2009 Linear Collider Workshop of the Americas

Detectors:
Tracking and Vertex Detection

Bruce Schumm, UC Santa Cruz
Bill Cooper, Fermilab

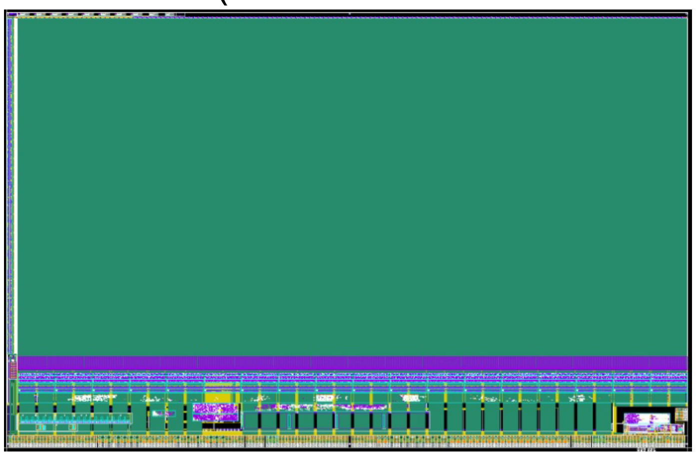
Presentations

- 6 presentations in vertex detection sessions
- 12 in tracking sessions
- All presentations were excellent.
- Regrettably, there is not time to cover each of them.
- We will concentrate on developments and issues.
- One related topic, 3D technology developments, was covered in Marcel Stanitzki's plenary talk on Detector R&D, so will not be included here.
- My thanks to Bruce Schumm, who provided the transparencies summarizing the tracking sessions.

Vertex Detection: Sensors

- Steady progress in sensor/readout development (5 talks)

Mimosa 26 (Rita De Masi – Strasbourg)



21.5mm x 13.7 mm
660K pixels
Fast full scale sensors: ~10kFrame/s
column parallel architecture + integrated zero-suppression
Rolling shutter readout
Good analogue, digital, and zero suppression performance
Total noise 0.7 mV (~12-13 e^- ENC) like MIMOSA-22.
120 μm thickness to be thinned to 50 μm

ISIS 2 (Andrei Nomerotski – Oxford)

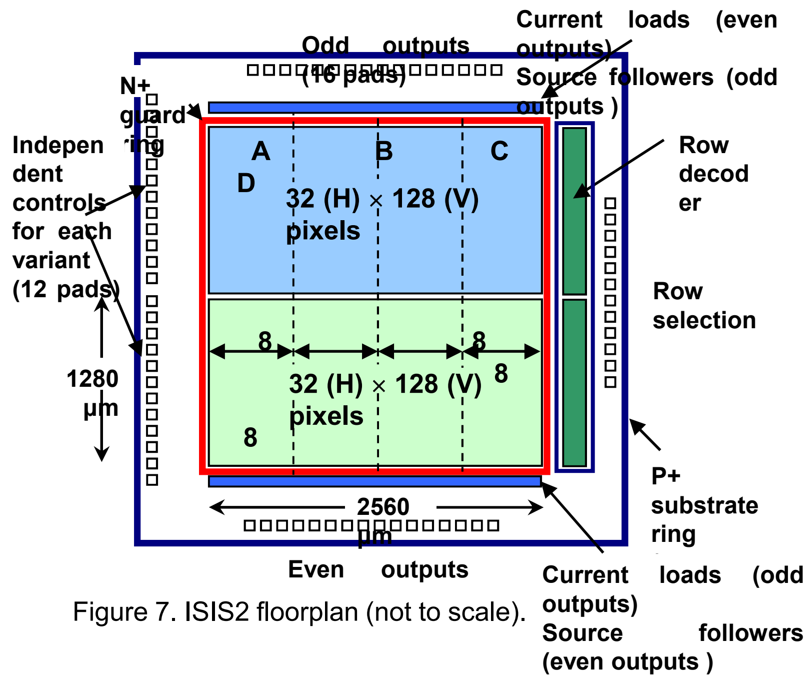
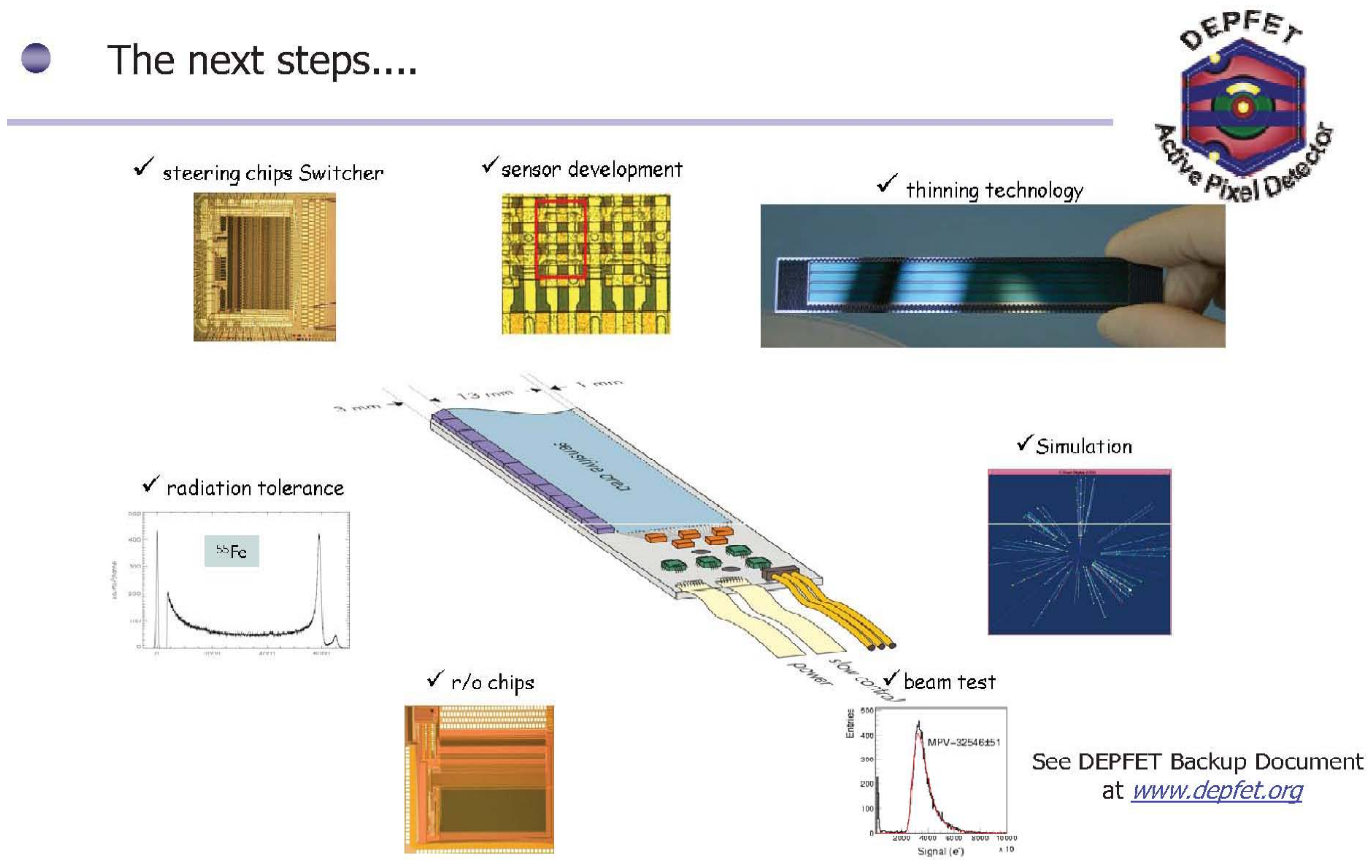


Figure 7. ISIS2 floorplan (not to scale).

- Received ISIS2 from Jazz Semiconductor in Oct 2008
  - Process: 0.18 μm with dual gate oxide
  - Developed special process: buried channel and deep p+ implant
- First time ever CCD buried channel in a CMOS process

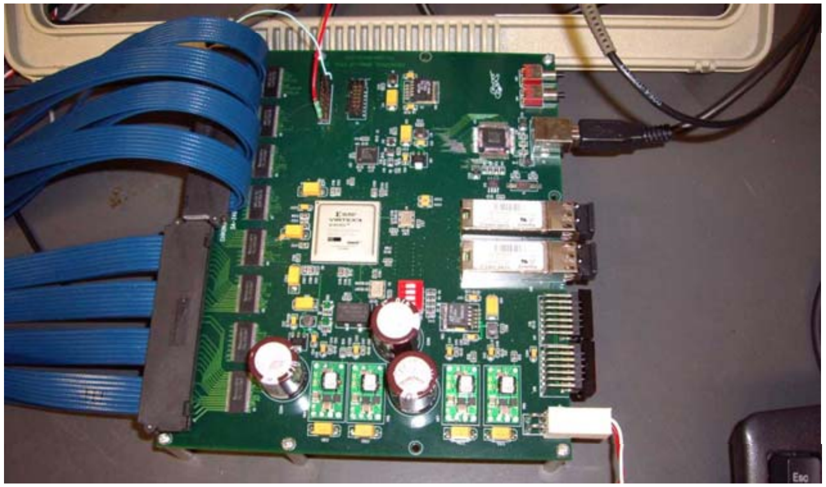
Vertex Detection: Sensors

- DEPFET Collaboration www.depfet.org (Carlos Mariñas - IFIC)
- 12 members at present: U. Barcelona; Ramon Llull U.; Bonn U.; Heidelberg U.; Goettingen U.; Karlsruhe U.; IFJ PAN (Krakow); MPI Munich; Charles U. (Prague); IGFAE, Santiago de Compostela U.; IFIC, CSIC-UVEG, Valencia; U. Giessen
- Full-sized sensors for ILC, Belle-II (KEK)

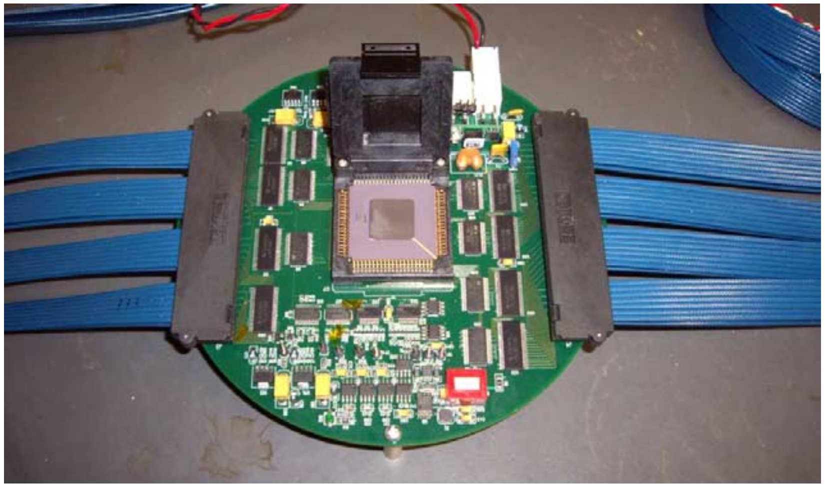


Vertex Detection: Sensors

- Chronopixels (N. Sinev, U. Oregon)
- May 2008
  - Fabricated 80 5x5 mm chips, containing 80x80 50 μm Chronopixels array (+ 2 single pixels) each
  - TSMC 0.18 μm ⇒ ~50 μm pixel
    - Epi-layer only 7 **μ**m
    - Low resistivity (~10 ohm*cm) silicon
    - Talking to JAZZ (15 μm epi-layer)
- August 2009
  - Test boards debugged and calibrated
- September 2009
  - Chronopixel chip tests begun
  - Some problems, but the general concept works
- Next prototype, implementing deep P-well, may be ready for submission at the end of 2009 or early 2010.



FPGA board

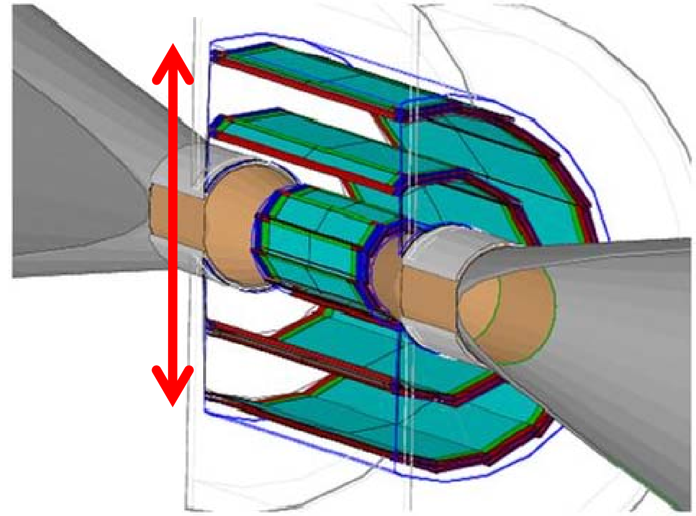


Chronopixel test board

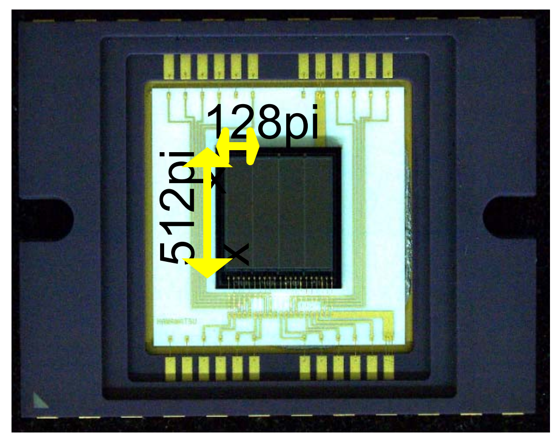
Vertex Detection: Design and Readout

- (K. Itagaki, Tohoku U.)
- FPCCD vertex detector
  - Fine Pixel CCD
    - Pixel size : 5μm × 5μm
    - Epitaxial layer thickness : 15μm
  - 20,000 ×128 pix/ch
  - # of channels ~ 6,000ch
  - Double layers : CCDs are attached on two sides of the ladders.
- Readout ASIC goals:
  - Power consumption < 6 mW/ch
  - Readout rate > 10 Mpix/sec
  - Noise level < 30 electrons
- First test sample
  - 0.35mm TSMC process
  - Chip size : 2.85 mm × 2.85 mm
  - # of channels : 8
    - Some problems with noise and lost ADC bits

120mm



A 4-ch test sample (below) is intended to address these issues.

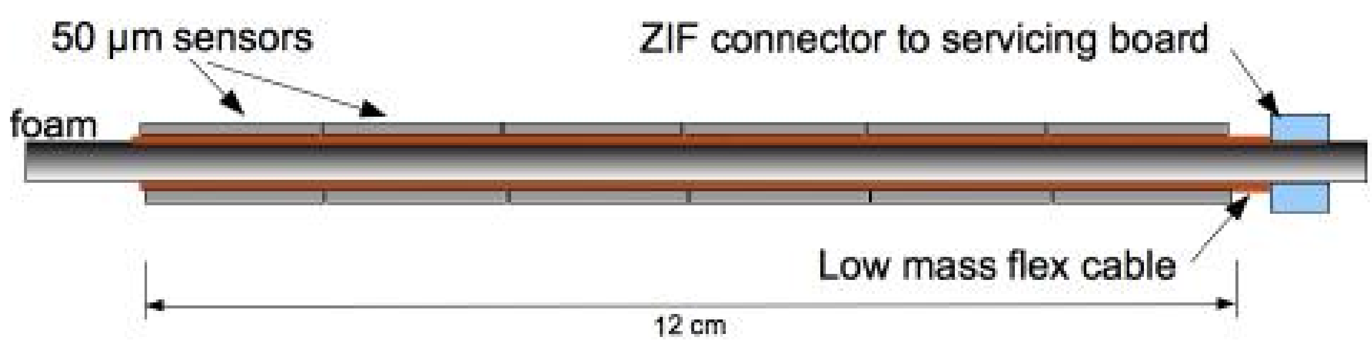


Vertex Detection: Mechanics

- The PLUME project

  Bristol, Strasbourg, DESY, Oxford (others welcome)

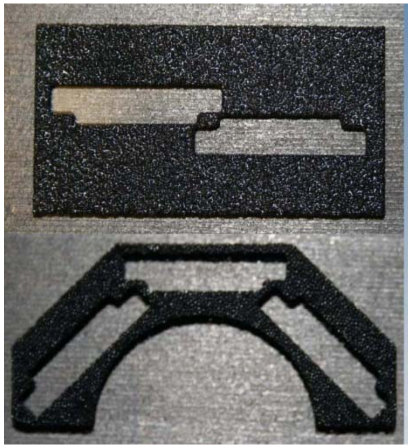
Mimosa 26 sensors on a foam core
0.2-0.3 % X_0
First prototype (reduced scale) to be tested in SPS beam next November.
Full scale prototype expected in 2010.



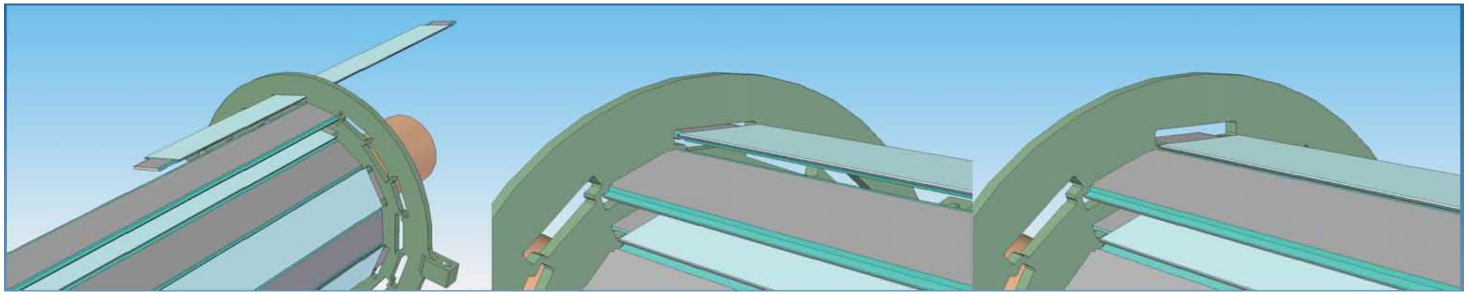
Vertex Detection: Mechanics

- Vertex detector structures using SiC foam (Ryan Page, U. Bristol)
- Collaboration of U. Bristol, U. Glascow, U. Liverpool, and STFC RAL
- Investigated:
  - Machining Methods
  - Mechanical Properties
  - Charactering of features
  - Module construction
  - Thermo-mechanical analysis
  - Vertex detector geometry

Machined samples of end-plate type geometry



- Ladder samples fabricated with foam having densities of 6% and 3.2% that of solid material –- 3.2% foam is a new development!
  - With a 30 μm sensor, 3.2% foam ➔ 0.079% X0 (meets goals)
  - Good thermal stability
    - Half module straightness < 10 μm for $\Delta T = 40^oC$



Highlights from the Tracking Sessions

12 talks in three sessions

<u>Rough accounting</u>:

ILD	SiD	Generic
6	1.5	4.5

-OR-

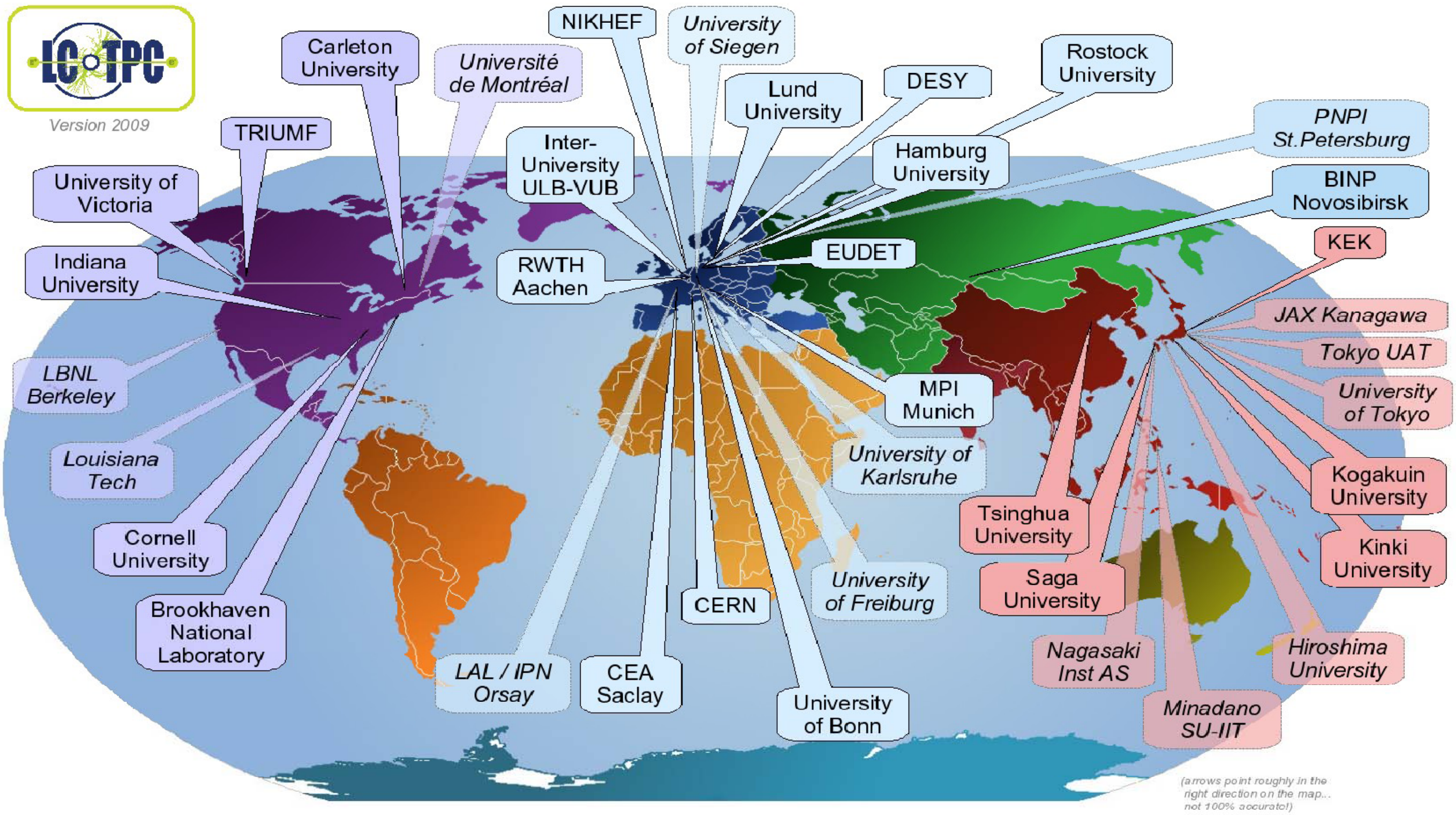
Gaseous	Solid State
4.5	7.5

Topics sampled for summary:

- Results from TPC Large Prototype
- TPC Pixel Readout
- TPC Backgrounds
- SiD Tracker Performance (simulation)
- Charge Division for Silicon Sensors
- "Alignment Aware" Si Sensors

And much more (apologies to colleagues)

Results from the Large TPC Prototype at DESY
Klaus Dehmelt (DESY), Hirotoshi Kuroiwa (KEK), Takeshi Matsuda (DESY/FLC)



Large TPC prototype in operation at DESY

- 0.77 meter diameter
- 30 cm longitudinal drift
- Magnetic field up to 1.25 T

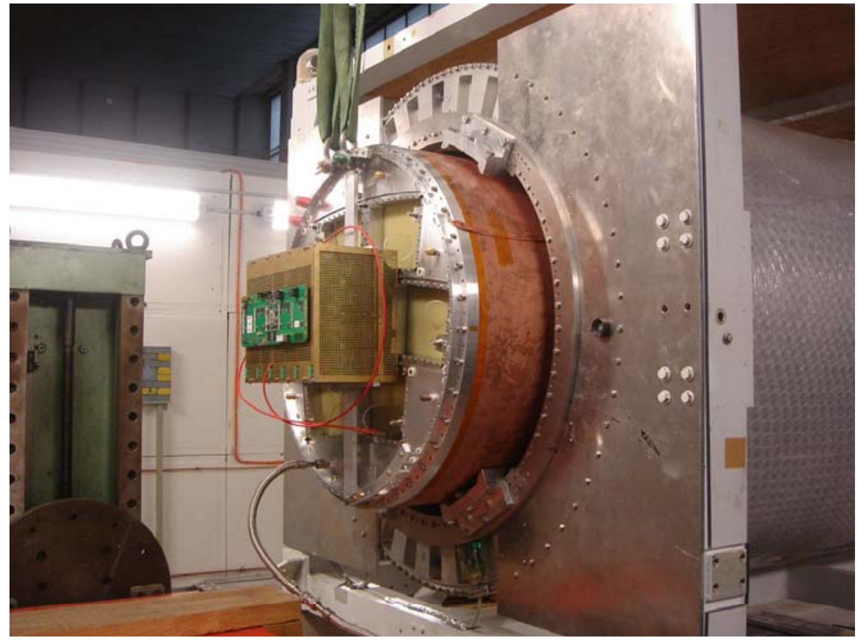
Readout:

- Double/triple GEM
- MicroMeGaS

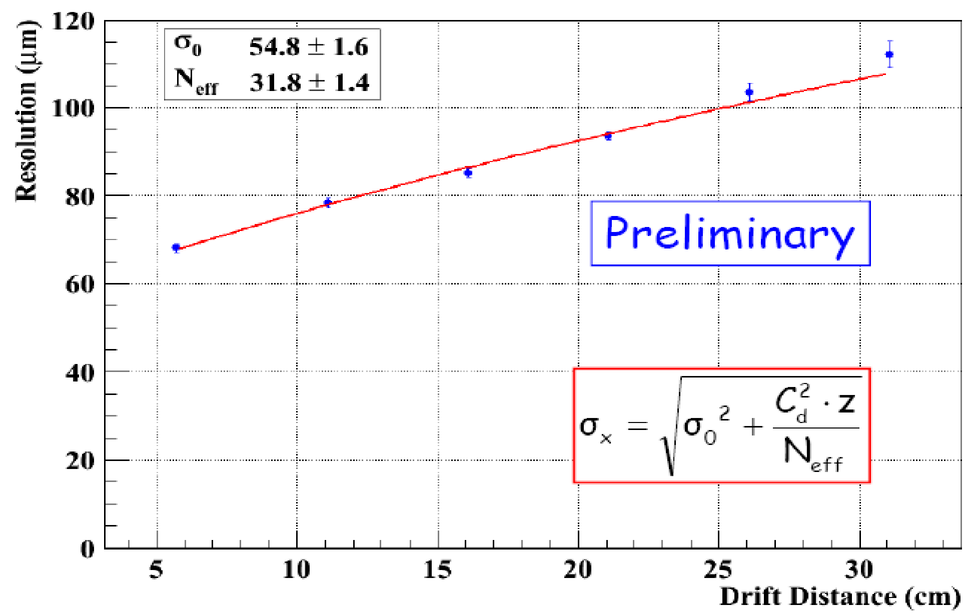
+

- (Resistive) Pads
- Pixels (TimePix)

100 μm resolution goal should be met at 4T



- Resolution at z=0: σ_0 = 54.8±1.6 μm with 2.7-3.2 mm pads (w_{pad}/55)
- Effective number of electrons: N_{eff} = 31.8±1.4 consistent with expectations



TimePix Readout

Cluster counting for an ILC TPC?

"MediPix" Imaging chip

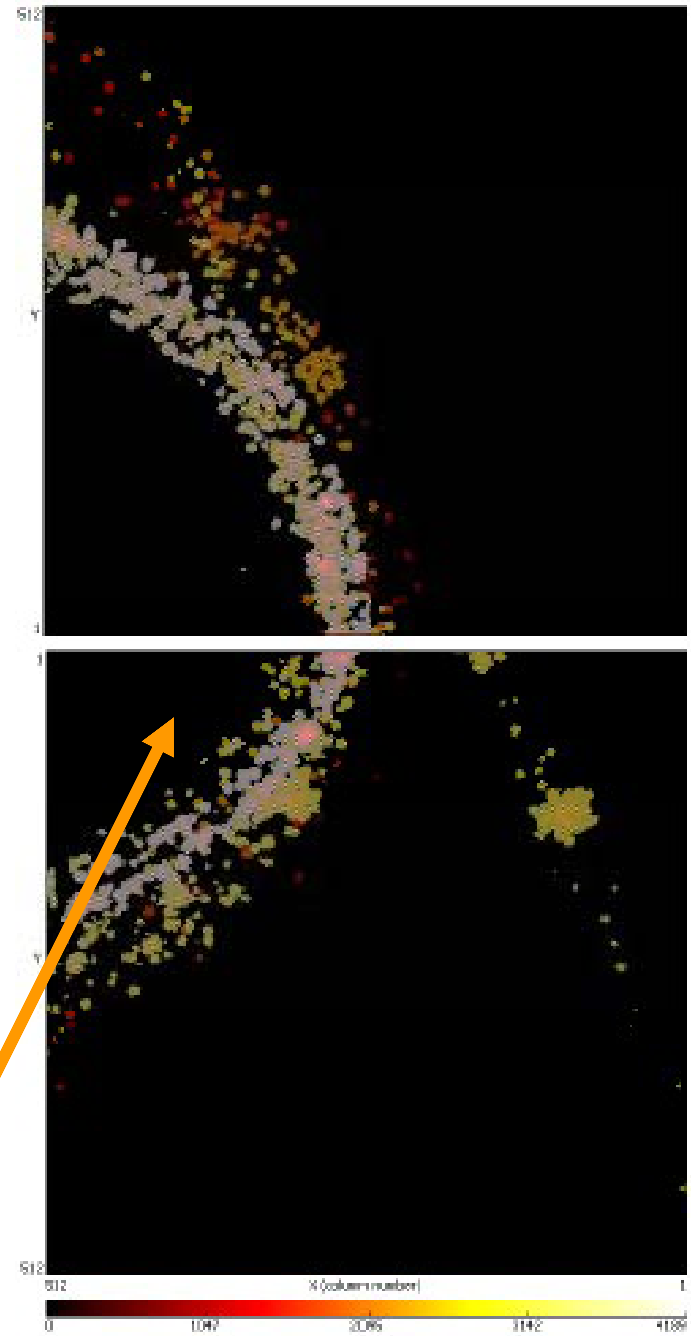
+

3rd Coordinate (drift time)

➔"**TimePix**" sensor (Jan Timmer-mans, NIKHEF)

55µm x 55µm x 100MHz pixelation

Avoid Landau statistics if diffusion doesn't mix clusters together

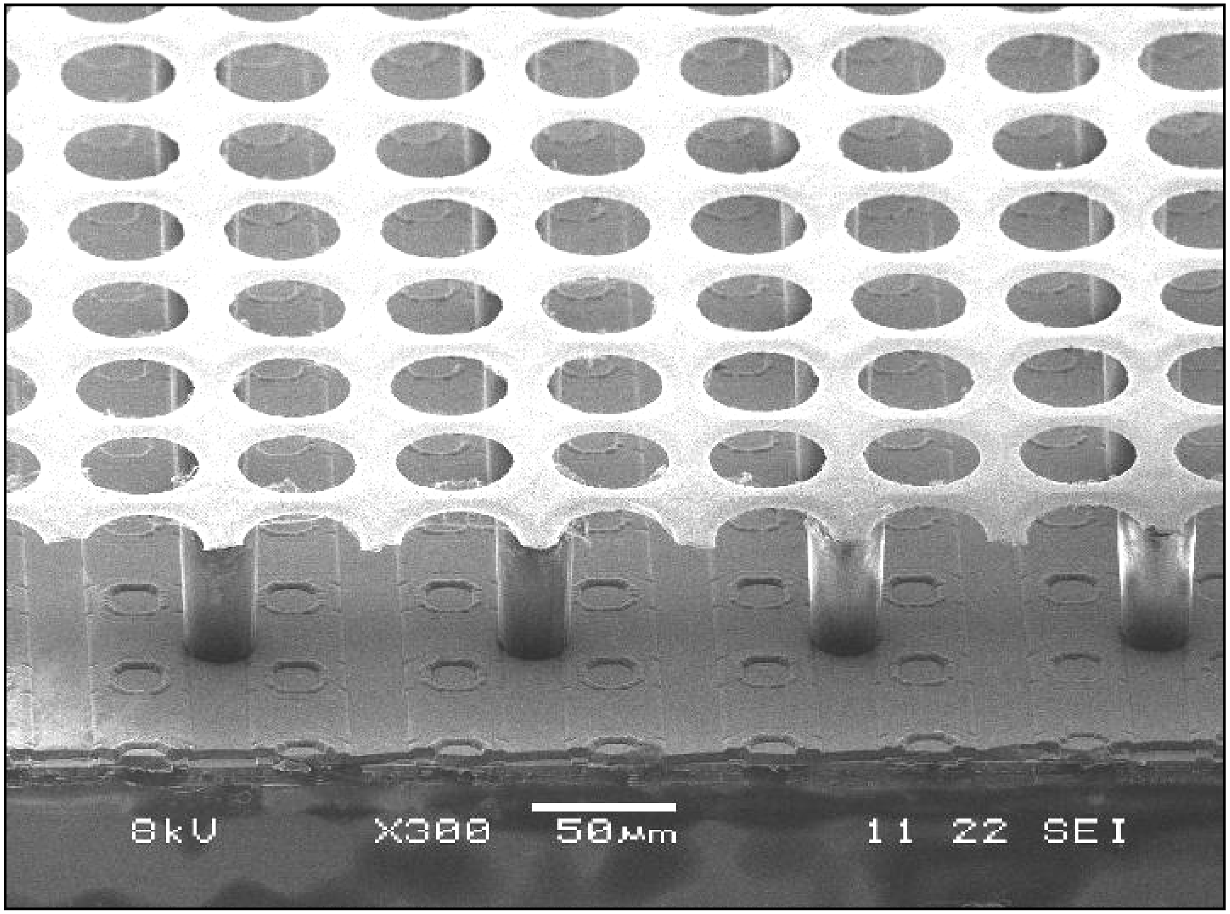


3-GEM amplification plus 500K TimePix channels

From MediPix to INGRID (Jan Timmermans, NIKHEF)

TimePix chip plus deposited grid plus stand-offs: INGRID readout system (gas-gain plus 50 µm pixelated readout)

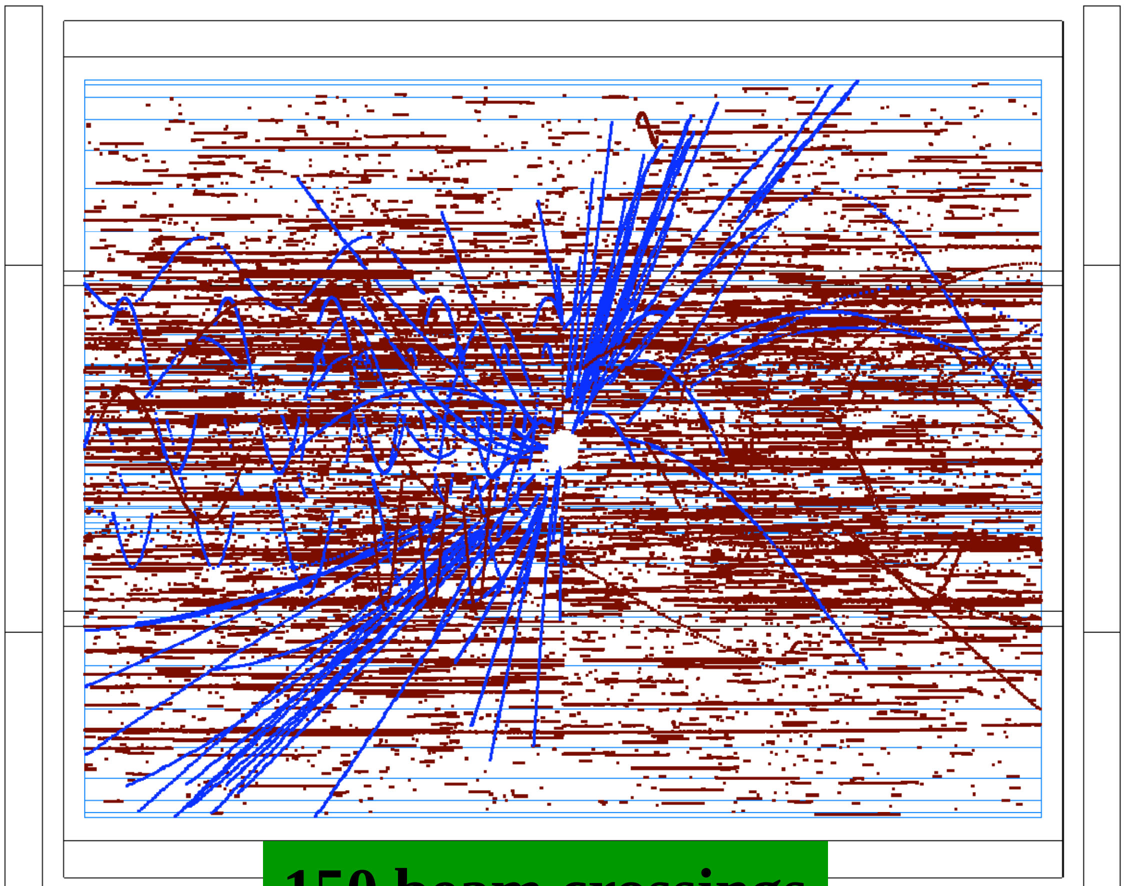
Working towards ~10cm x 10cm array



Full instrumentation of ILD TPC requires $\sim 10^{10}$ channels (same order as VXD)

IDAG: Can a TPC handle LC backgrounds?

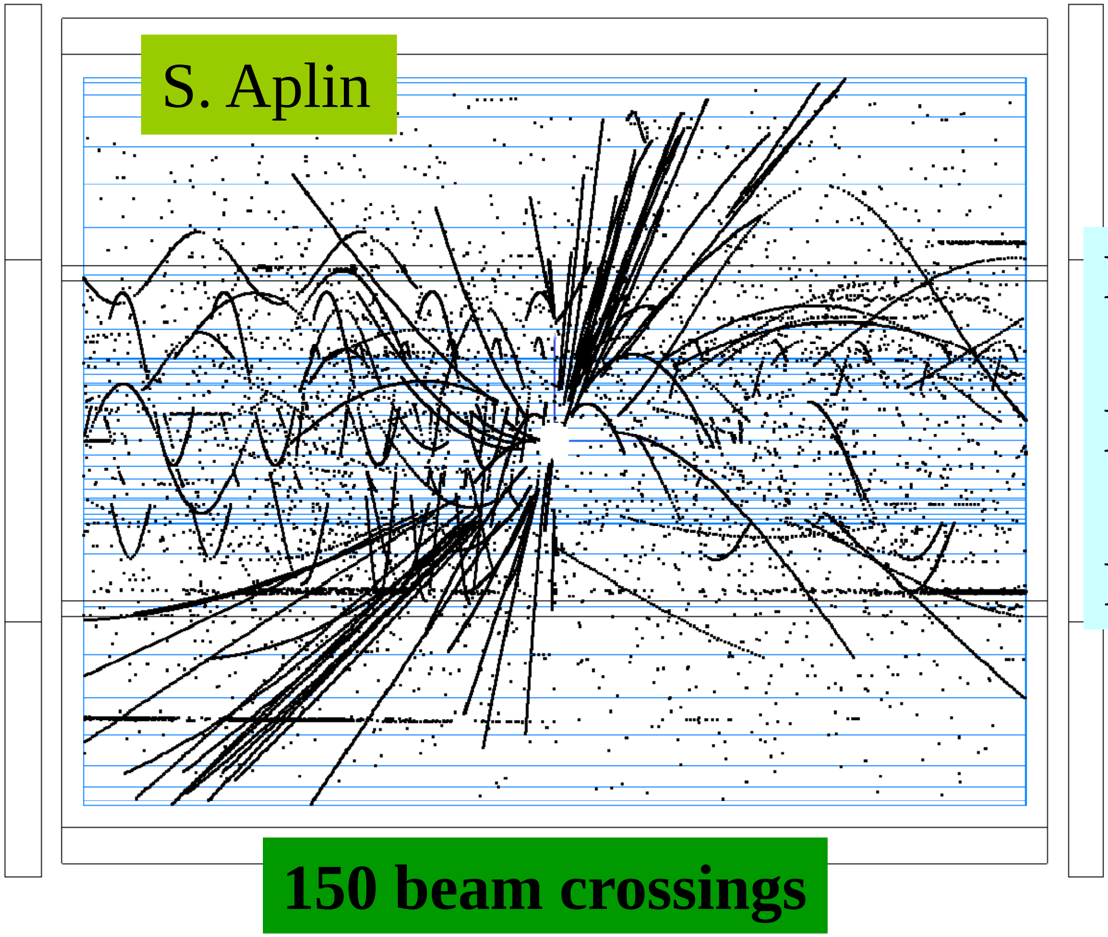
Explored by Steve Aplin (DESY)



150 beam crossings

Approach: develop algorithm to eliminate “micro-curlers” by looking for contiguous strings of voxels

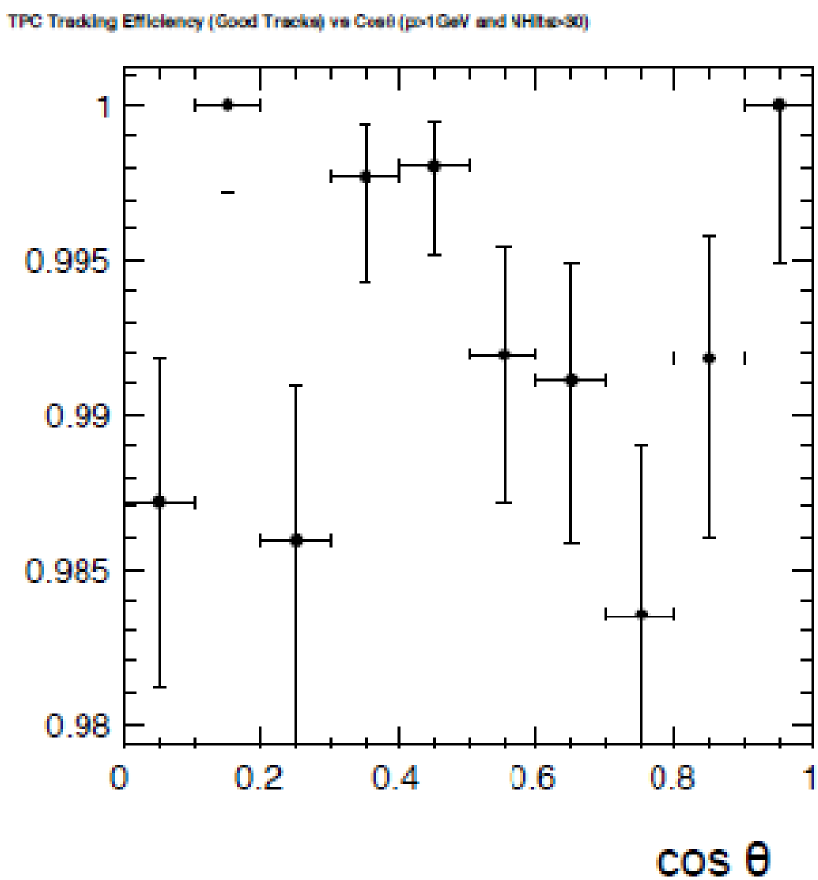
Simulation of 100 ttbar events with backrounds



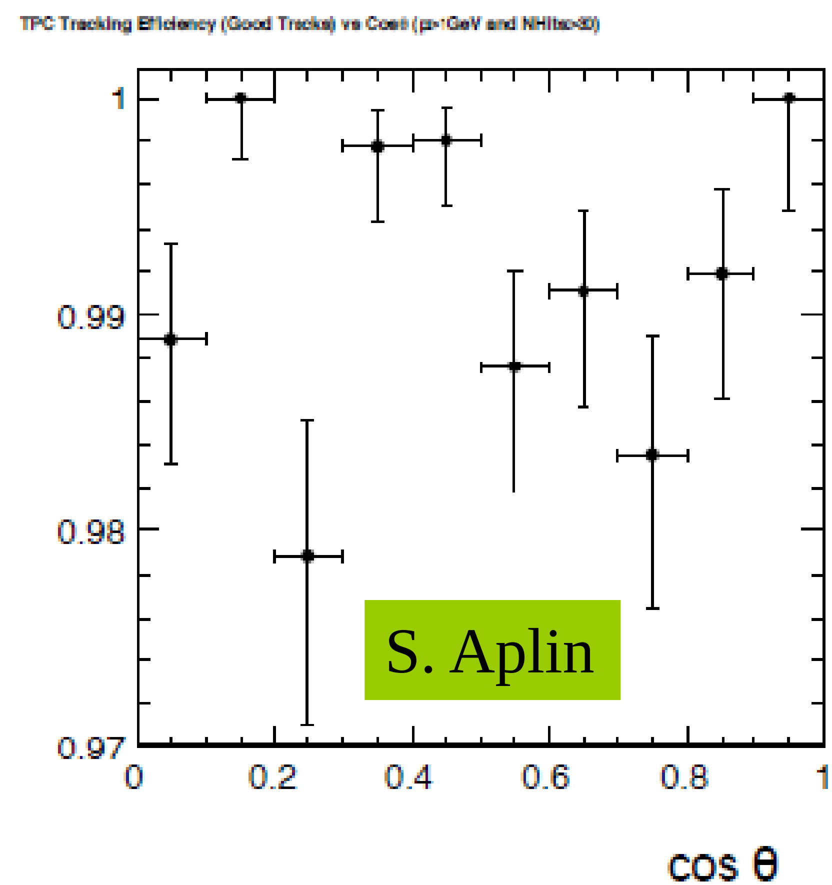
Hits:	Total	Removed
Bkgnd	265000	254000
Physics	23100	290

Tracking efficiency appears robust even at 3x nominal background.

Nominal Background 150 BX



~3 x Nominal Background 500 BX

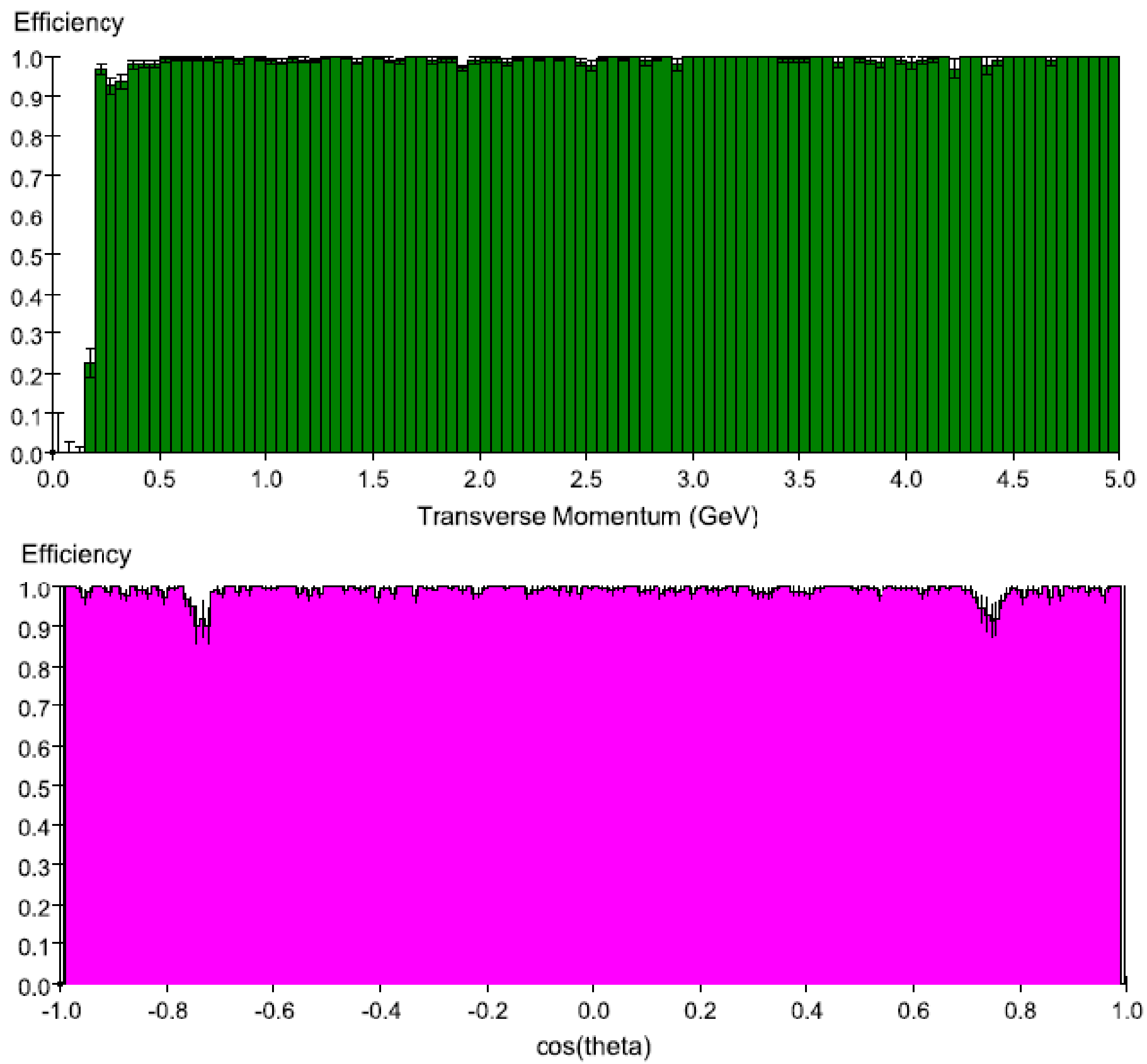


SiD Tracker Performance (full-ish simulation)

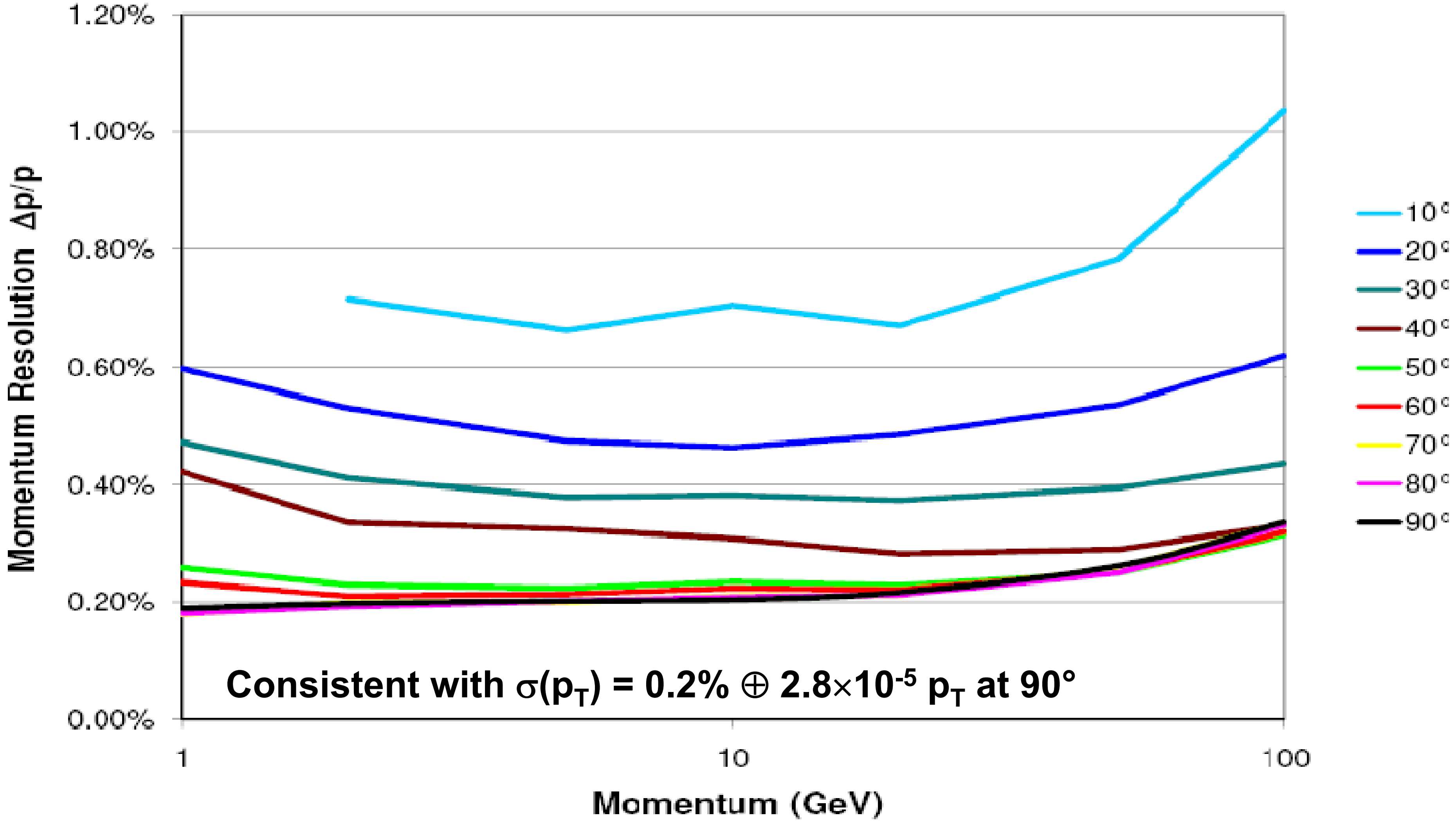
Top pair events at E_{cm} = 500 GeV

Full GEANT simulation plus strategy-based pattern recognition (Richard Partridge)

➔ Near-perfect efficiency over full range in p_T , $|\cos\theta|$



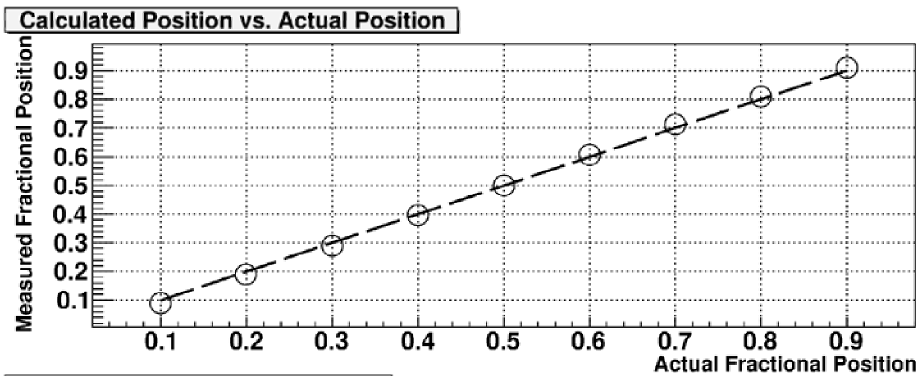
SiD Tracker Performance (full-ish simulation)

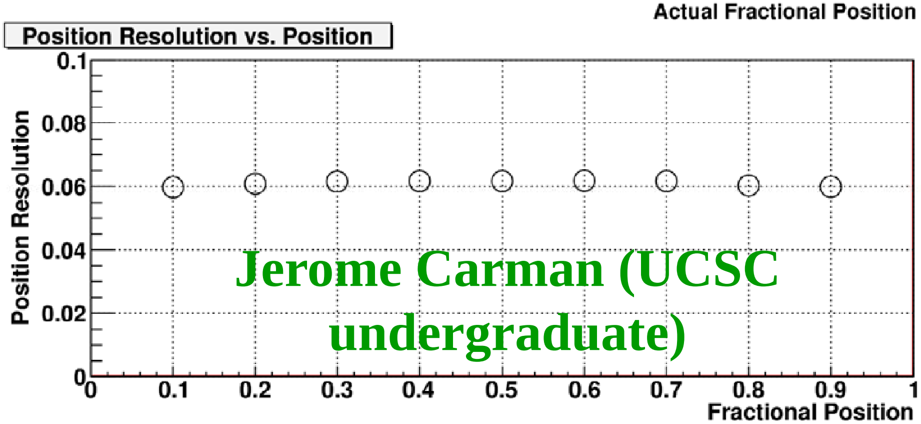


Momentum resolution probed with single muons

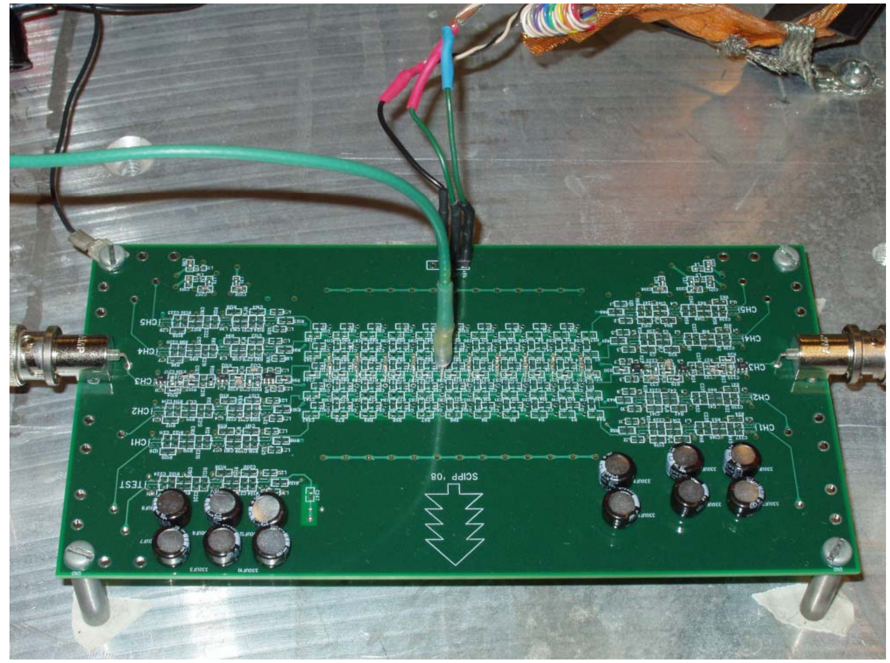
Charge Division for Silicon Sensors

- SCIPP built discrete resistive network (SiD "charge division" sensor not available)
- Benchmark PSpice simulation





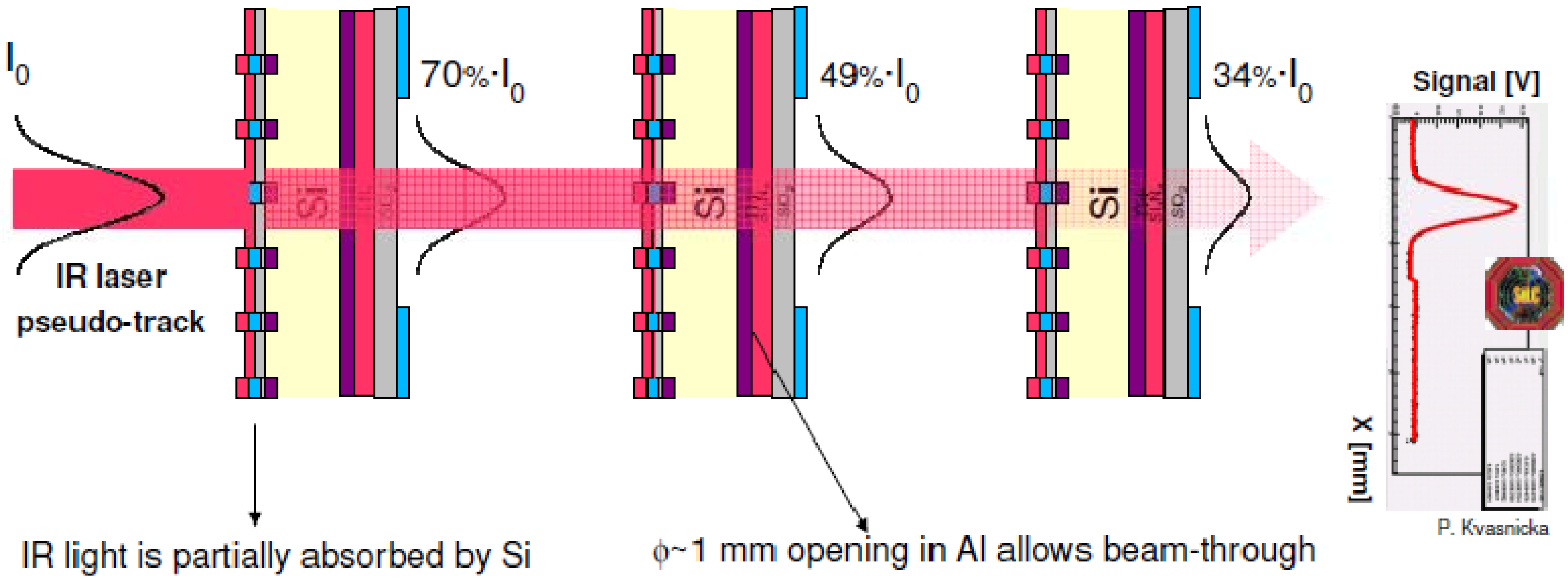
Jerome Carman (UCSC undergraduate)

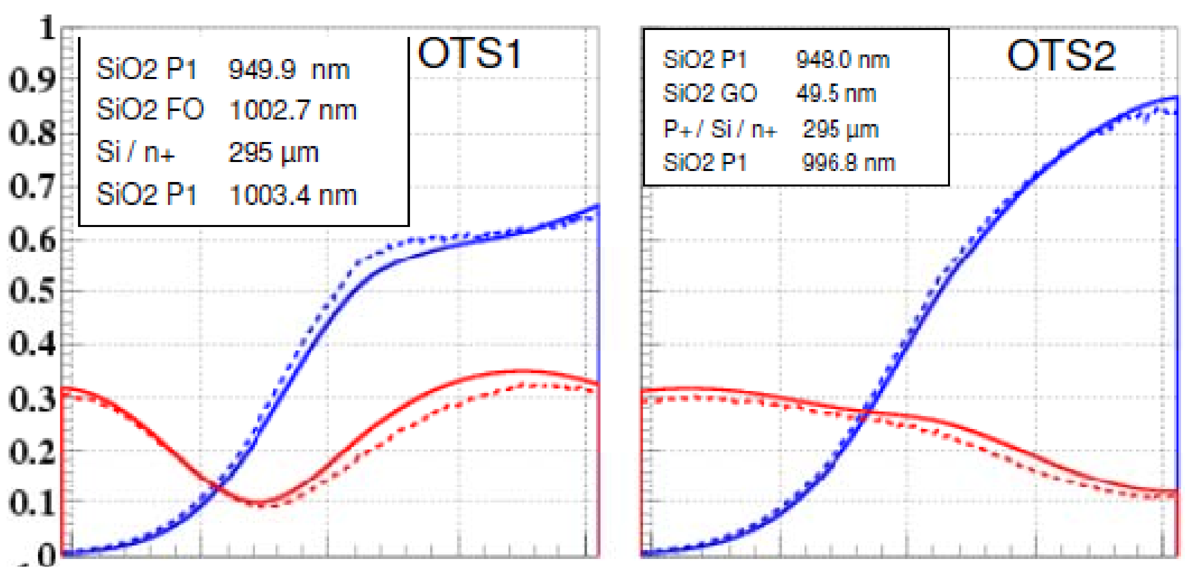


Observations:

- Longitudinal resolution independent of R; grows as √C
- Noise dominated by network, not amplifier
- Achieve resolution of ~6% of sensor length
- **σ_Z ~ 6mm for 10cm sensor**

Alignment-Enabled Sensors (Alberto Ruiz-Jimeno; Cantabria)





- **New parametrization** for SiO2 refr. index used !!!

In Conclusion

- Vertex detector collaborations are being formed to develop sensors and detector mechanics, particularly overseas.
- The development of sensor technologies continues at a good rate.
  - For many technologies, full-sized sensors are still in the future.
- Excellent progress has been made on vertex detector mechanics.
- A few issues which deserve attention (some covered in talks, some less completely covered):
  - All detectors:
    - Power cycling and power distribution
    - Alignment
  - Silicon-based detectors
    - Chip on sensor connections
  - TPC's:
    - Gating to control ion feedback into the fiducial volume
    - Tracking in a non-uniform magnetic field
    - End plate structures satisfying a budget of 15% X0
- Thank you!