0.45 mm pitch), separated in the middle
  - Flatness of readout plane to better than 50 µm over full area
- Construction:
  - Follow the scheme used for the 1 x 1 m^2 chamber
    - Four 0.5 x 1.2 m^2 PCBs (thickness 0.5 mm) glued to stiffening panel
    - PCB boards for 1st chamber have been made at CERN
  - Resistive strips have been printed (in industry), with interconnects
  - Floating mesh, integrated into drift-electrode panel

The making of the drift panel





Measurement of four readout boards for 2 x 1 m^2 MM (CERN)

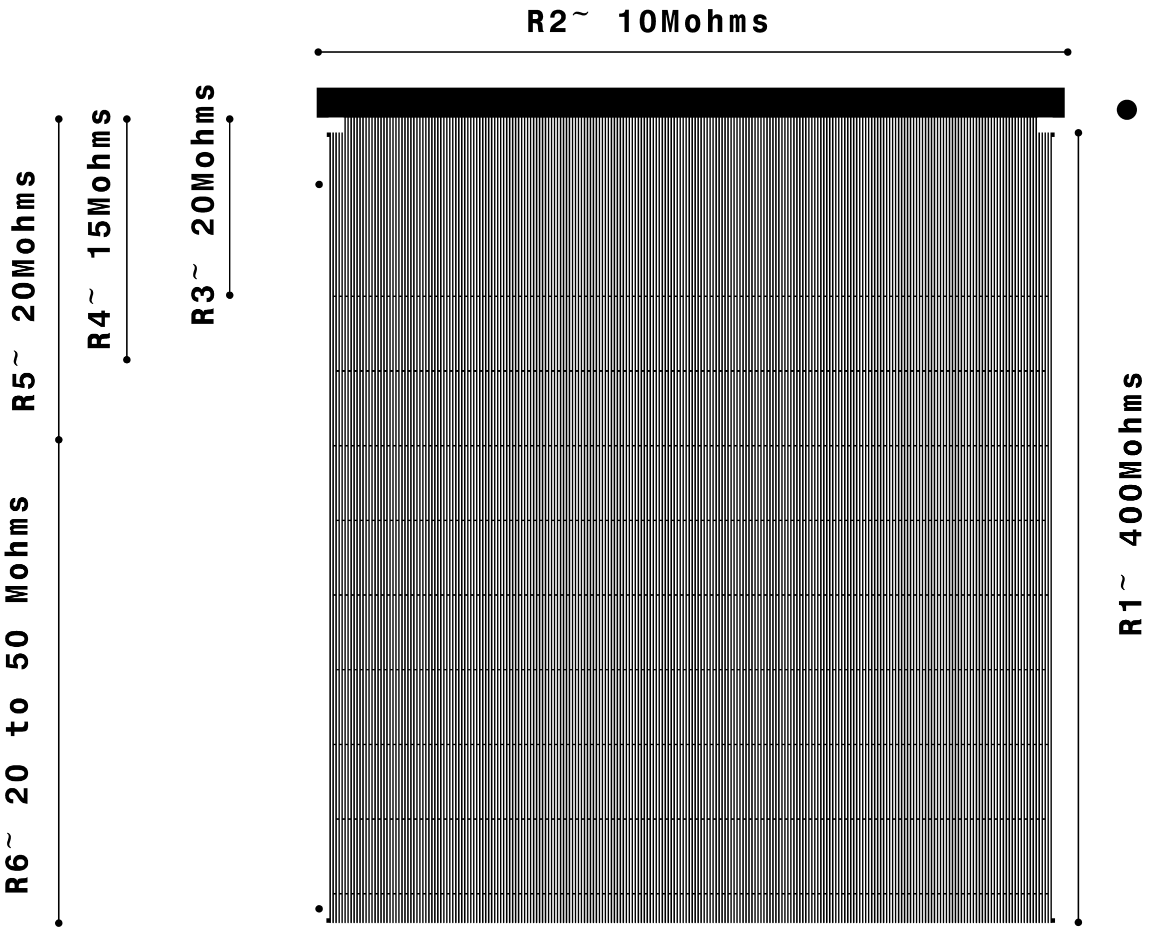


σ ≈ 10 μm

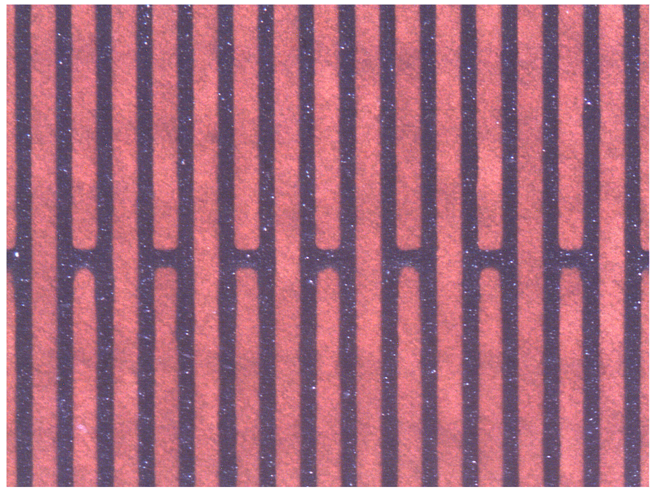
Readout board improvements

- Printing of resistive and 2nd coordinate strips instead of etching
  - First tests with printing the resistive strips were done in Kobe (Japan) and at CERN with promising results
  - Z1 and Z2 chambers (CERN) , 2D chambers with 2nd coordinate and resistive strips printed, are now in H6 test beam, working very nicely with much reduced spark rate (smoother surfaces)
  - Kobe chamber has arrived at CERN, to be measured in H6 this week
- Resistive strip interconnects
  - Incorporated in Z1 and Z2, first impression: looks fine
  - Next step: optimization of resistivity values
- Zebra connection scheme
  - Z1 and Z2 chambers incorporate elastomer Zebra interconnects that do not require soldering
  - Works fine, after reworking a bit the mechanics

Z1 & Z2 resistive strips



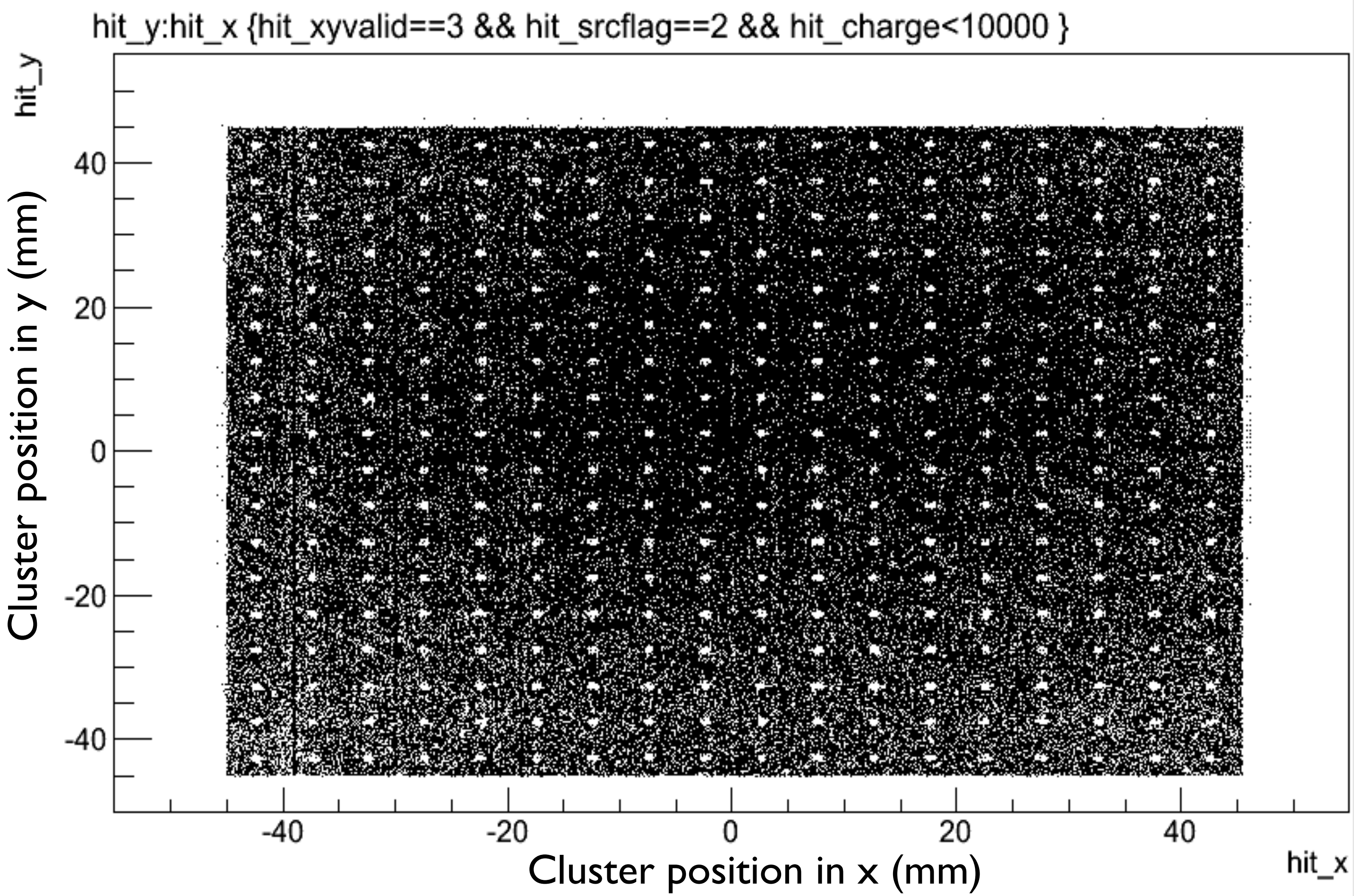
- Interconnects reduce global resistivity by a factor 10



Test print of resistive strips

-

Z1 radiography (^{55}Fe)



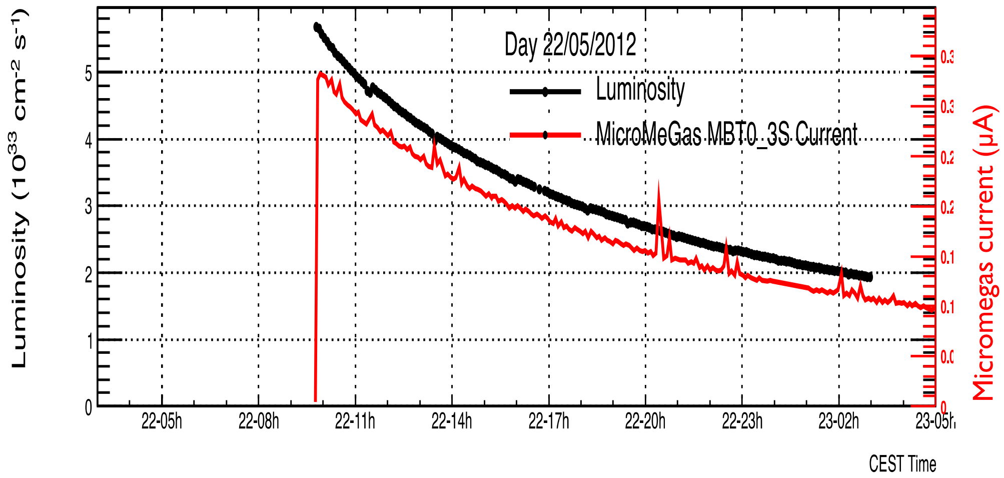
Micromegas in ATLAS

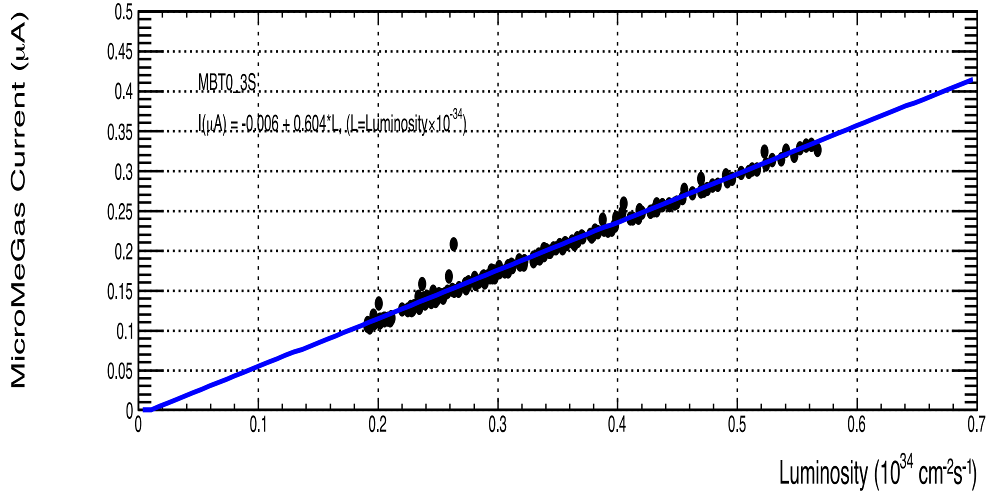
- Four small MM chambers were installed in ATLAS behind the last muon station in April 2011 and smoothly operated all along the 2011 (background measured to be ~3 Hz/cm^2 at L=10^{34} cm^{-2}s^{-1})
- First large size resistive MM assembled and tested in muon beam in 2011
  - To be installed in the ATLAS cavern on the small wheel early 2012 for test
- A small prototype will be installed to evaluate the possibility to replace the Minimum Bias Trigger Scintillator of ATLAS with Micromegas
- Integration in the ATLAS acquisition system

MBT0 rates (preliminary)

- Random trigger (62 Hz)
- Record activity over 525 ns (fiducial 300 ns)
- Events scanned by eye + program
- Rates: ≈20 kHz/cm^2 @ L=10^{33} cm^{-2} s^{-1}

  (or 1 MHz/cm^2 @ L=5 x 10^{34} cm^{-2} s^{-1})
- Rates scale with luminosity





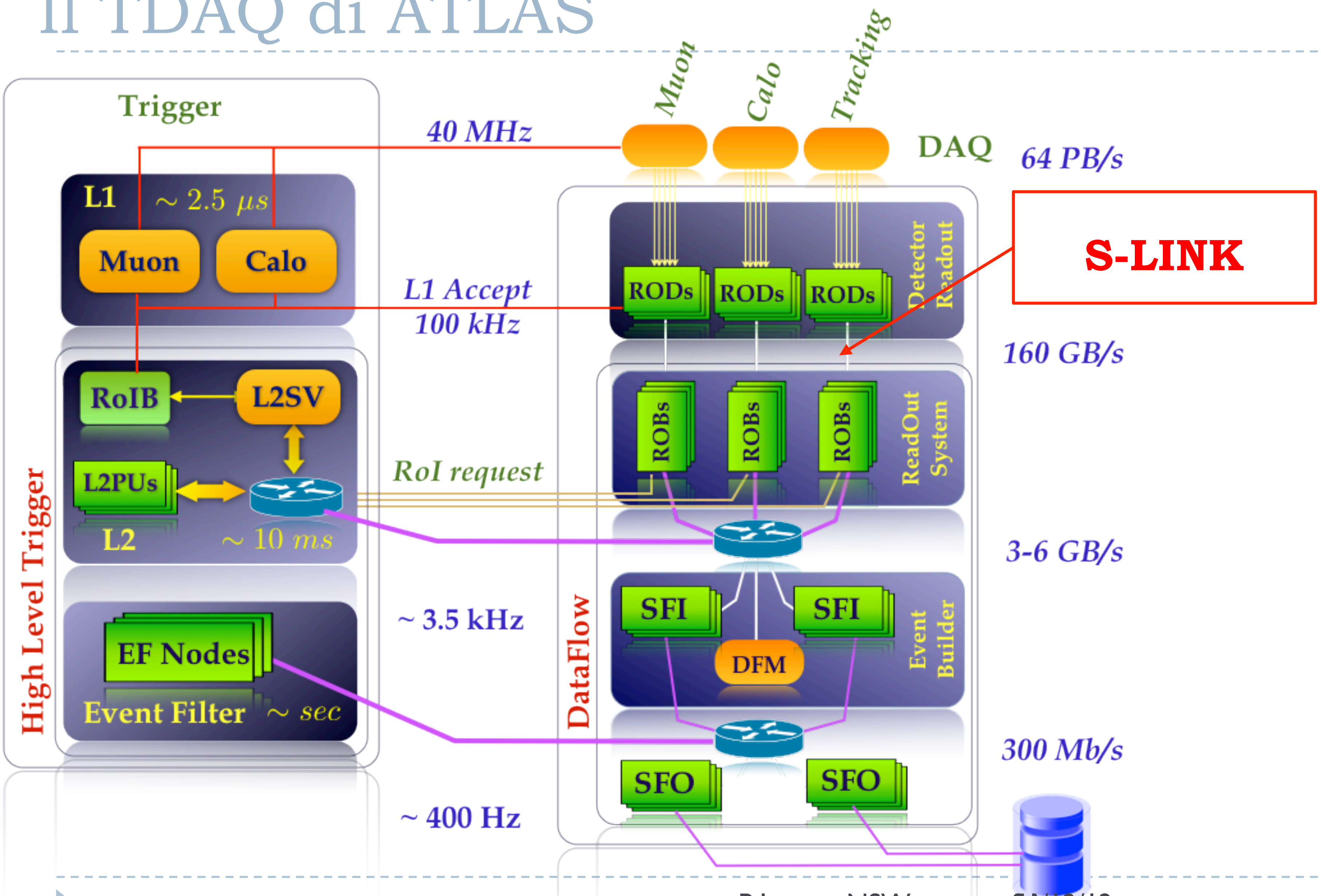
Integrazione delle Micromegas in ATLAS DAQ tramite link seriale ad alta velocità su FPGA

Domenico della Volpe, Raffaele Giordano, Sabrina Perrella e Vincenzo Izzo

Obiettivo del lavoro

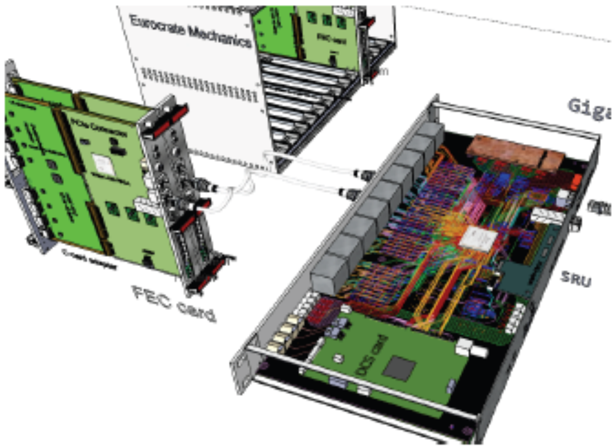
- **Permettere la lettura delle camere MicroMegas installate in ATLAS tramite il sistema di TDAQ esistente in esperimento**
- **Data l'obsolescenza di alcuni componenti usati in passato nel TDAQ di ATLAS, realizzare un progetto completamente integrato su dispositivi FPGA**
- **bassi costi di produzione e brevi tempi di sviluppo**
- **Caratterizzazione, test e integrazione in esperimento del sistema di trasmissione**
- **Caratterizzazione del sistema di trasmissione anche per utilizzi futuri in apparato (es. altri subdetector, maggiori data rates e throughput)**

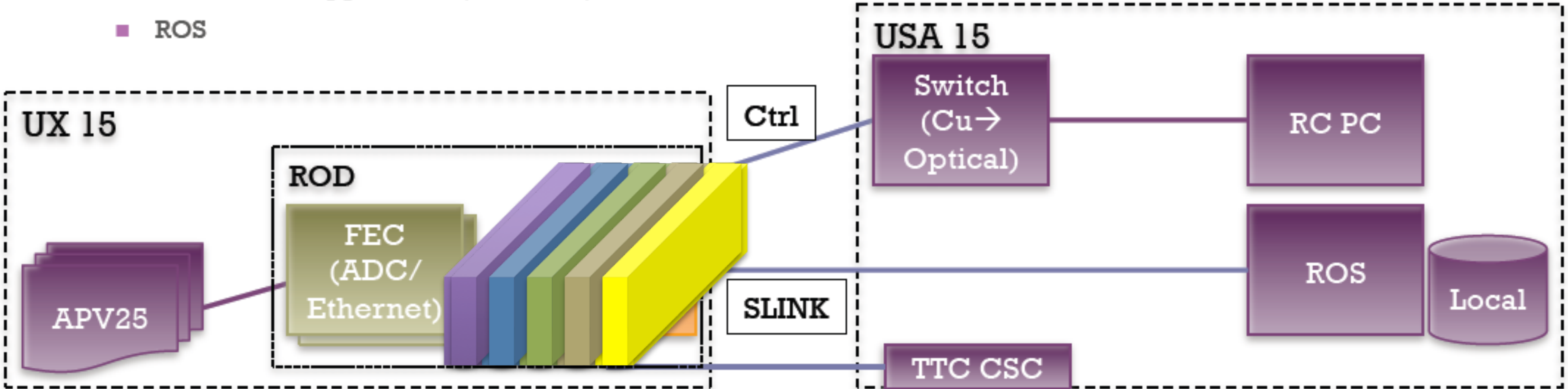
Il TDAQ di ATLAS



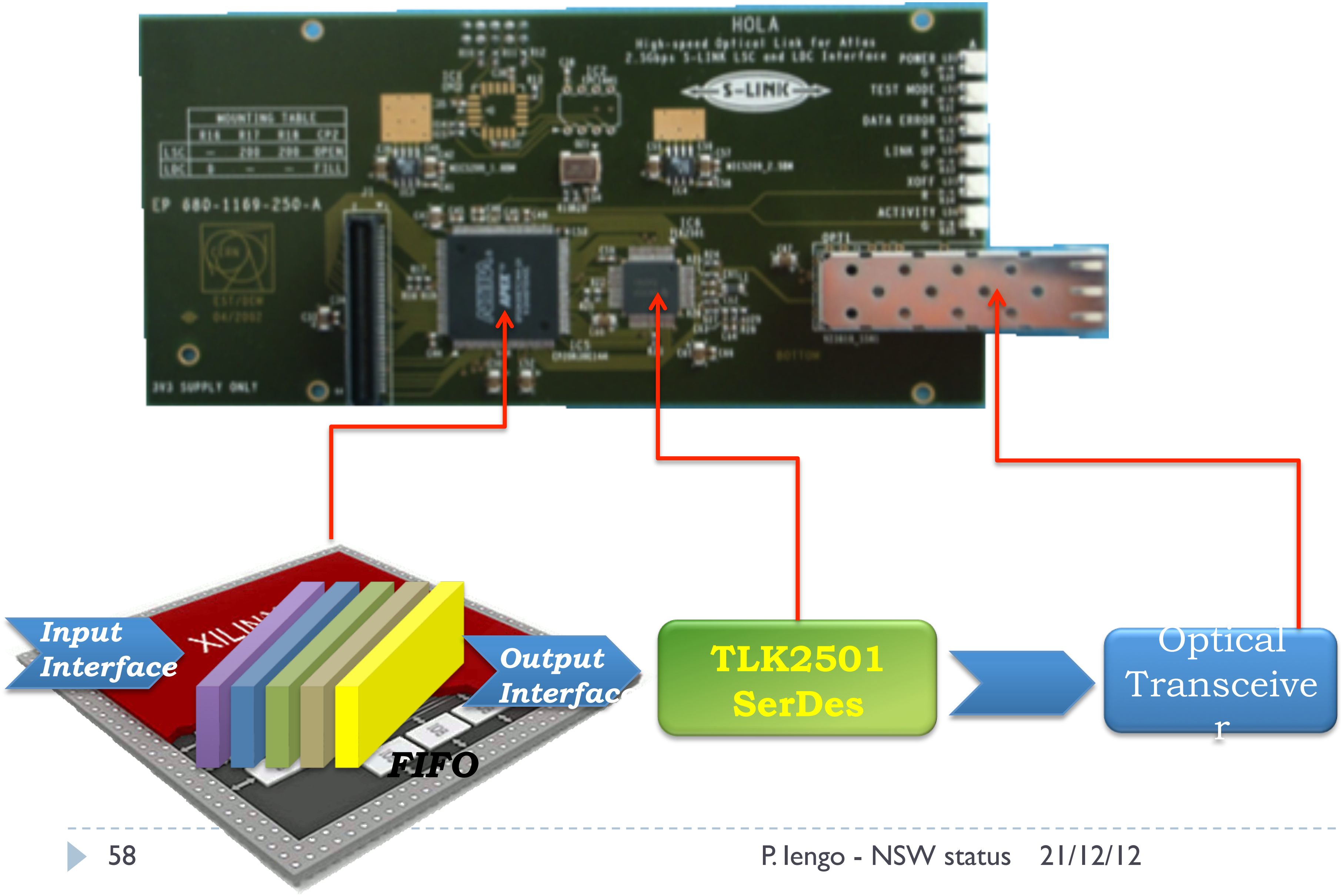
SRS-based readout

- Front end electronics:
  - APV25 chips (CMS tracker, no other choice)
  - HDMI cables (LV, data)
- ROD in UX15:
  - 2x SRS FEC – digitization, peak finding, zero suppression
  - DTC (one per FEC) link to SRU
  - SRU – EB, TTC, LV1, DCS , SLINK
- USA15
  - CSC TTC, DATA, DTC fibres
  - Run Control Application (on RC PC)
  - ROS

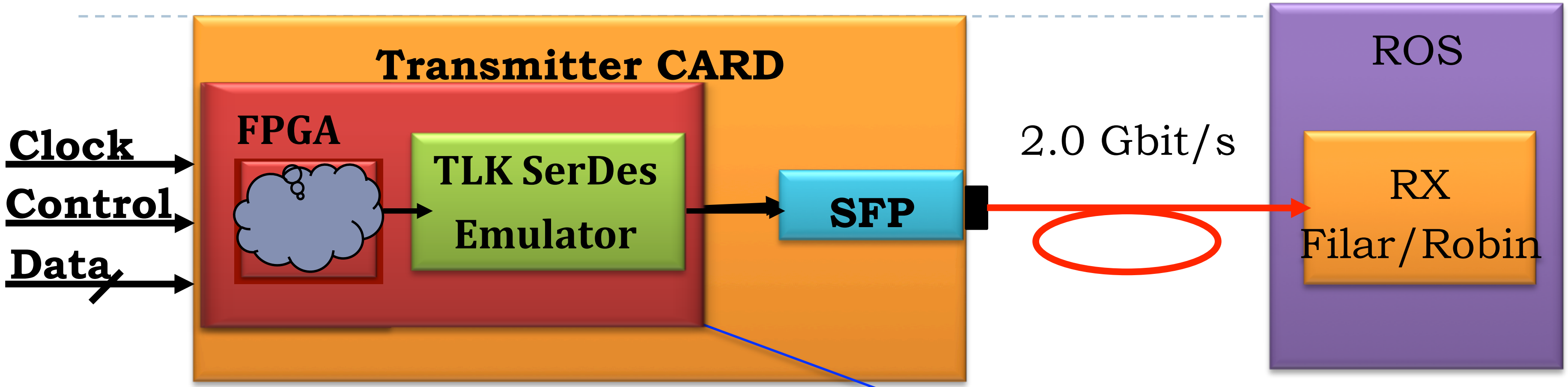




ATLAS S-LINK Transmitter

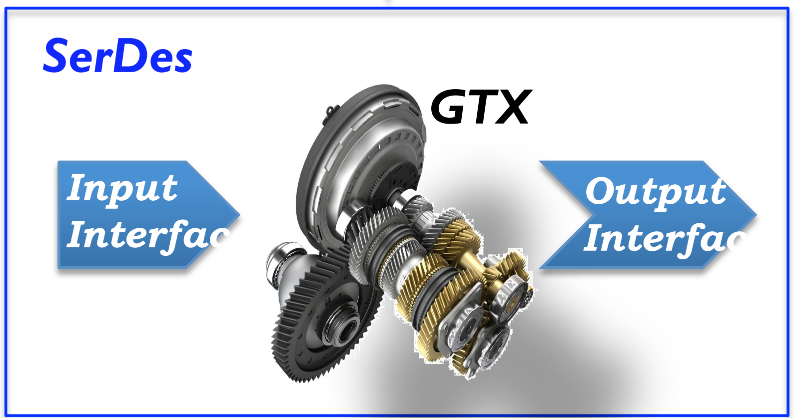


TLK2501 su FPGA



Il contributo originale di questo lavoro: progettare un **emulatore del TLK2501** su FPGA ultima generazione utilizzato sfruttando le potenzialità del **GTX**

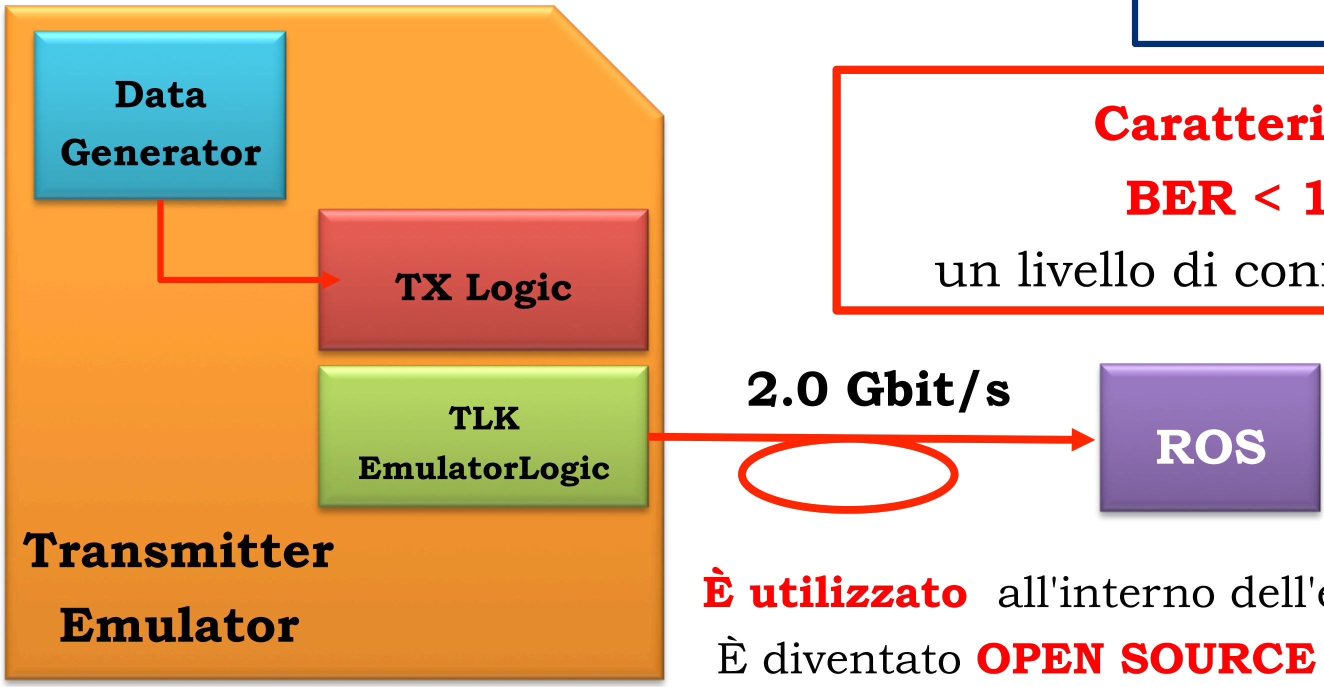
transceiver riprogrammabile
incorporato nell'ultima generazione di FPGA



Emulatore Trasmettitore

Test su PC (**ROS**) → **Funzionalità** **Compatibilità** col **DAQ**

Test
nei laboratori a Napoli
e al CERN
in **condizioni reali**



Caratterizzazione
BER < 10^{-12} con
un livello di confidenza del **95%**

È utilizzato all'interno dell'esperimento
È diventato **OPEN SOURCE** ed è **rilasciato** dal **CERN**
Disponibile su un **repository** pubblico del CERN

Miglioramento e Caratterizzazione

- **Richiesta** del gruppo del CERN per lo sviluppo dei link
  Miglioramento del protocollo (**Aumento** del **throughput**)

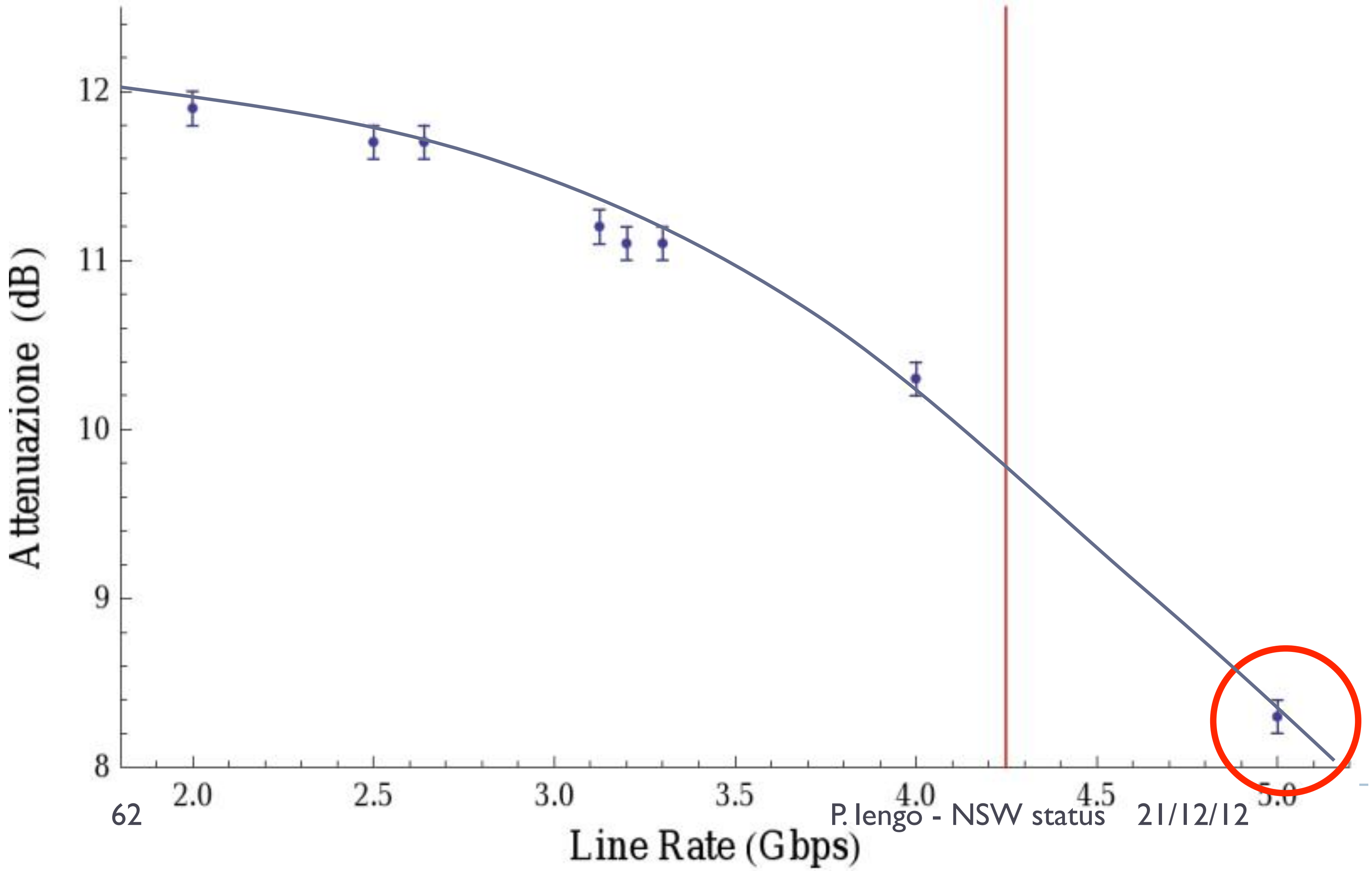
- **Necessità** di realizzare anche la scheda **ricevitore**

Progettazione → **Integrazione** del firmware dell'emulatore del TLK2501 con il firmware del receiver
Implementazione Generatore e Controllo dati

Verifica → Nuovi moduli ottici

2 schede di valutazione

Caratterizzazione di S-LINK



Conclusioni…

- Il progetto è stato qualificato in base alle attuali specifiche di S-LINK (line rate = 2.0 Gbps) con un BER < 10^{-12}
- È diventato un oggetto proprietario del CERN e è open source

…inoltre…

- Il protocollo è stato migliorato per raggiungere un throughput più elevato
- Il protocollo risulta funzionare fino a 4Gbps (5Gbps!)

…e sviluppi futuri

- Caratterizzare limiti intrinseci del protocollo
- Protocollo GTX-GTX

Additional material