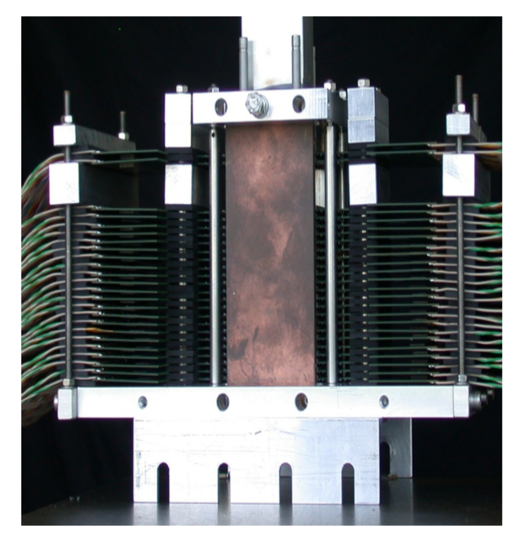

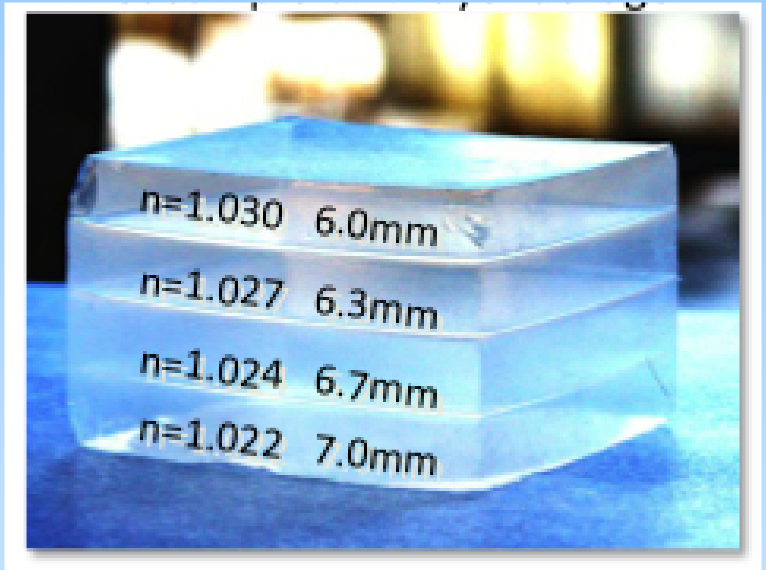

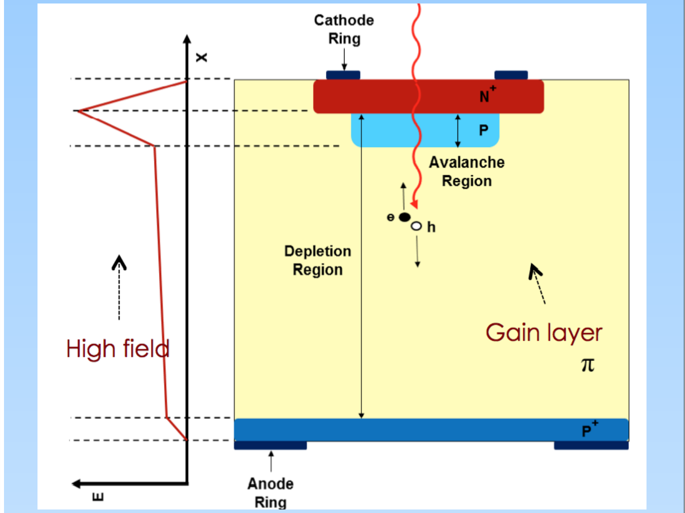

New detectors

Silvia Masciocchi
GSI Darmstadt and University of Heidelberg

39th Heidelberg Physics Graduate Days, HGSFP
Heidelberg
October 13, 2017

Detectors in development

- Silicon calorimeters
- Aerogel RICH
- Ultra fast silicon detectors (UFSD) for 4D tracking

Look for recent conferences on instrumentation:
INSTR-17: https://indico.inp.nsk.su/event/8/overview

Silicon calorimeters

- Goal: measure with high precision electrons and photons at very high rapidities in collider experiments→ need for extremely high angular resolution to separate individual showers
- Need compact, highly segmented and fast calorimeters with imaging capabilities
- Not based on proportionality of deposited energy, but on counting the number of showering particles

Silicon detectors (strips or pixels plus pads) coupled to an absorber:

Few tens of layers (20-30) + segmentation to few squared millimeters

This also shows very good radiation hardness

Example project: FOCAL in ALICE (under study)

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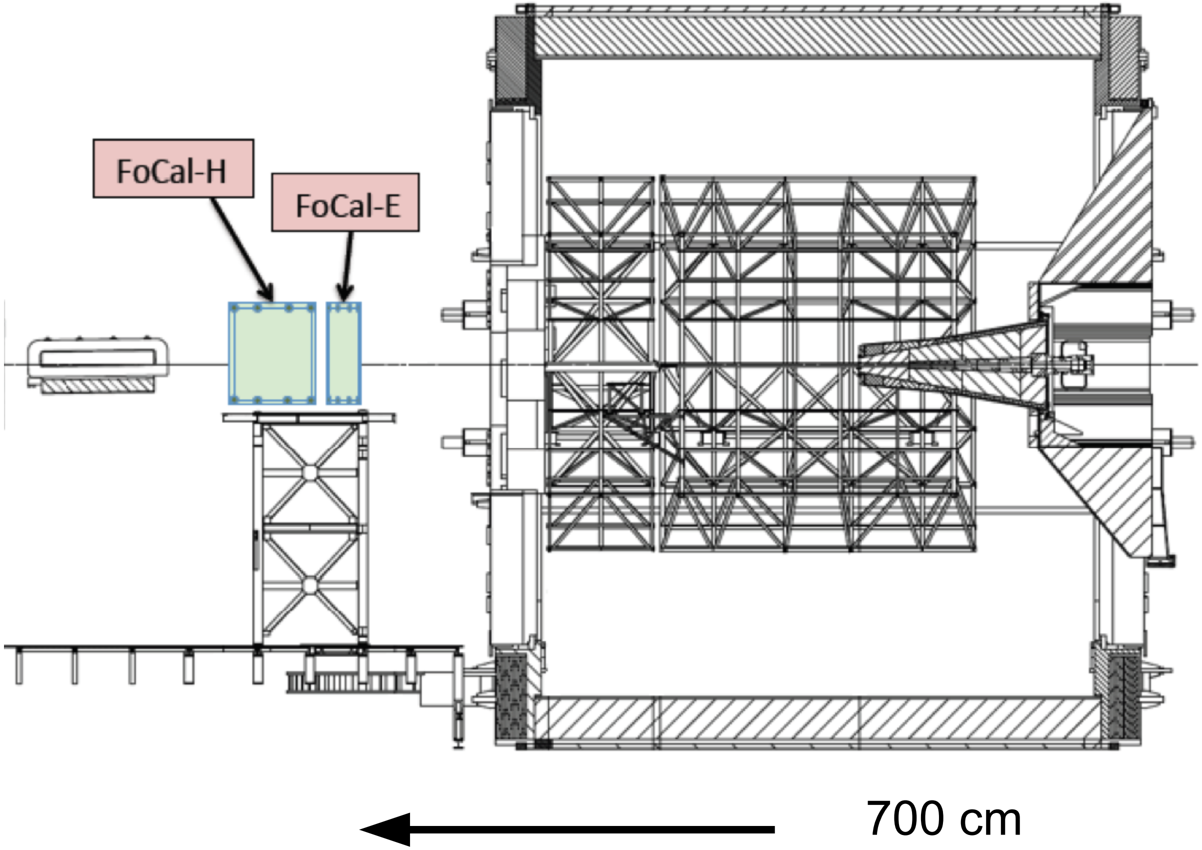
Silicon calorimeters



700 cm

Goal: separate close-lying electromagnetic showers and reconstruct their direction with high accuracy

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Silicon calorimeters

- High lateral segmentation to discriminate between the large number of particles incident on the detector, specifically distinguish direct photons from those coming from π^0 decays
- Absorber material: tungsten: Moliere radius 10 mm

  radiation length 3.5 mm

  20 layers, about 1 X_0 each
- Sensor material: silicon

  Alternate layers with fine segmentation to others with rougher segmentation to limit costs and the volume of data collected
- High granularity: CMOS MAPS (30 µm x 30 µm)

  Low granularity: pad sensors

Silicon calorimeters

Thesis
M. Reicher

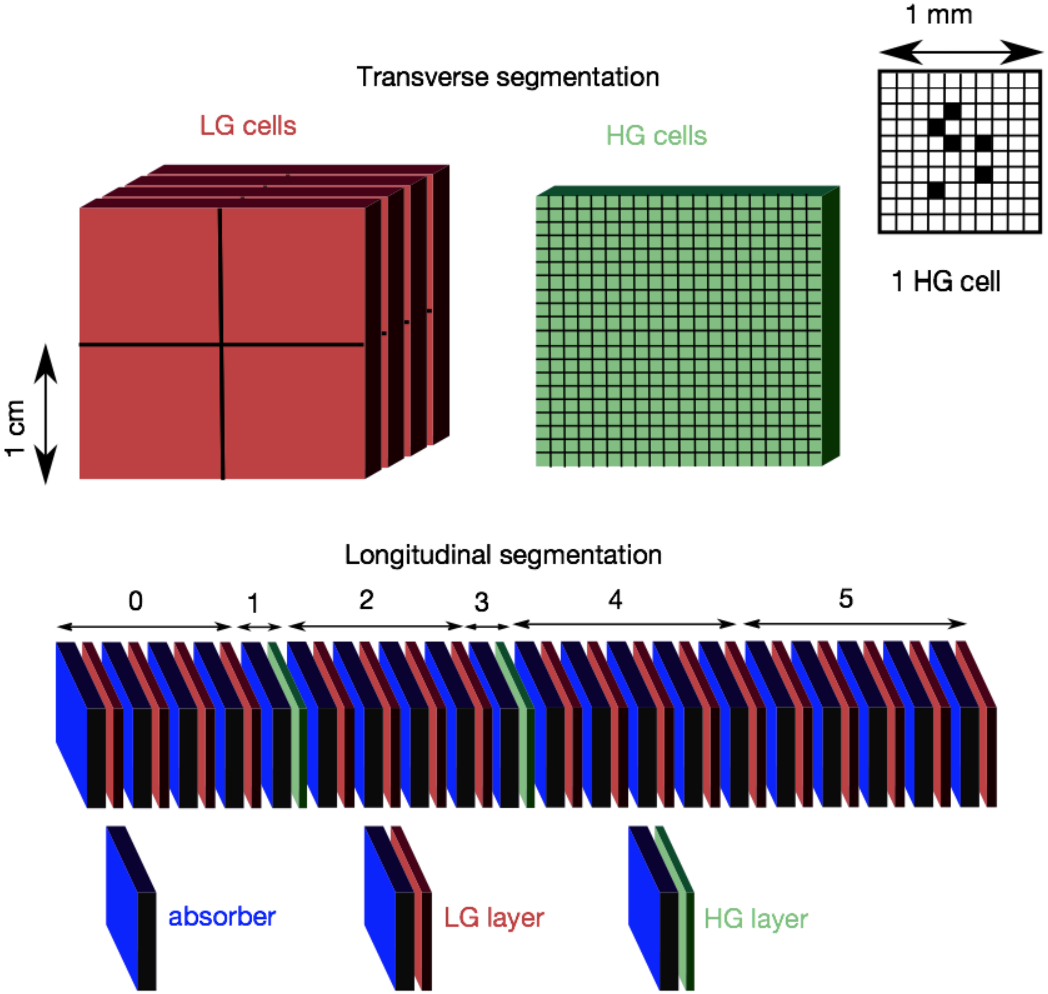
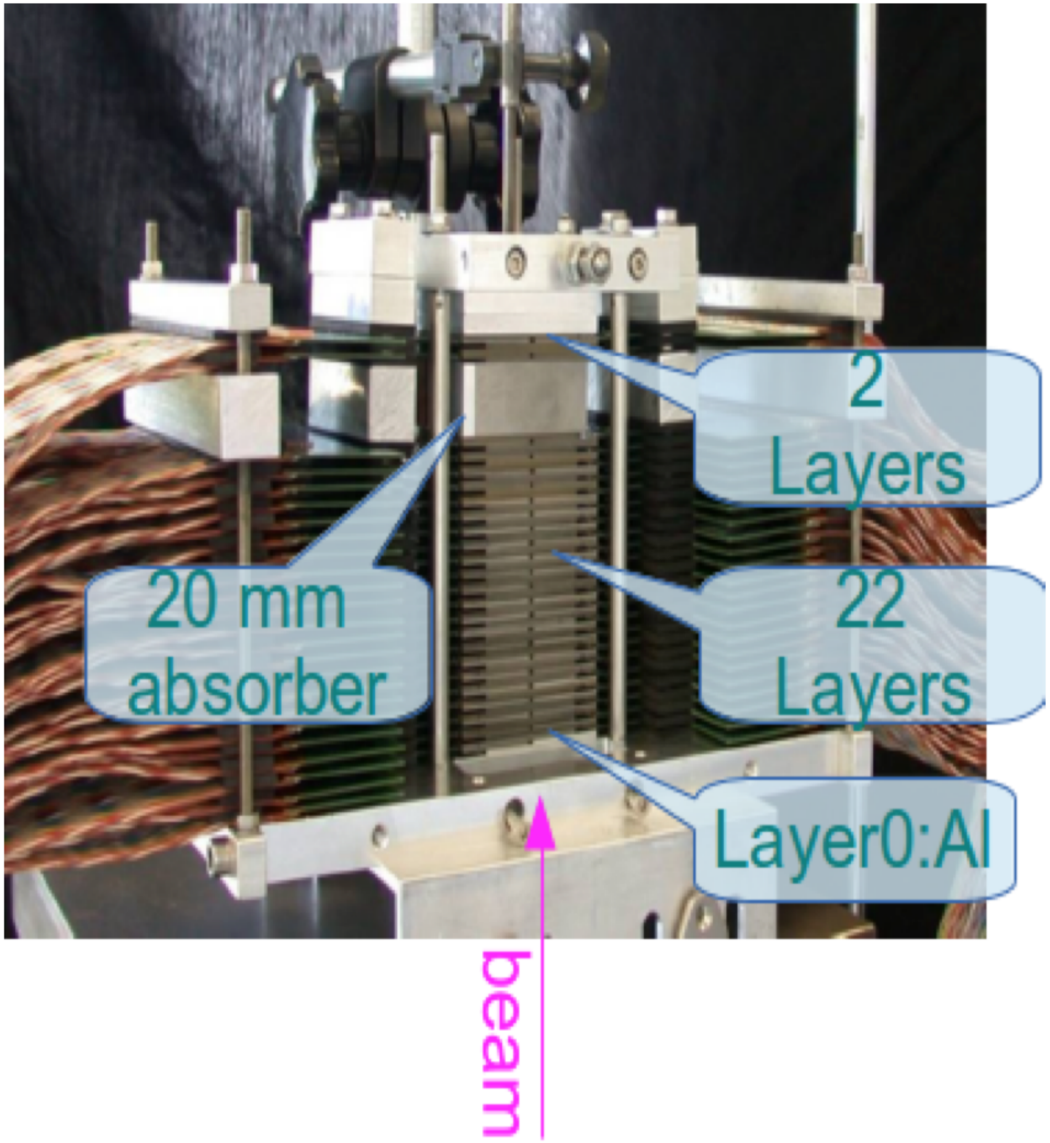


Figure 2.13: The concept for the FoCal detector. (below) Absorbers (blue) will be approximately 1 X_0 of depth, with low granularity (red) and high granularity (green) sensor layers inserted between them. Independent readout units are indicated by numbers, with the low granularity layers being summed 4 to 5 layers deep, and the high granularity layers being read out independently. (above) Illustration of the difference in granularity of the low and high granularity cells.

Silicon calorimeters

Stack of W and Si layers



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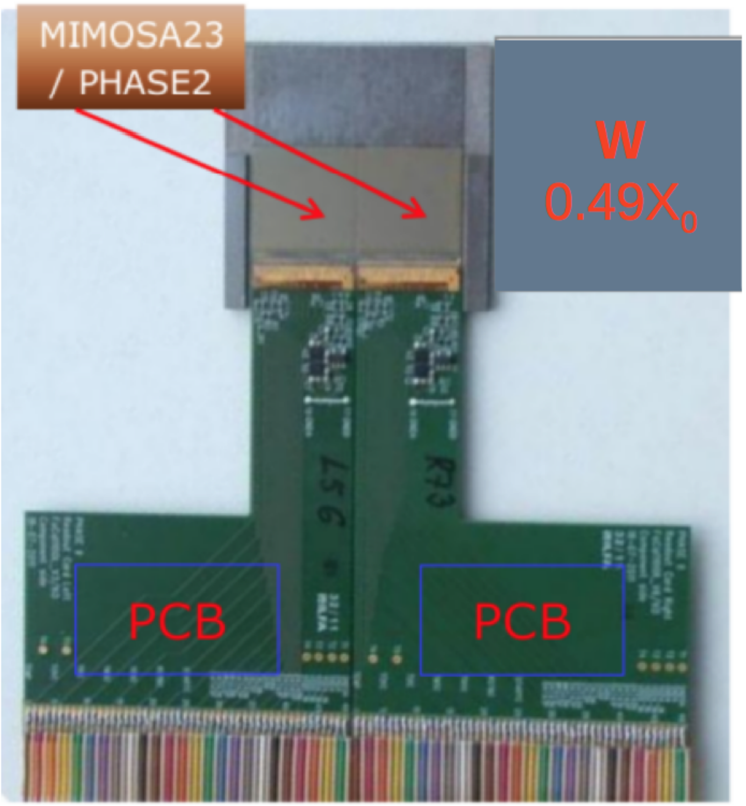
Silicon calorimeters

CMOS silicon sensor

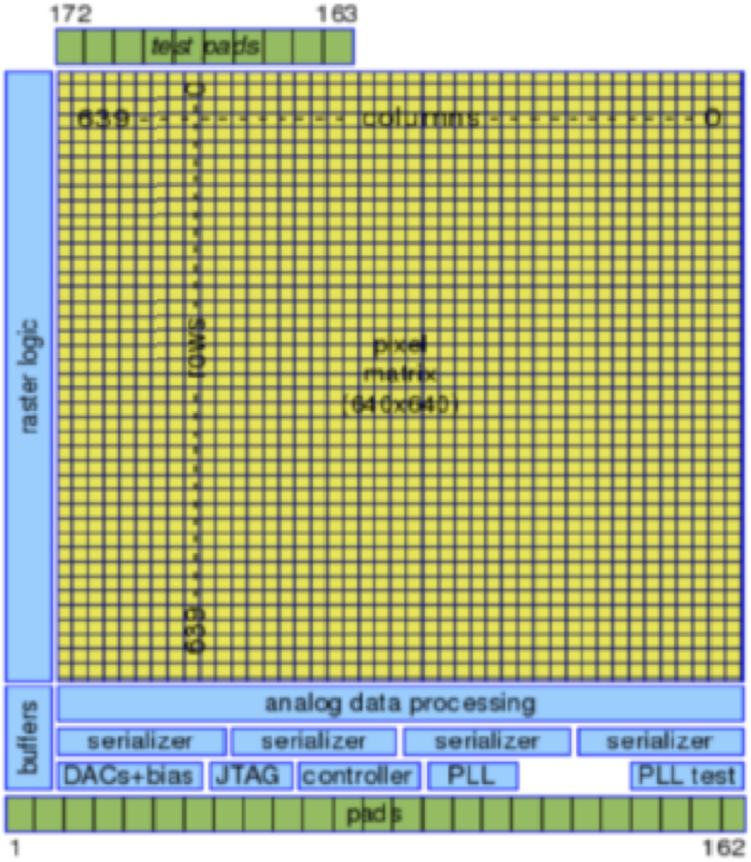
PHASE2 MIMOSA 23 [3]

- 640×640 pixels
- Pitch: 30μm
- Rolling shutter
- 640μs/frame

Single half layer($0.49X_0$)



Sensor schematics



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Silicon calorimeters

Number of hit pixels proportional to energy of incoming particle

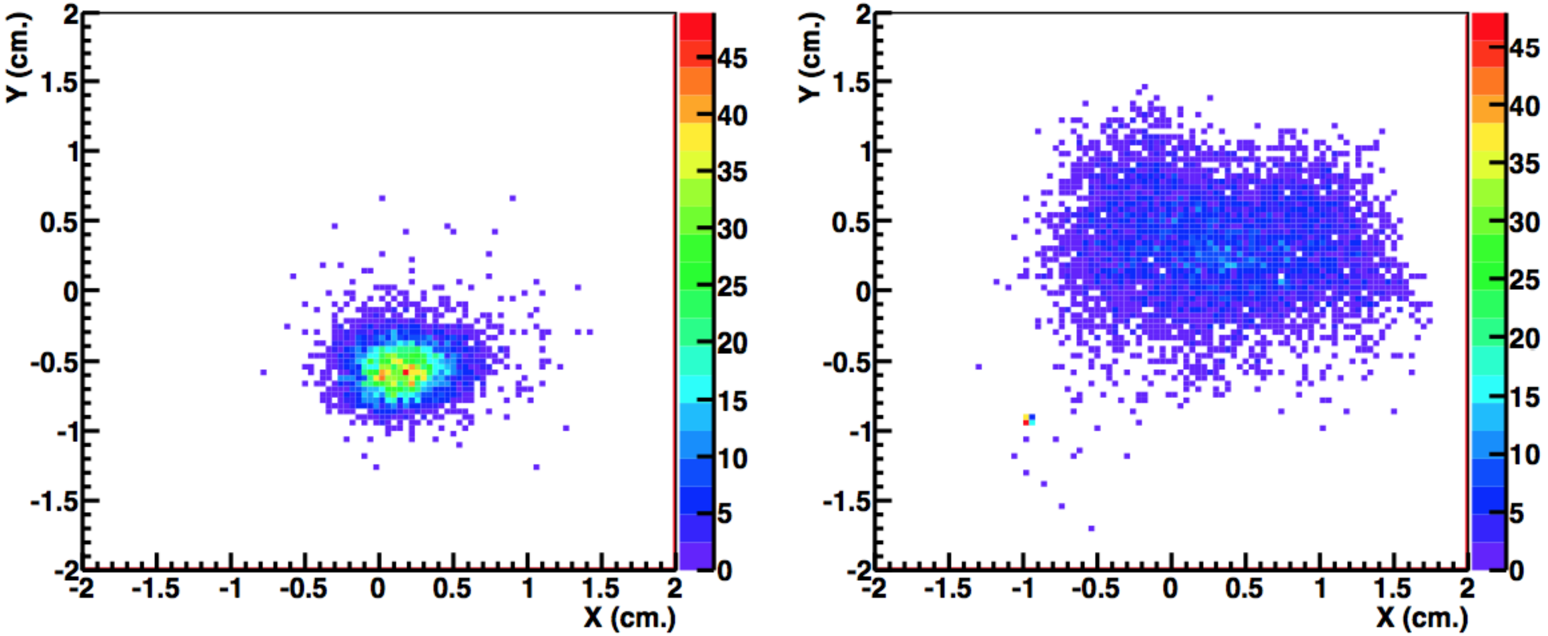

Figure 5.8: The distribution of the location of tracks (left) and the location of showers (right), a splitting of the beam into 2 types of interactions can be seen at data obtained at SPS at 100 GeV/c.

Silicon calorimeters

Number of hit pixels proportional to energy of incoming particle

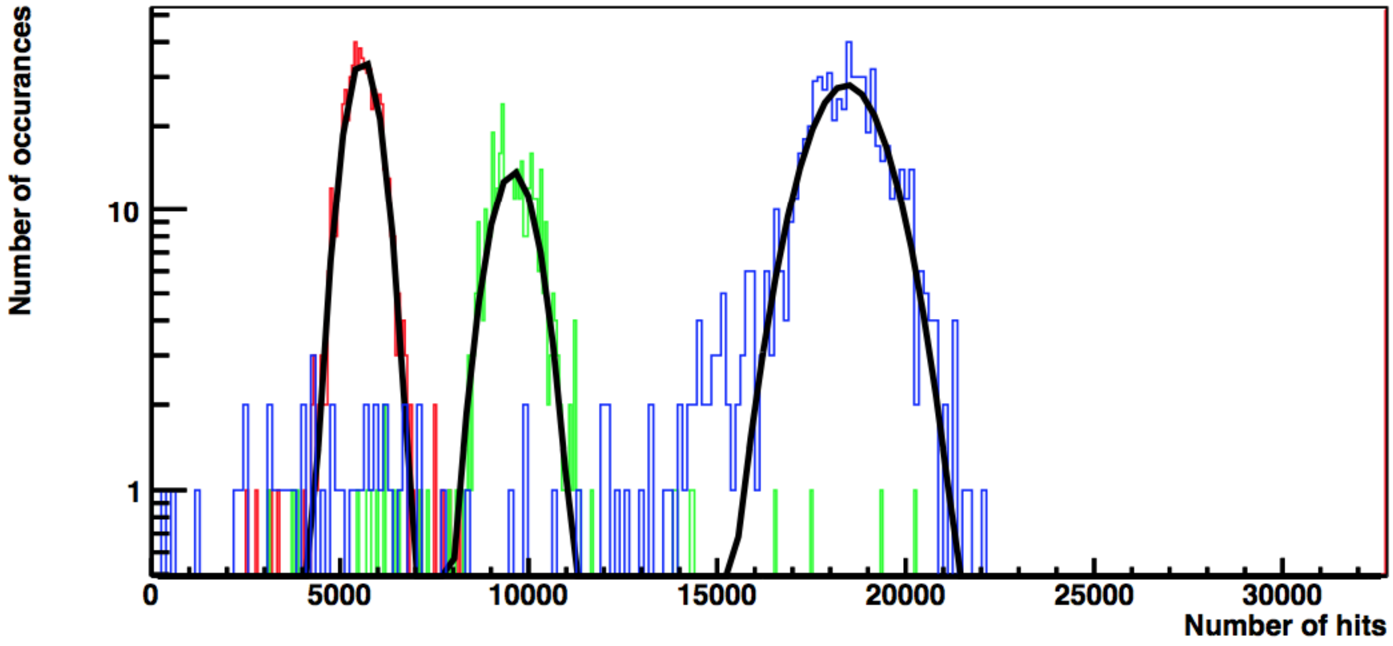

Figure 5.9: Distribution of hit pixels for e^+ at 30 GeV/c (red), 50 GeV/c (green) and 100 GeV/c (blue), as measured at SPS as in figure 5.7. In addition cuts on the shower position based on the results of the analysis of figure 5.8 are applied.

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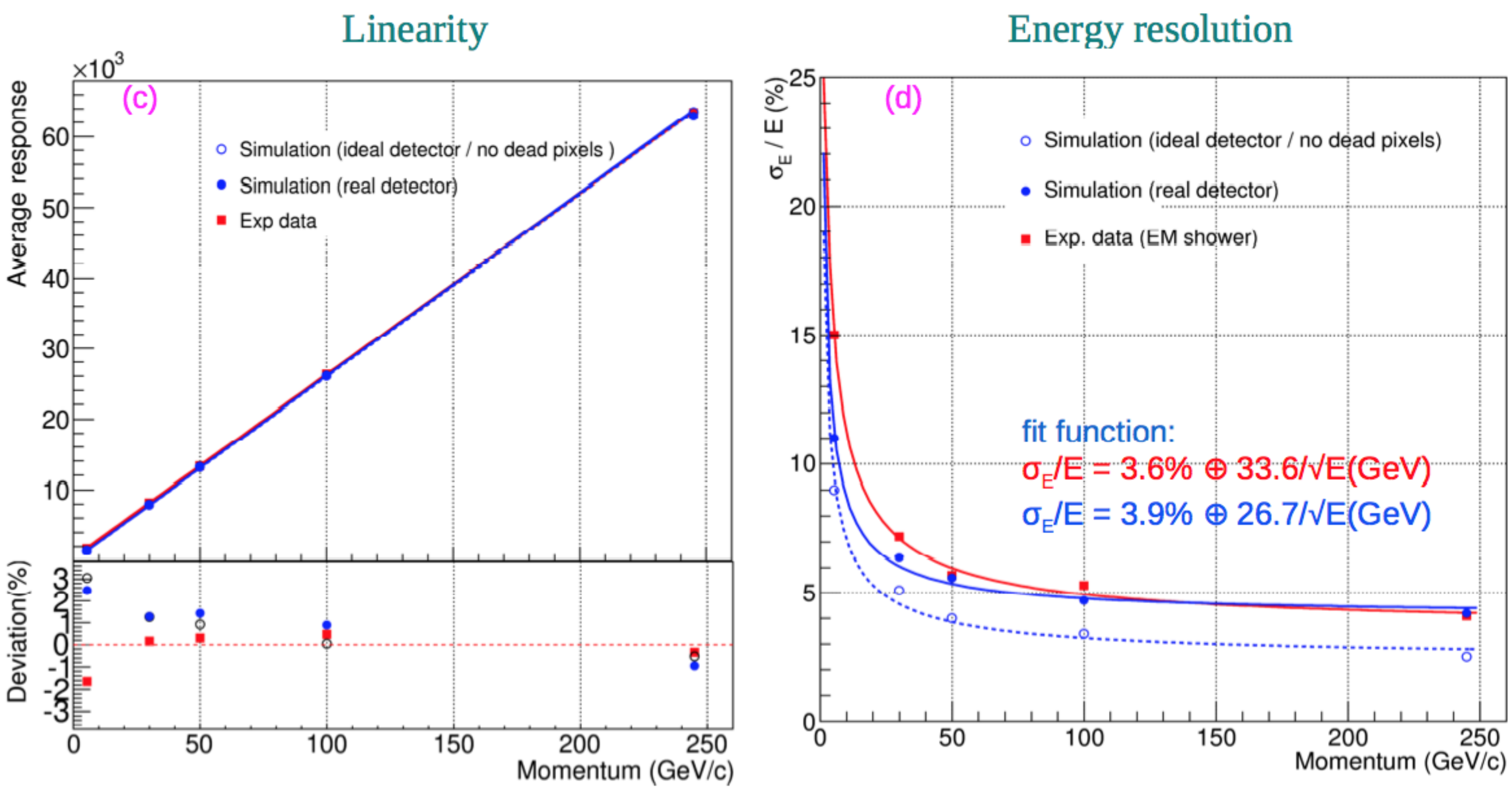
Silicon calorimeters

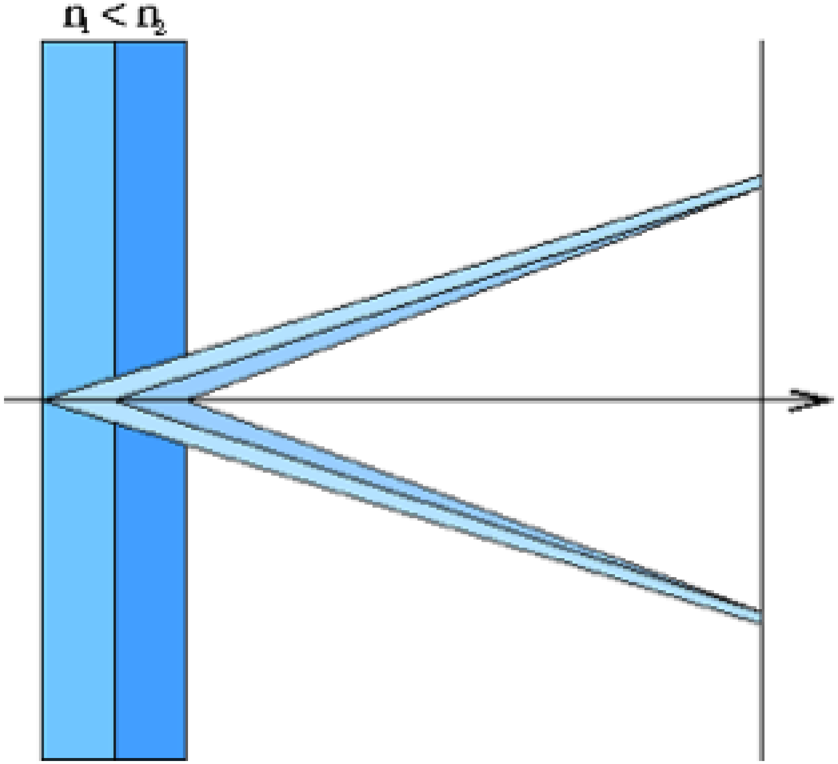
Results: linearity and energy resolution

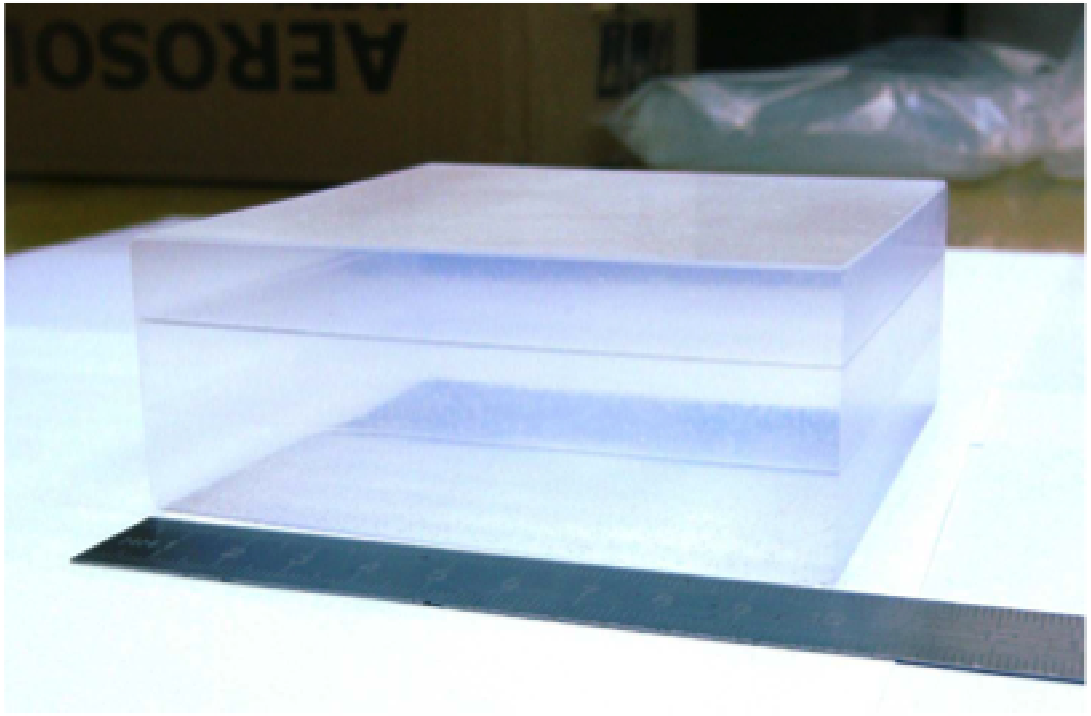


QM2015 poster by Chunhui Zhang

Aerogel RICH detectors

- Use aerogel for radiators (n=1.035 – 1.06) to allow π/K discrimination at “higher” momenta (4-10 GeV/c)
- Focusing aerogel RICH: improves proximity-focusing design by reducing the contribution of radiator thickness to the Cherenkov angle resolution





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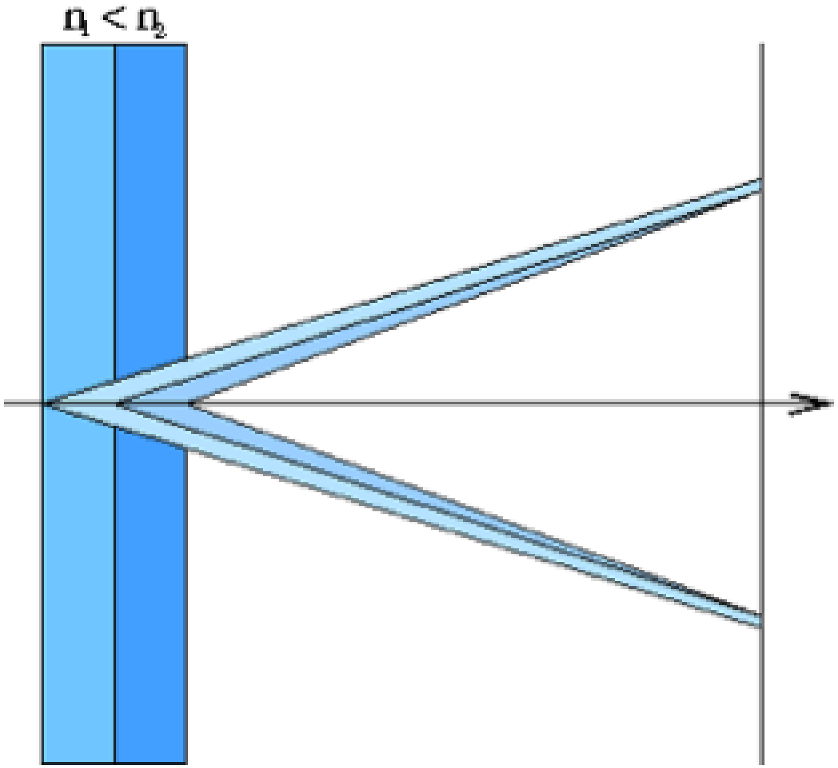
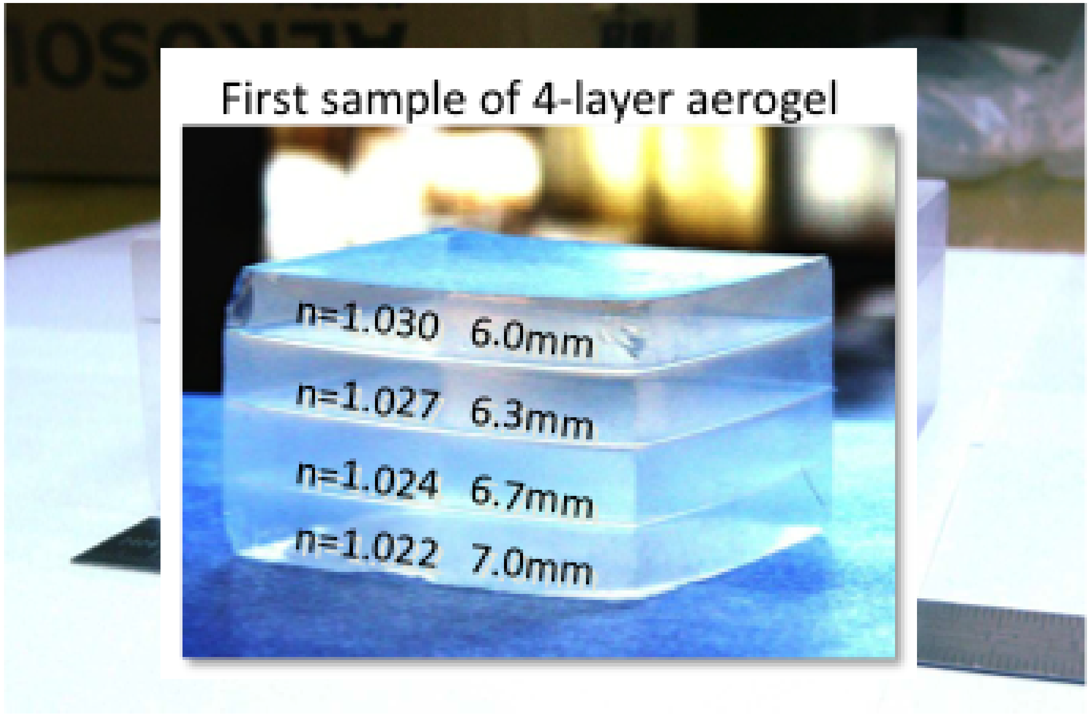
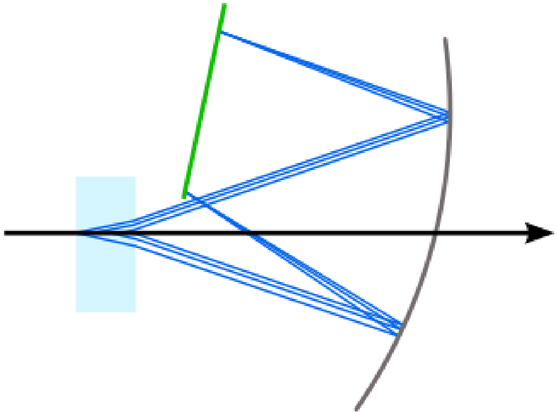


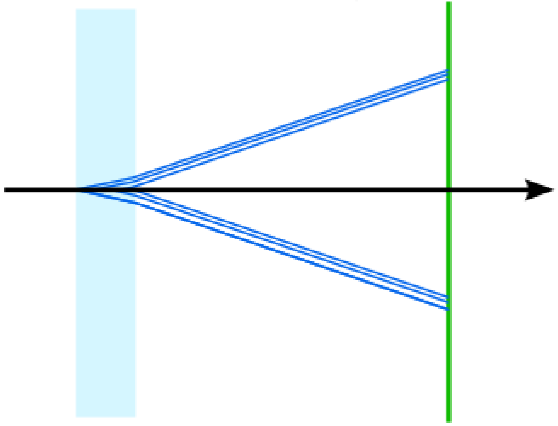

First sample of 4-layer aerogel

Aerogel RICH detectors

- Focusing

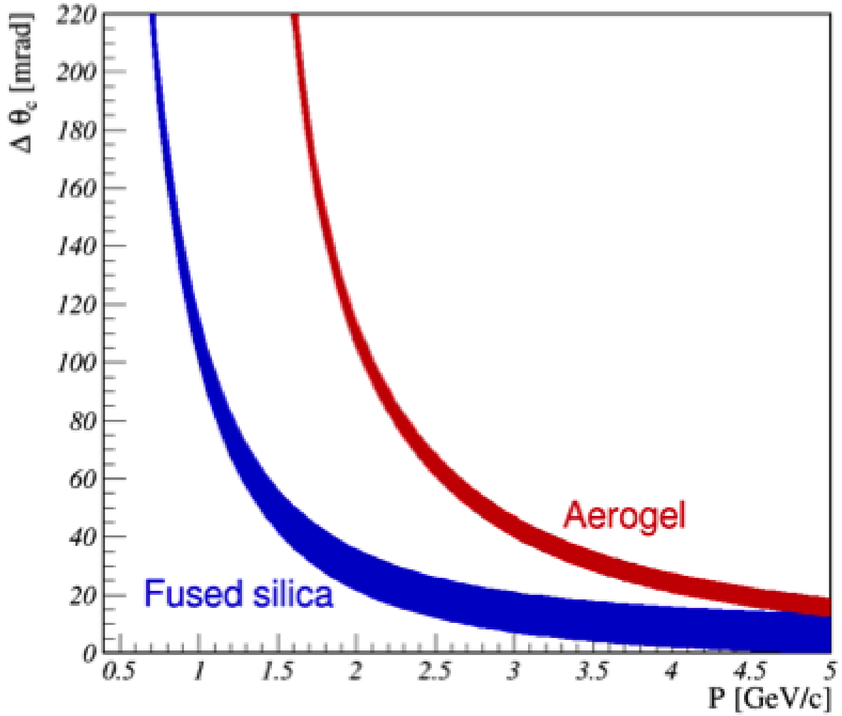


- Proximity focusing



Aerogel RICH detectors

- Aerogel layers allow compact RICH designs
- Provide a much larger difference between the Cherenkov angles for different particles. Here shown for pions and kaons



- Photon detection with powerful SiPM (single-photon sensitive device based on Avalanche PhotoDiodes, APDs – analog)
  or DPC (Digital Photon Counter - digital)

Other compact RICH detectors

- Radiator = gas under pressure
- Example: pressurized C4F8 (1 m long) plus GEM stack structure to detector photons

  Pressure: 3.5-4 atm
  - Clear π, K, p separation up to 32 GeV/c obtained with a prototype in a test beam

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Ultra fast silicon detectors for 4D tracking

- Development lead by RD50 and several Italian groups (N. Cartiglia, V. Sola et al.)

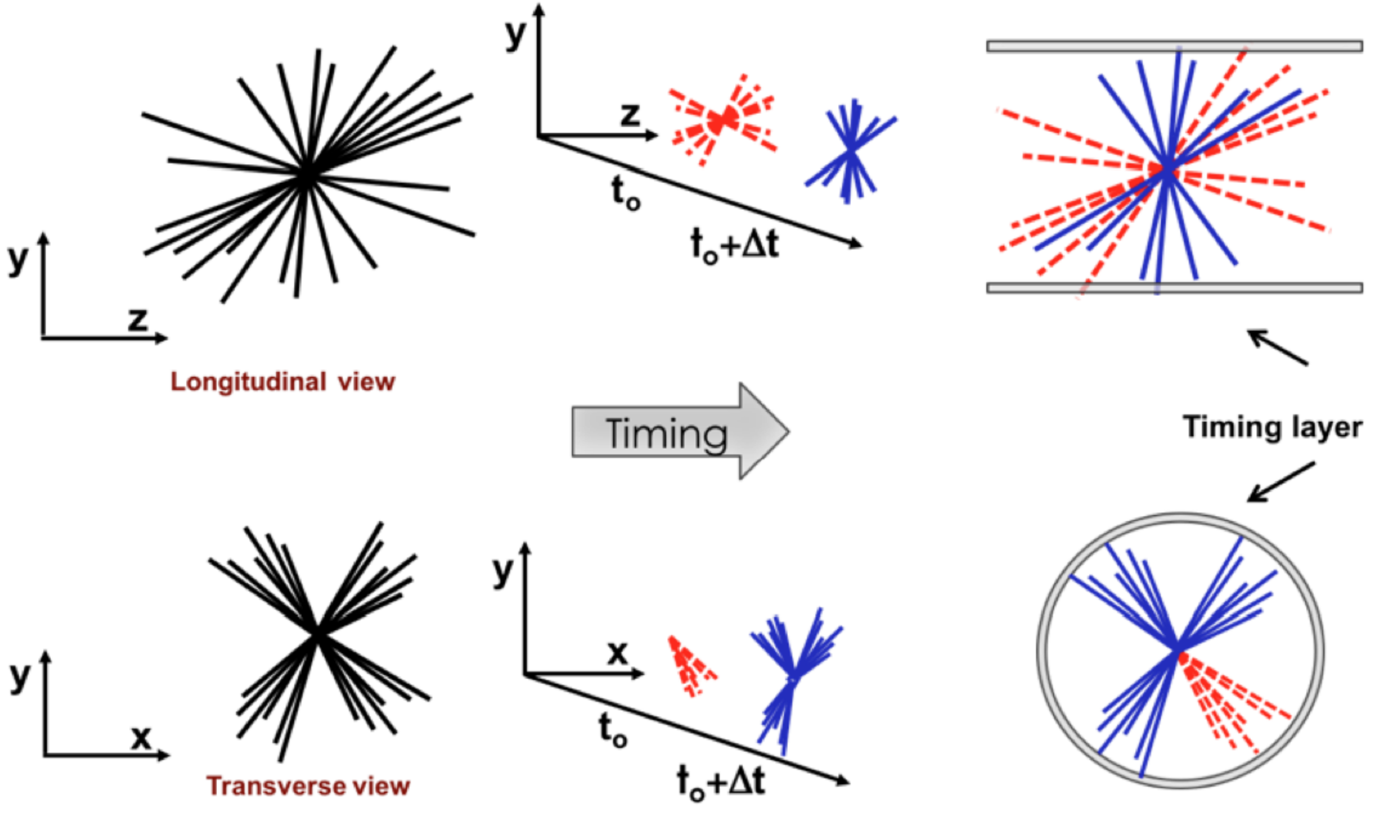
- 4D tracking: to cope with
  - Extremely high interaction rates and pile-up

    High-Luminosity LHC: 150-200 collisions per bunch crossing
  - High rate interactions in fixed target mode → no bunch crossing information (CBM, PANDA at FAIR)

- Goal: 4D event reconstruction with a spatial resolution of 20-50 µm and time resolution of 10-20 ps

TIMING IN THE EVENT RECONSTRUCTION

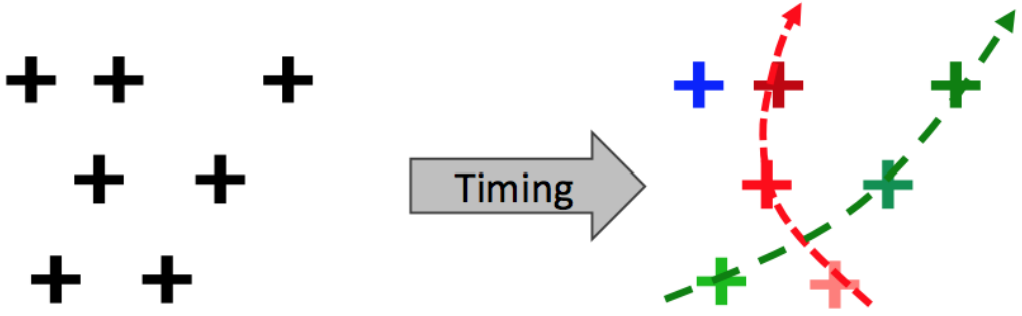
- ✏ Timing allows distinguishing overlapping events by means of an extra dimension



Material from V. Sola
IPRD16 Siena

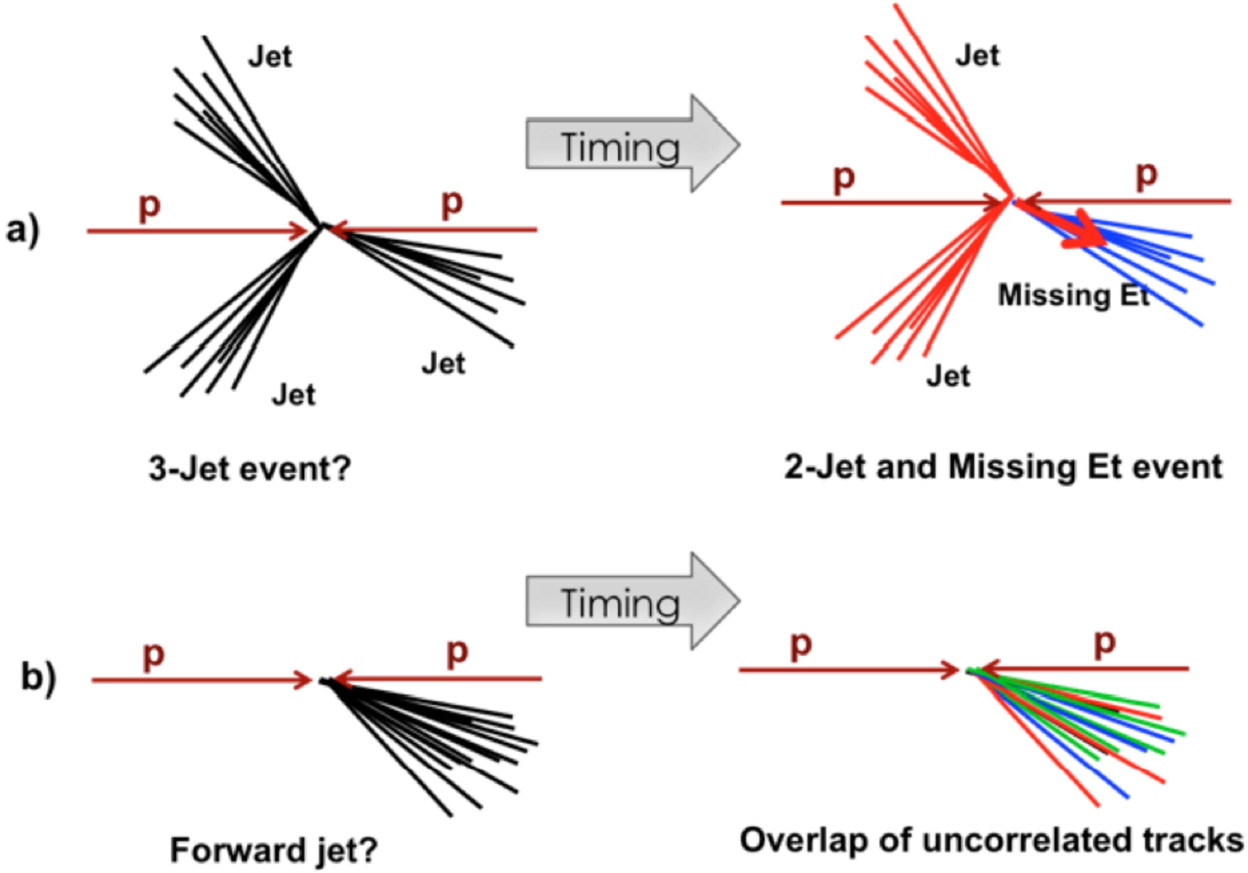
TIMING AT EACH POINT ALONG THE TRACK

- Massive simplification of pattern recognition, new tracking algorithms will be faster even in very dense environments
- Use only *time compatible points*

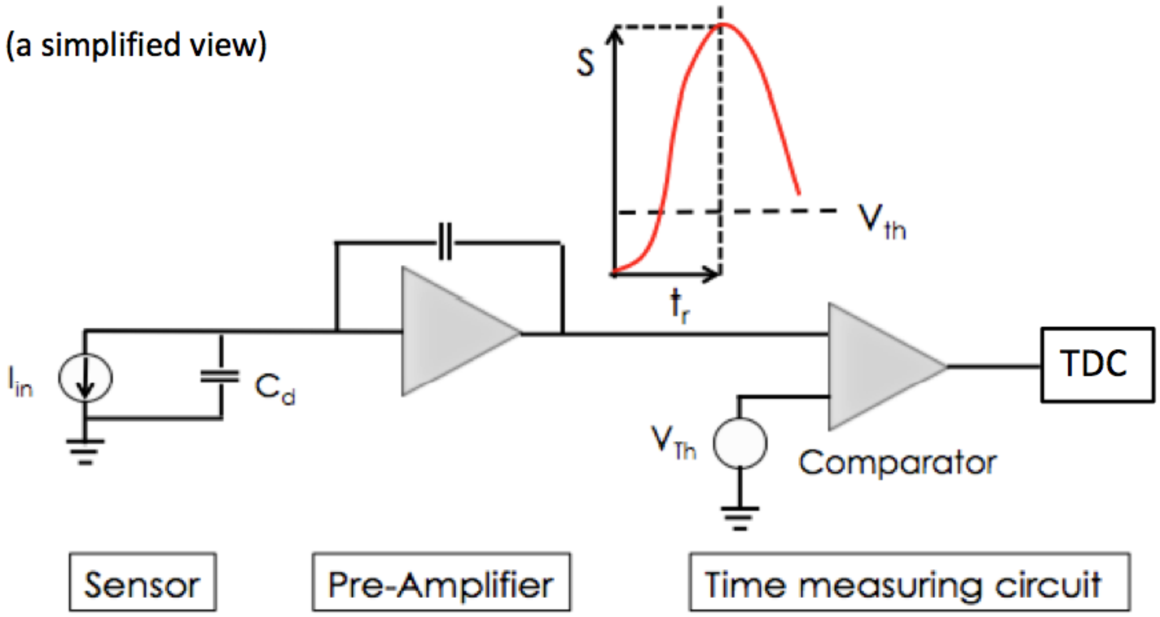


TIMING AT THE TRIGGER LEVEL

- ✏ Timing at the trigger decision allows reducing the trigger rate rejecting topologies that look similar



A TIME-TAGGING DETECTOR

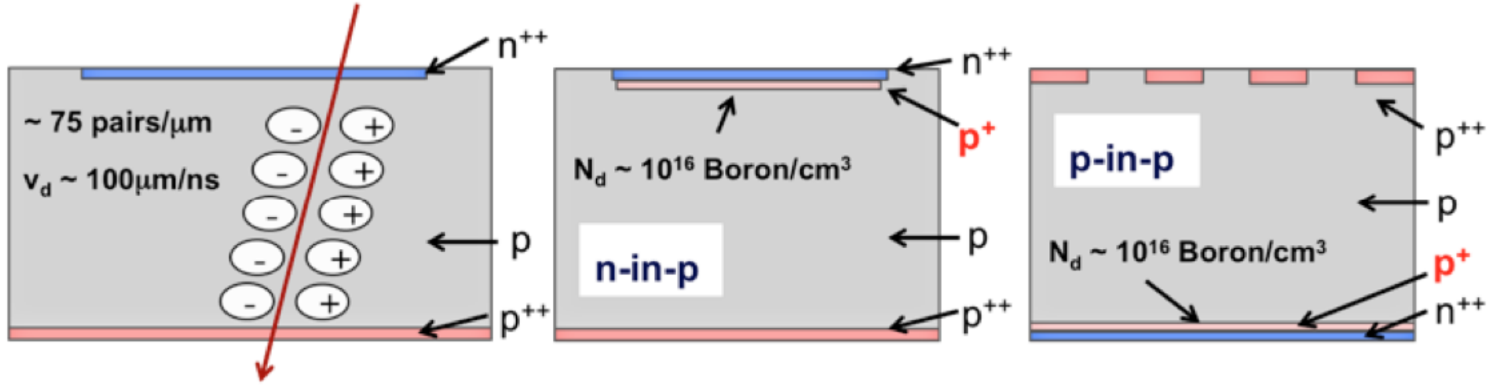


Time is set when the signal crosses the comparator threshold

The timing capabilities are determined by the characteristics of the signal at the output of the pre-Amplifier and by the TDC binning

▻ **Strong interplay between sensor and electronics**

UFSD: Low Gain Avalanche Diodes



Traditional Silicon Detector **Ultra-Fast Silicon Detector**

Adding a highly doped, thin layer of p-implant near the p-n junction creates a high electric field that accelerates the electrons enough to start multiplication (same principle of APD but with much lower gain)

- Gain changes very smoothly with bias voltage
- Easy to set the optimal value of gain

Aim at something like a pixel detector, but with a much larger signal

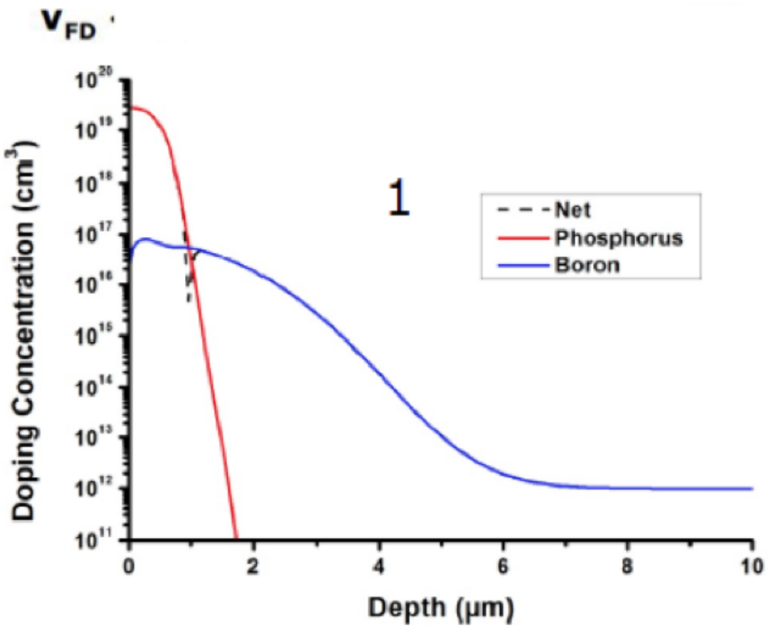
UFSD: Low Gain Avalanche Diodes

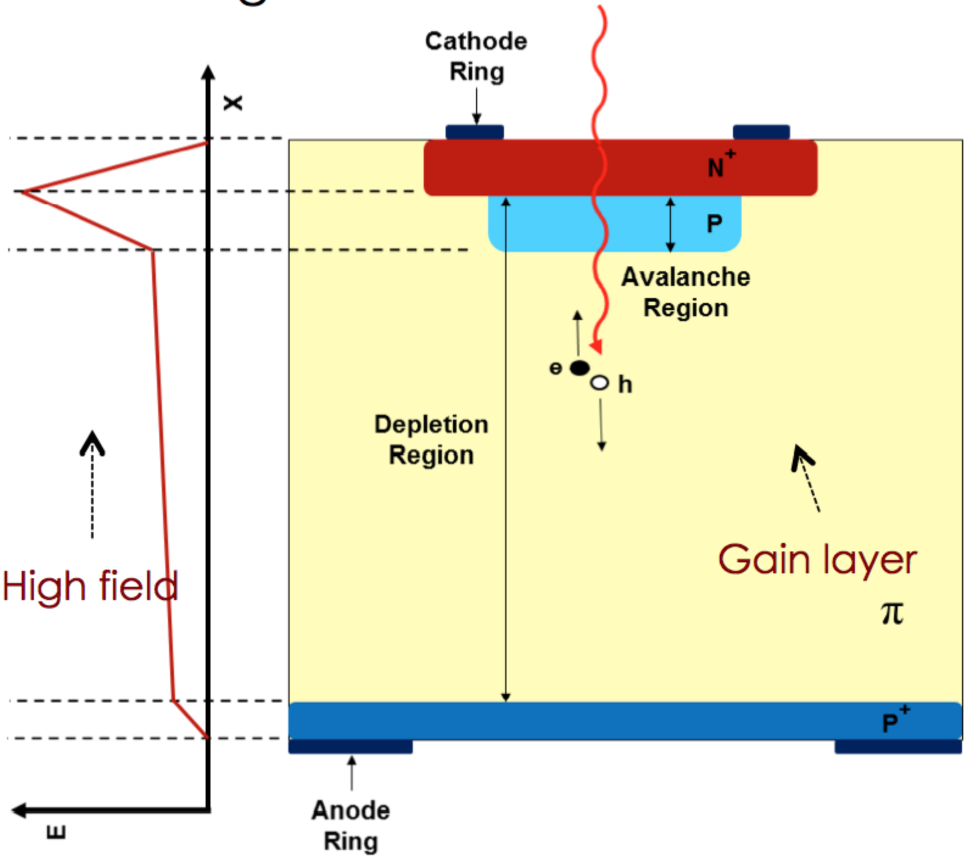
The LGAD sensors, as proposed and manufactured by CNM

(National Center for Micro-electronics, Barcelona):

High field obtained by adding an extra doping layer

E ~ 300 kV/cm, closed to breakdown voltage





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UFSD

Ingredients to achieve the very fast timing and high timing resolution:

- Keep the gain around 10-20
- Use thin detectors (50 µm) to:
  - Minimize event-by-event variation of the charge produced by ionization
  - Minimize the rise time of the signal
- Use parallel plate geometry (strip implant ~ strip pitch ≫ thickness) to keep drift velocity as uniform as possible
- Reduce at minimum the shot noise → low gain, cool the detector, use small pads to limit the leakage current

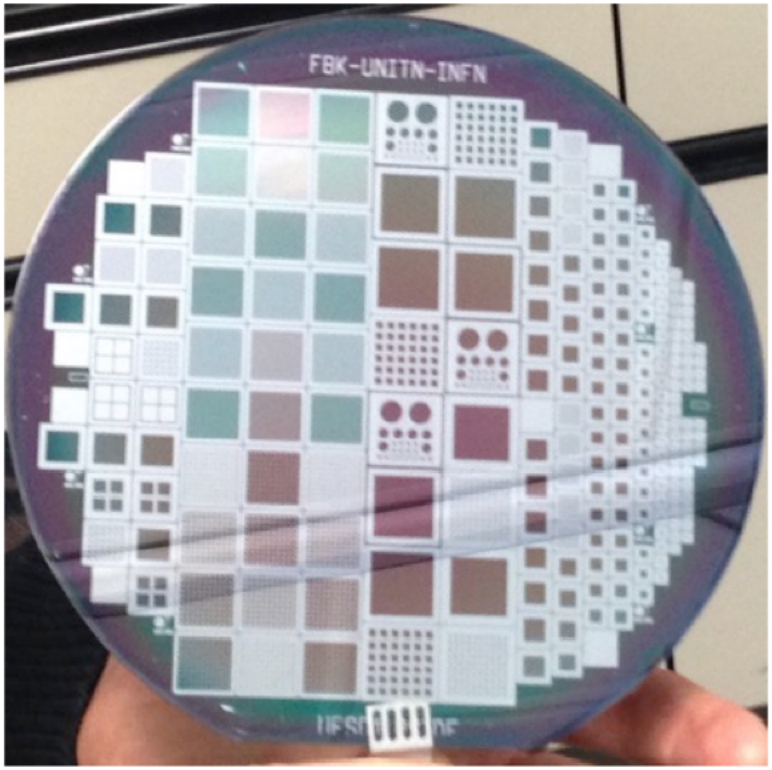
UFSD - Sensors

SENSORS - FBK & CNM

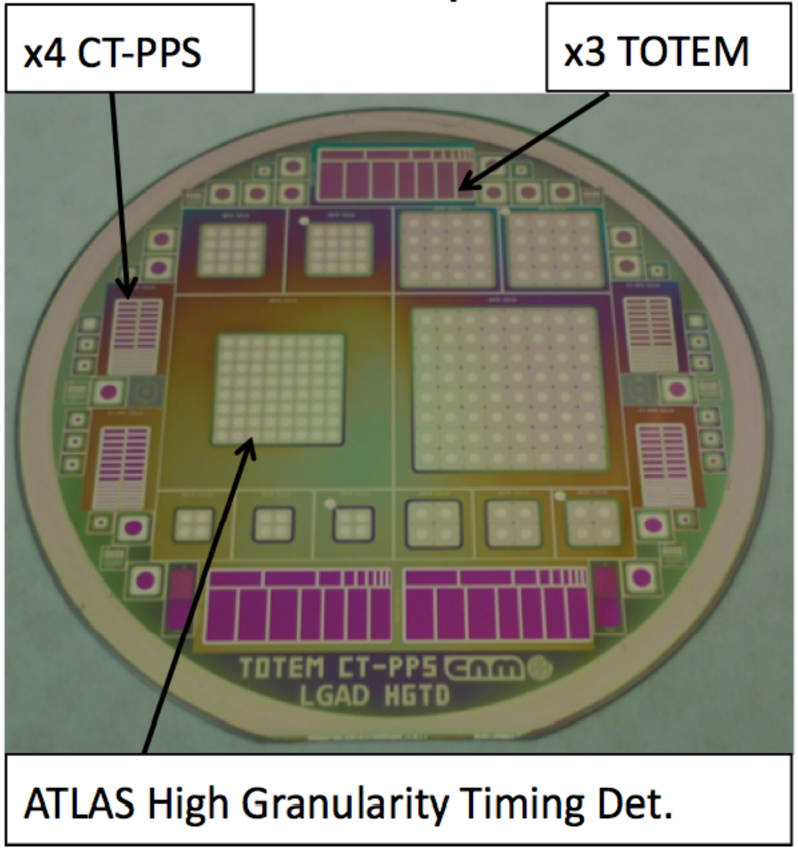
FBK 300 µm

Very successful: good gain and overall behaviour (see G. Paternoster talk)

→ FBK 50 µm expected by early 2017



CNM 75 µm
CNM 50 µm

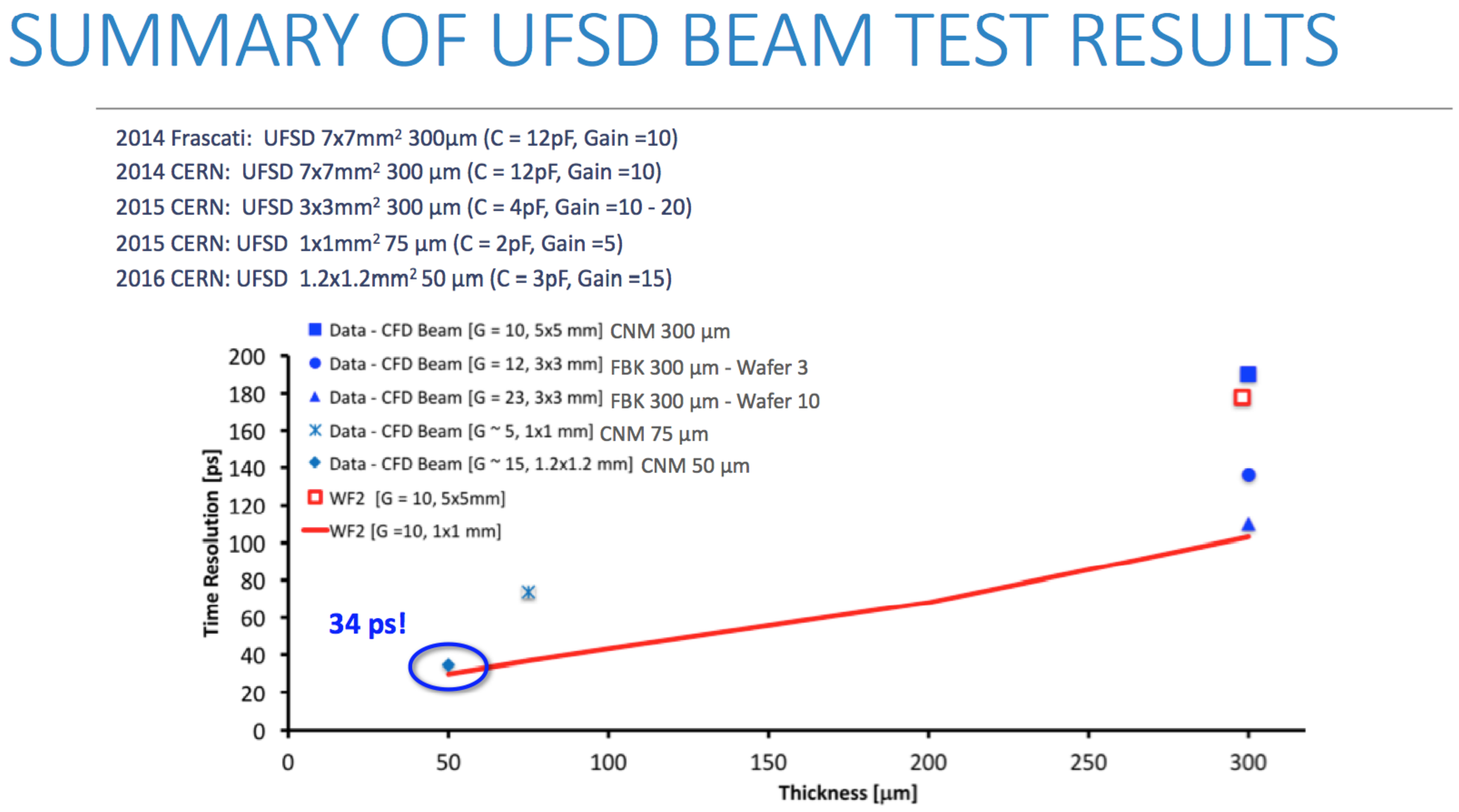


x4 CT-PPS

x3 TOTEM

ATLAS High Granularity Timing Det.

UFSD - results



SUMMARY OF UFSD BEAM TEST RESULTS

2014 Frascati: UFSD 7x7mm^2 300µm (C = 12pF, Gain =10)
2014 CERN: UFSD 7x7mm^2 300 µm (C = 12pF, Gain =10)
2015 CERN: UFSD 3x3mm^2 300 µm (C = 4pF, Gain =10 - 20)
2015 CERN: UFSD 1x1mm^2 75 µm (C = 2pF, Gain =5)
2016 CERN: UFSD 1.2x1.2mm^2 50 µm (C = 3pF, Gain =15)

UFSD - applications

- Particle identification in Time-Of-Flight (TOF) detectors
- Fast triggering
- Forward physics

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Conclusion

Thank you for your motivation,
your attention,
your questions,
your interest!!!

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