VERTEX 2008

17th International Workshop on Vertex Detektors

Gruvbryggan , Utö
SWEDEN
27 July - 01 August 2008

Conference Summary

by Roland Horisberger, PSI

Fantastic week with total of **42 talks** on all kinds of aspects vertexing and tracking with precision detectors:

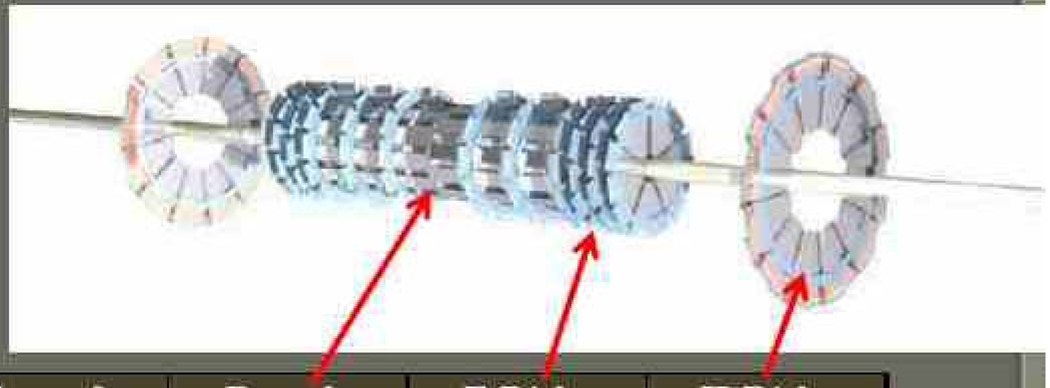
Session 1-3	**Running and commissioning experience**
Session 4	**R&D on future detectors**
Session 5	**Tracking and vertexing**
Session 6-7	**Novel detectors and electronics**
Session 8	**Performance and data quality**

All contributions were really excellent and deserve to be mentioned

However, its just impossible to summarize all the talks in a fair way

→ do a bit of a personal choice (please excuse my ignorance)

Session 1-3 Running and commissioning experience



D0	Layer0	Barrels	F-Disks	H-Disks
Layers/planes	1	4	12	2
Readout chip	SVX4	SVX2	SVX2	SVX2
Channels	12288	387120	258000	73728
Modules	48	432	144	96
Sensor Length	7 – 12 cm	12 cm	7.5 cm	14.6 cm
Inner Radius	1.6 cm	2.7 cm	2.6 cm	9.5 cm
Outer Radius		10 cm	10.5 cm	26 cm

- D0 has been able to find the right balance between ‘stable operations’ and maintenance. (over 7 years)
- Continued studies with the system also fostered new experts to keep up with system knowledge

Data quality / lost data

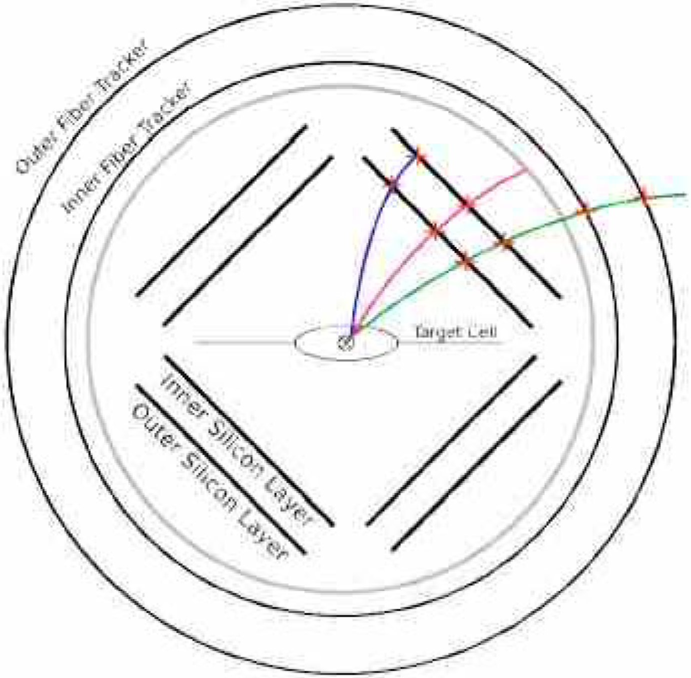
- Overall only 2.5% of luminosity declared bad for silicon data
- Almost all losses due to various power supply failures

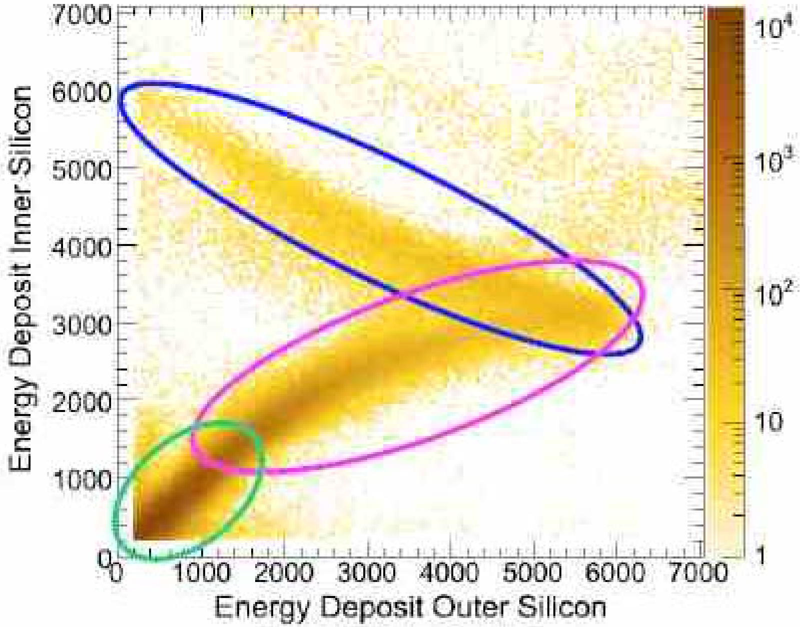
	Good	Bad	Special
May '07	98.0%	1.6%	0.4%
June '07	95.7%	4.3%	0.0%
July '07	99.7%	0.0%	0.3%
August '07	100.0%	0.0%	0.0%
October '07	99.5%	0.5%	0.0%
November '07	99.8%	0.2%	0.0%
December '07	99.8%	0.2%	0.0%
January '08	100.0%	0.0%	0.0%
February '08	95.4%	4.6%	0.0%
March '08	95.4%	4.6%	0.0%
April '08	99.5%	0.0%	0.5%
May '08	99.6%	0.4%	0.0%
June '08	95.9%	4.1%	0.0%

→ Impressive achievment on operating a sizeable silicon system done by "young leaders with senior support"

Hermes Silicon Recoil Detector

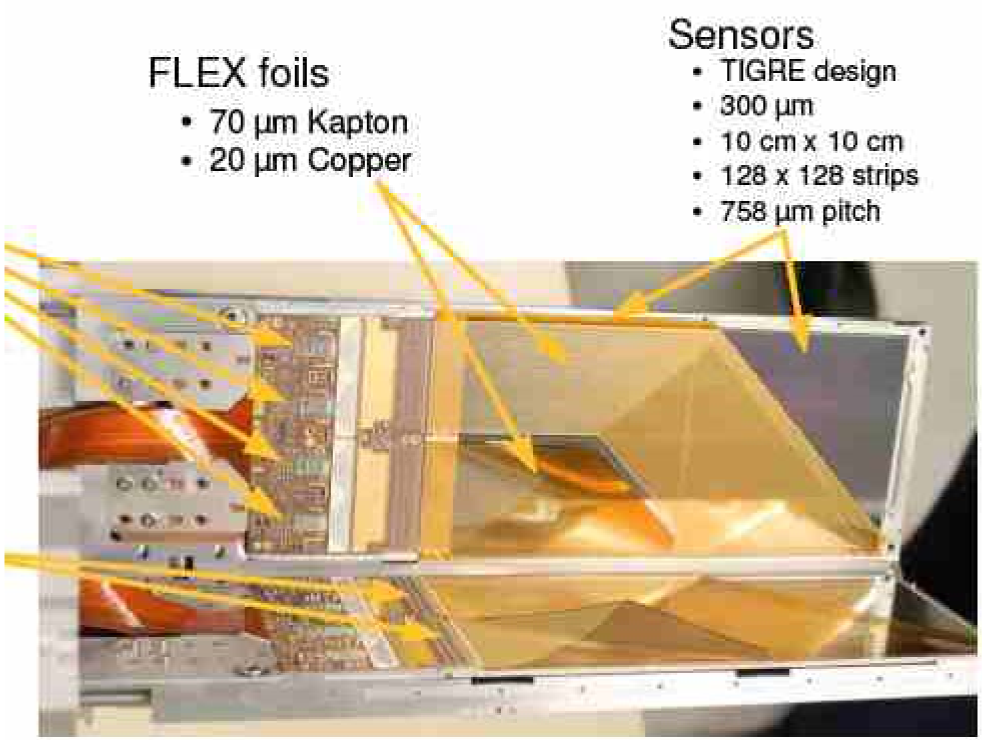
Momentum Reconstruction





- Low-energy protons
  - Momentum via sum of deposited energies
- Medium-energy protons
  - Momentum via dE/dx
- High-energy particles (protons/pions)
  - Momentum via bending in magnetic field

} Precise energy measurement in Silicon detectors (covers the low-energy and medium-energy protons)

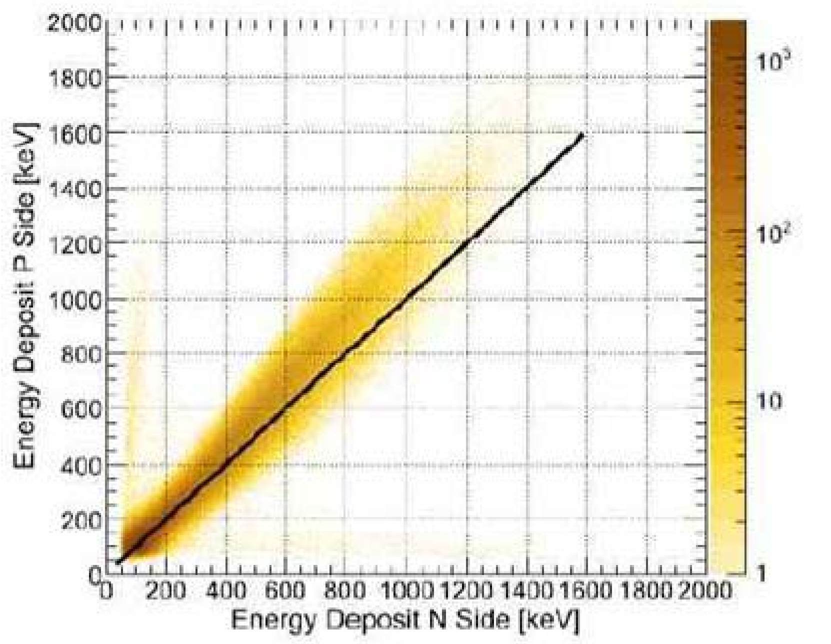


• corrected beam induced pedestal drifts

• channel dependent pedestal & crosstalk corrections

→ dealt inventive with occuring problems

Finally get very nice calibrated system !



→ System is as good as it gets calibrated and understood

Commissioning CMS Silicon Tracker (very large system)

SST integration at CERN main site

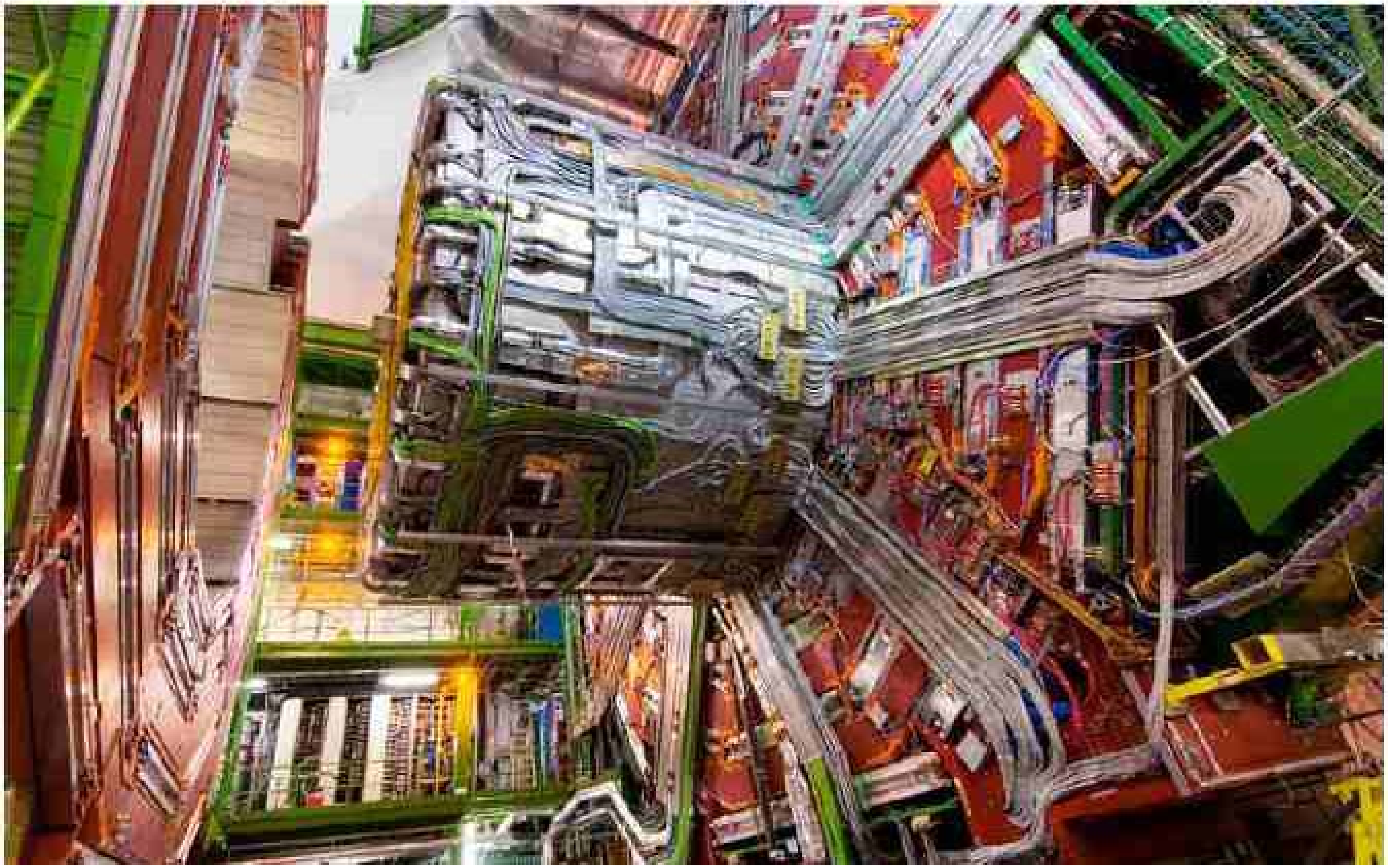
The SST ready for transport to CMS (20km journey)

Many Issues:	Synchronisation Opto-Gain Scan noisy strips <1% Latency scans

In very short period successfully installed and brought into operational mode (Congratulations)

CMS YB0 Cabling

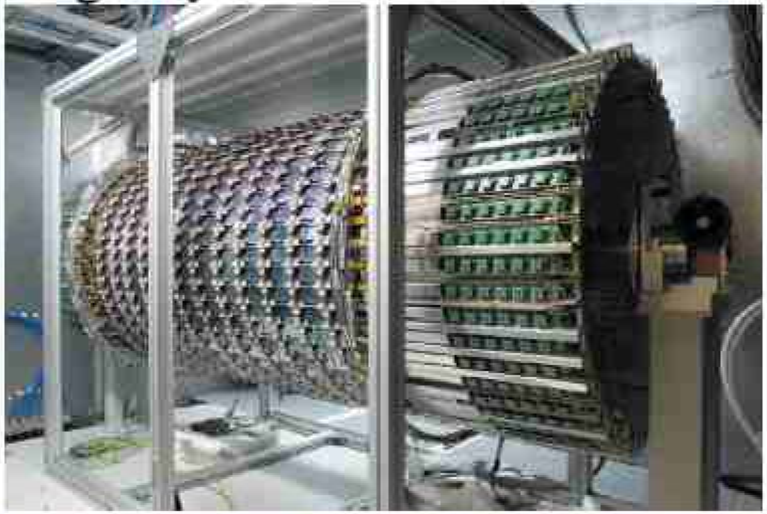
Considerable effort → needs top attention
→ must be at start of planning
→ likely to live with in SLHC

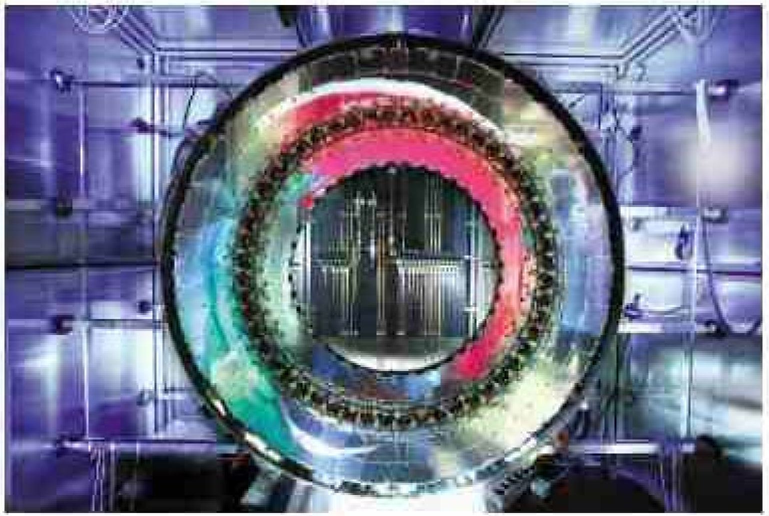


→ **don't under estimate cooling !**

Commissioning the ATLAS Tracker

Single cylinder tests





Sept. 2005: outer layer in thermal enclosure

Dec. 2006: inner layer insertion

Conclusions

The Atlas SCT is being commissioned quite rapidly.

Pace is signed by the evaporative cooling: use any slot available with cooling loops.

Cooling compressor accident delayed commissioning (exp. pixels) and stable running.

Cooling now back, beam pipe bake-out taking place in this moment.

Gaining experience with a very complex system

Modules seem to behave very uniformly.

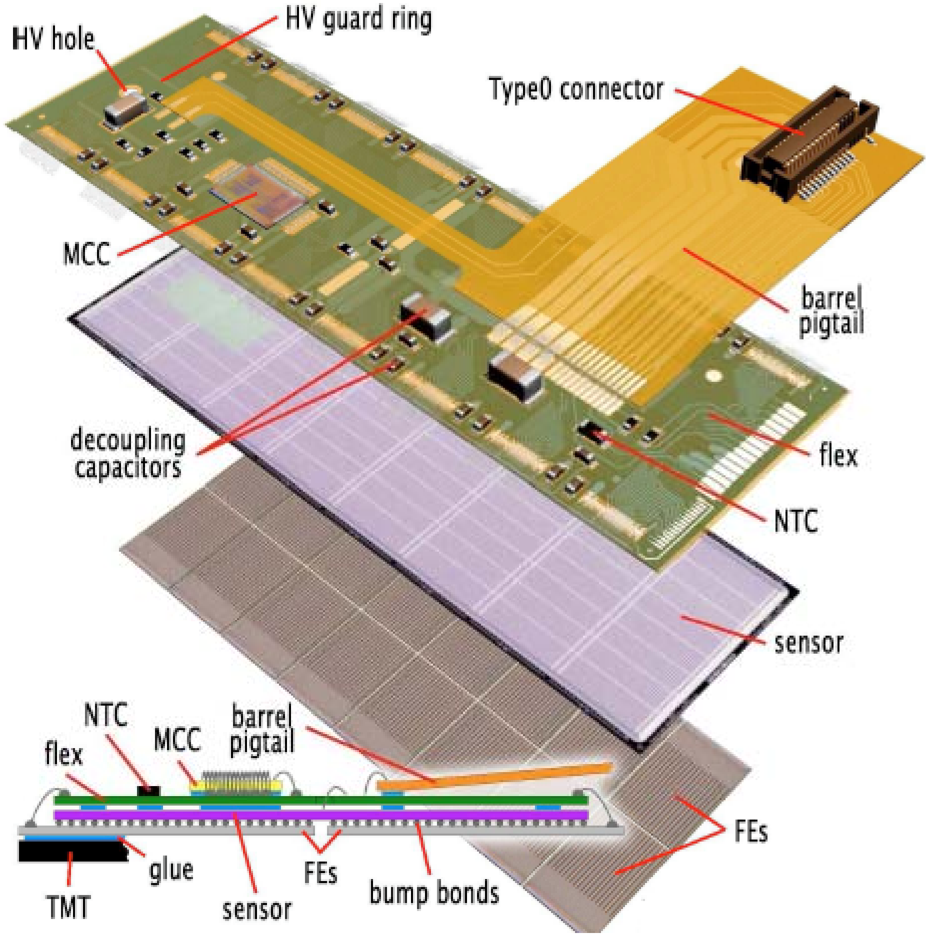
Solving initial problems at the <~ % level.

Cosmic rays detected in conjunction with other detectors

DAQ, DCS and Monitoring tuning up

Ready for collisions in a few weeks !

Atlas Pixel Detector Installation & Commissioning



Thickness :

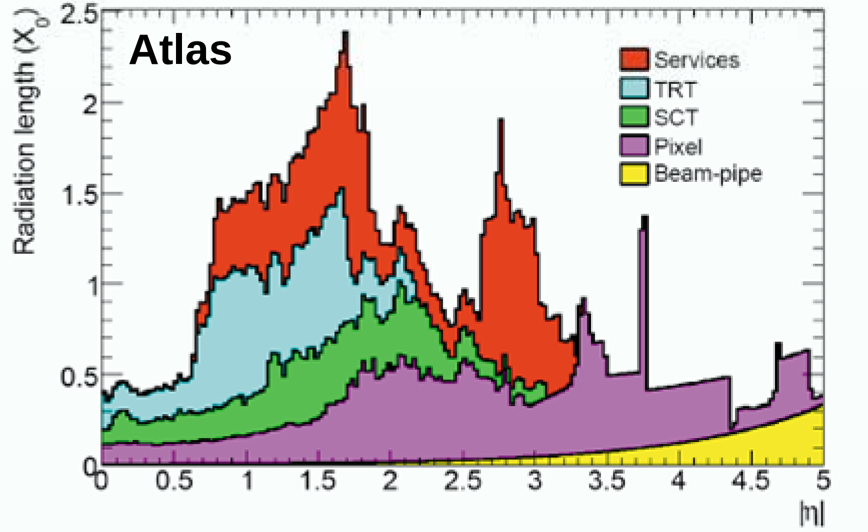
Sensor 250 μm
Drond-end 196 μm
Flex hybrid printed circuit 100 μm

Sensor :

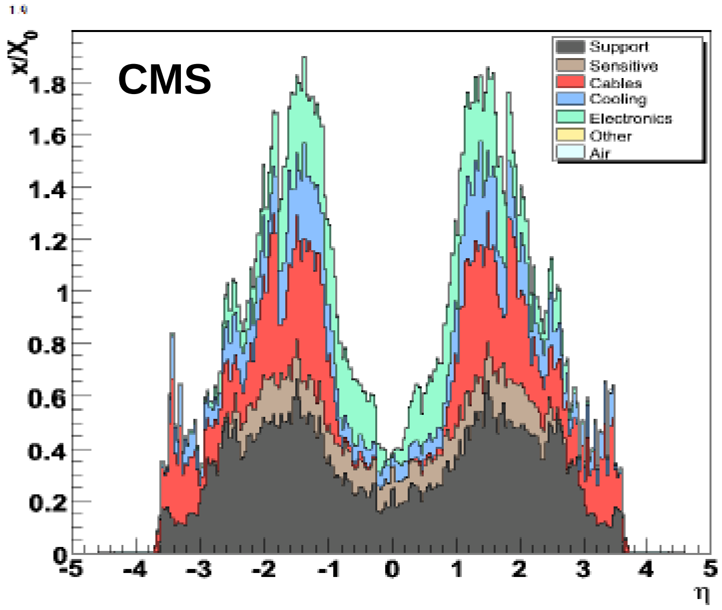
- Oxygenated high resistivity Si
- n+ in n-bulk
- 150 – 600 V bias

Material Budget of LHC Experiments

CMS & Atlas both slipped considerable in keeping X/X_0 originally aimed for !

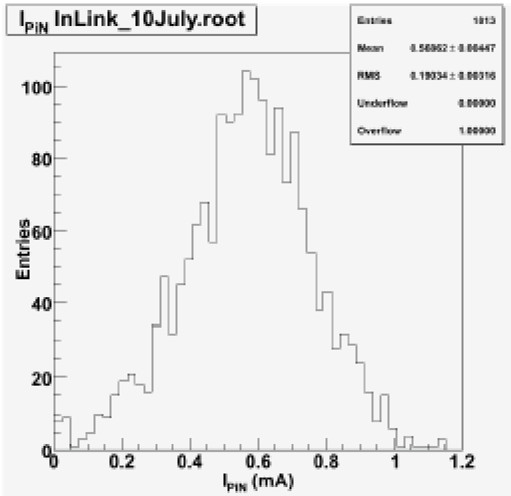


$\|\eta\|$	radiation length	interaction length
< 1	$\sim 0.2\, X_0$	$\sim 0.05\, \lambda$
< 3.3	$\lesssim 0.5\, X_0$	$\lesssim 0.2\, \lambda$



Old argument that Silicon would be too thick is a myth. “It’s the power & cooling.. stupid..”

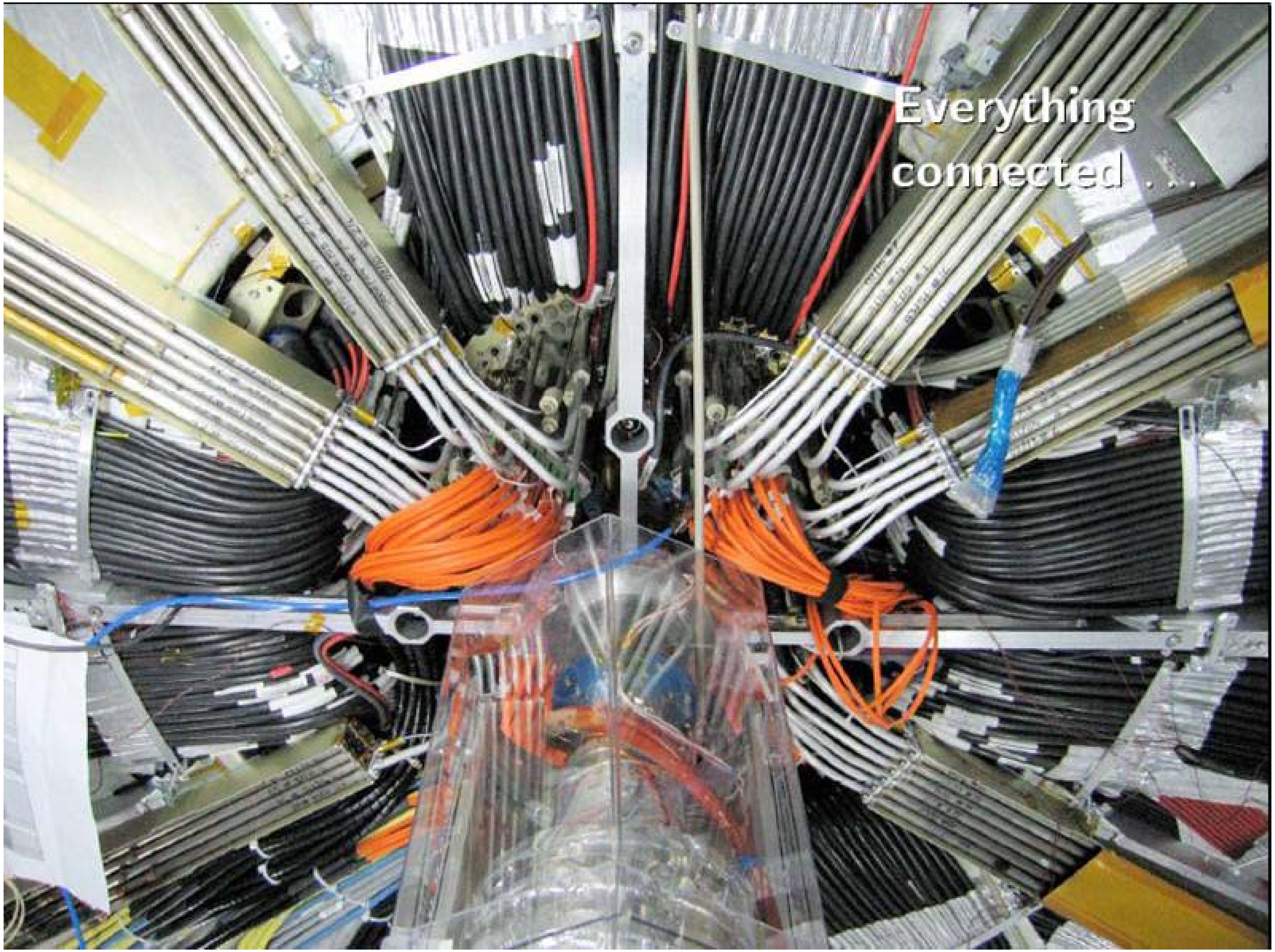
Issues with Optical Connections (In-Link)



- Light output lower then expected, but sufficient to control modules (clock, configuration, commands).
- Light output increased by 16% in two month.

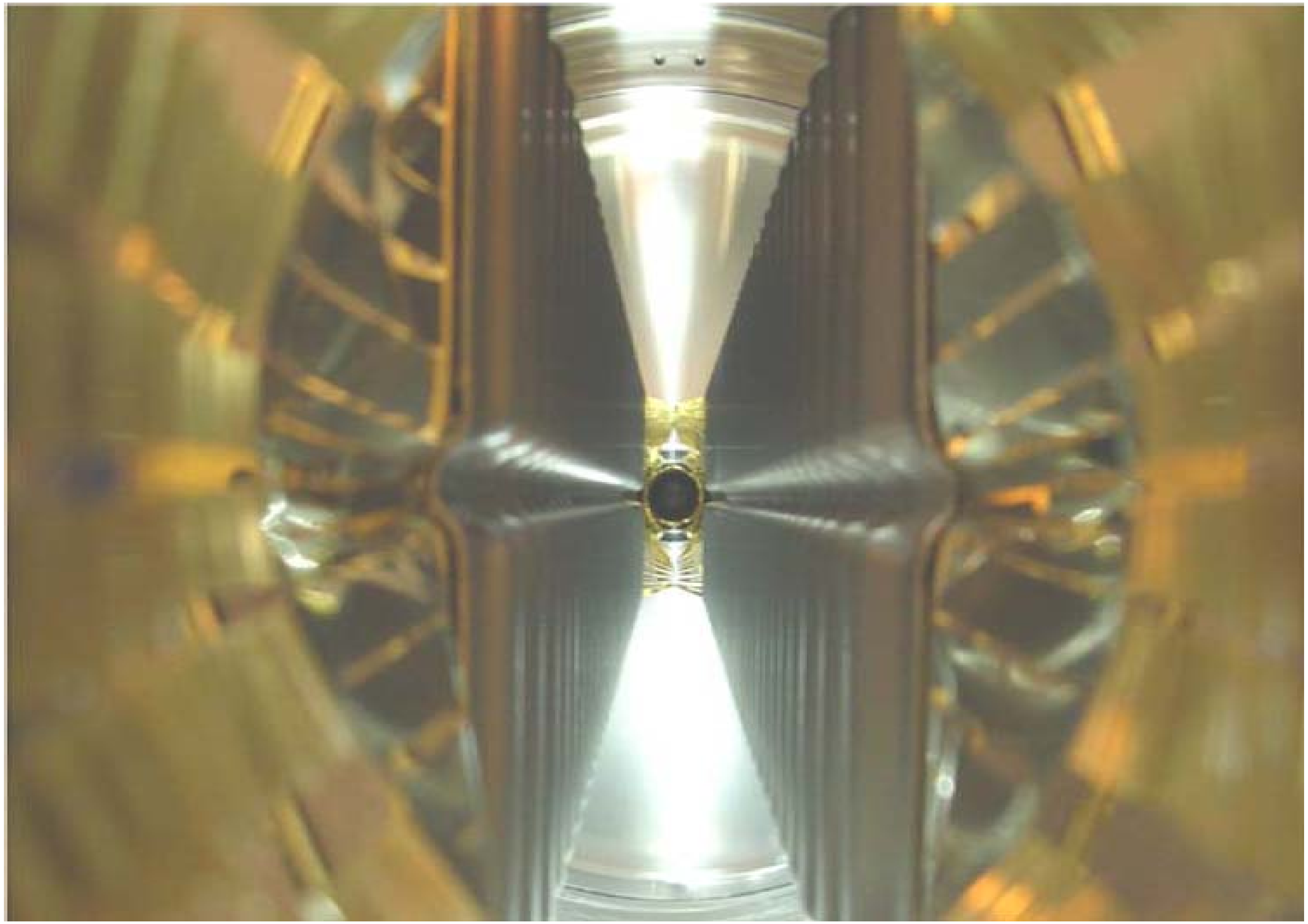
Experience in CMS:

• Optical connectons can easily become dirty → absobtion, reflections
• Affect digital just like analog
• Slack management with short optical fibres pieces is terrible



Very neatly done!   All set to go! →   Congratulations

LHCb Velo Installation & Commissioning

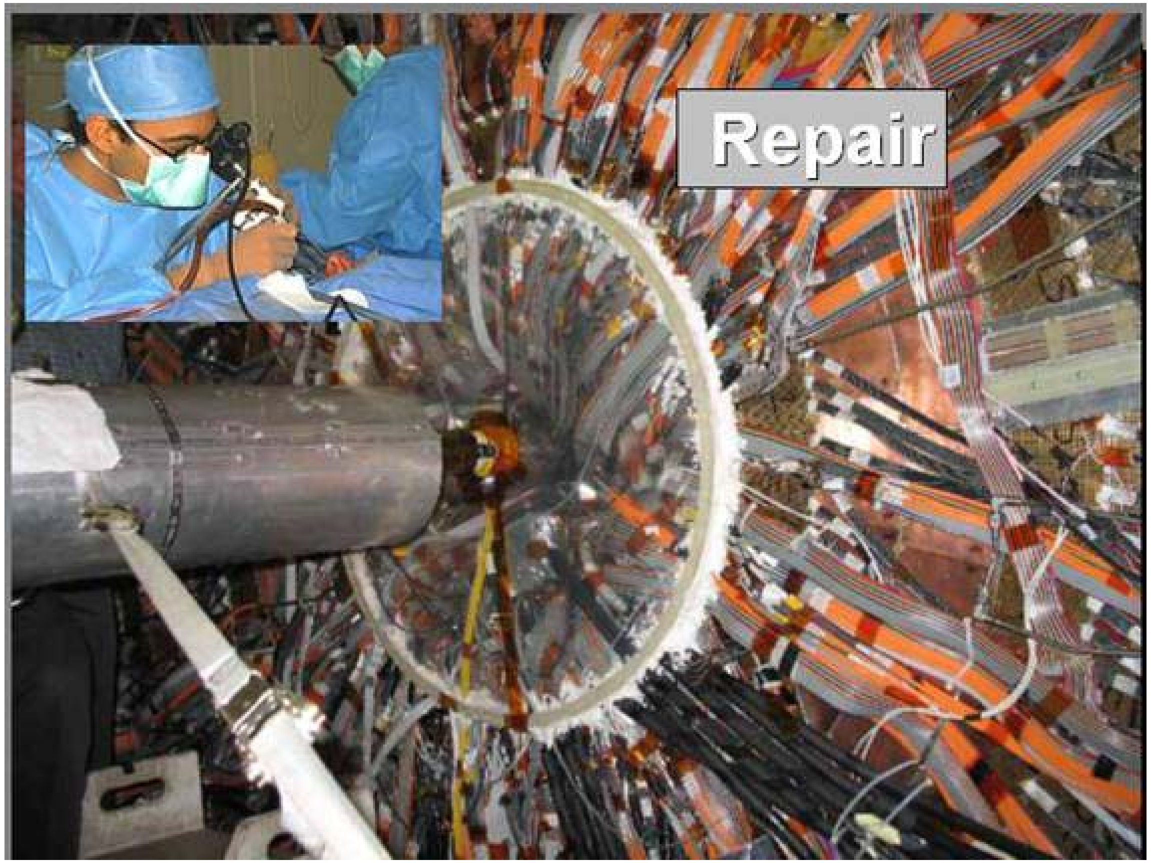


Conclusions

- All components fully installed and tested.
- Extensive commissioning programme over last year.
- First operation of whole detector under vacuum
- 99.2% of channels fully operational.
- LHCb VErtex LOcator in good shape for first beams

Again: Power supply issues !

CDF silicon cooling: problems and recovery



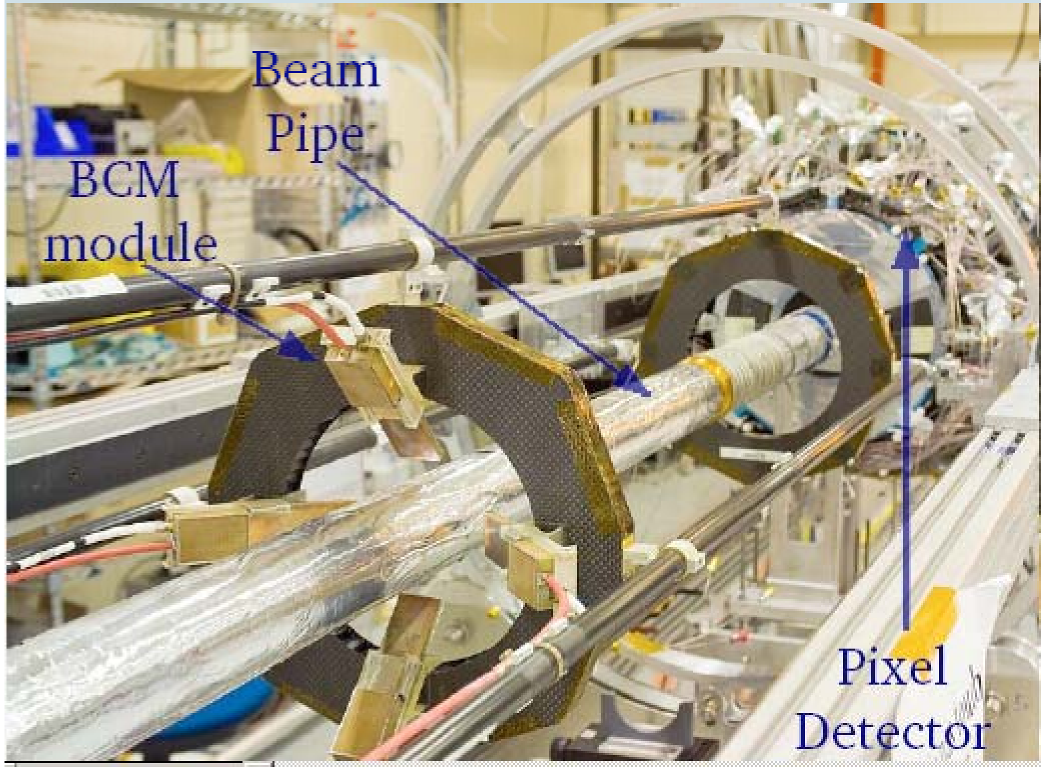
With great admiration I observe how difficult situations can be mastered !

Atlas Diamond Beam Conditions Monitor

short construction period

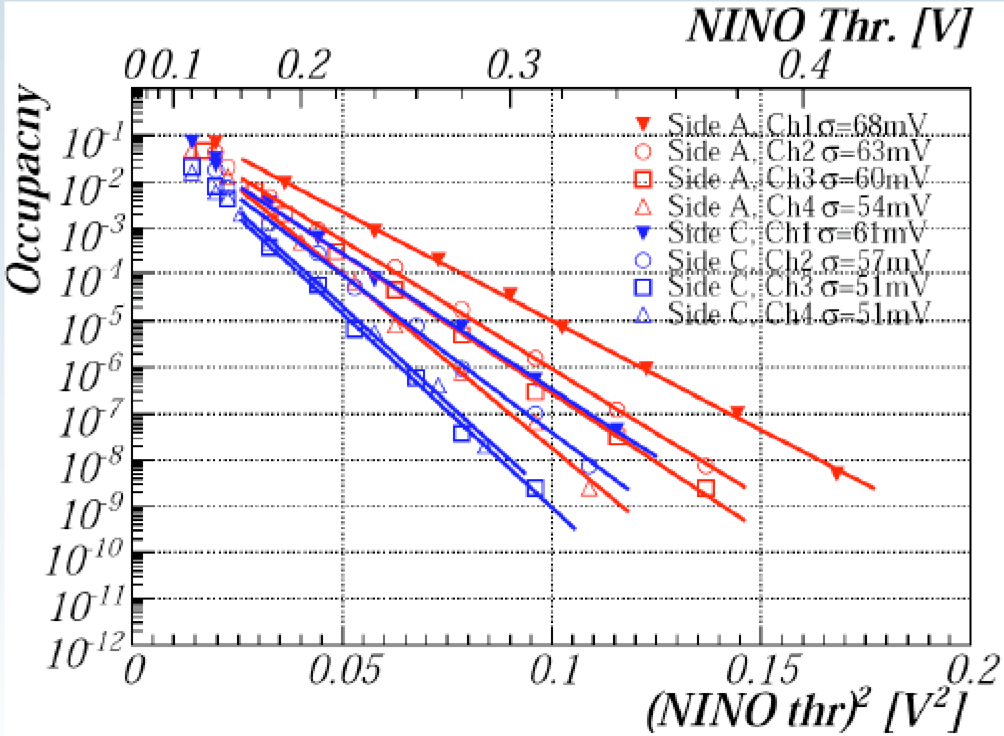
BCM Detector Modules Installed

BCM modules were installed on Beam Pipe Support Structure in November 2006 and lowered into ATLAS pit in June 2007



Performance of installed NINO boards

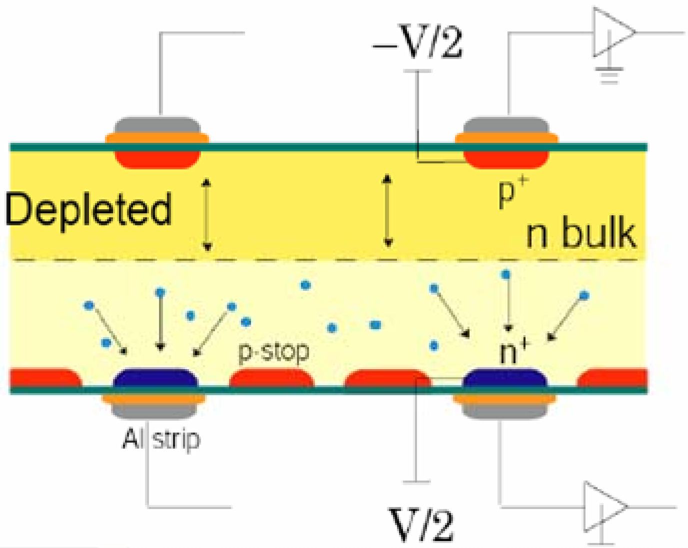
Noise rate measured in ATLAS pit (after installation of NINO boards in ATLAS)

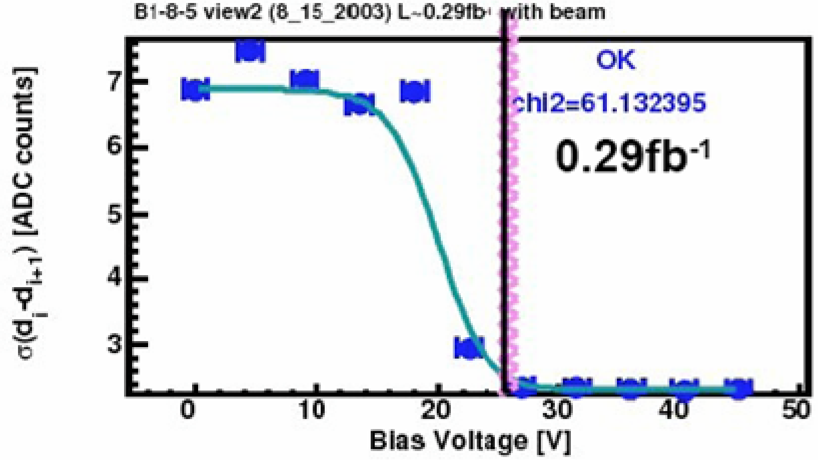


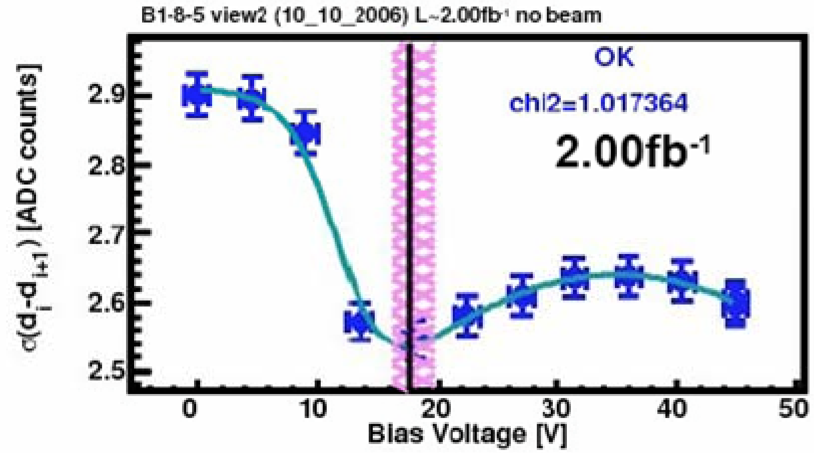
Rad. Damage Studies of D0 Silicon Tracking System

Noise on the n-side

- Look at noise on the n-side as a function of applied voltage
  - Double-sided sensors only
  - Before type inversion



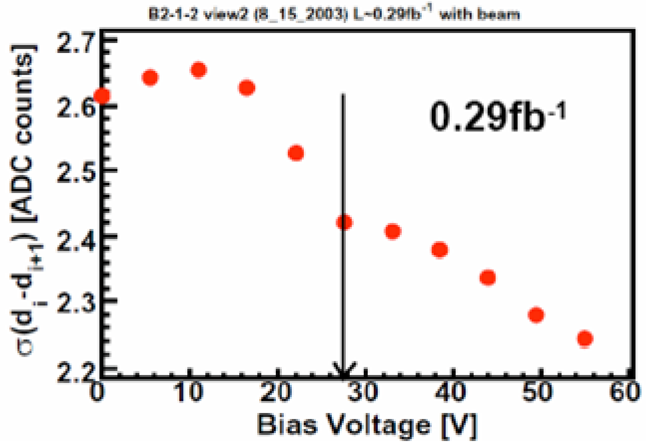


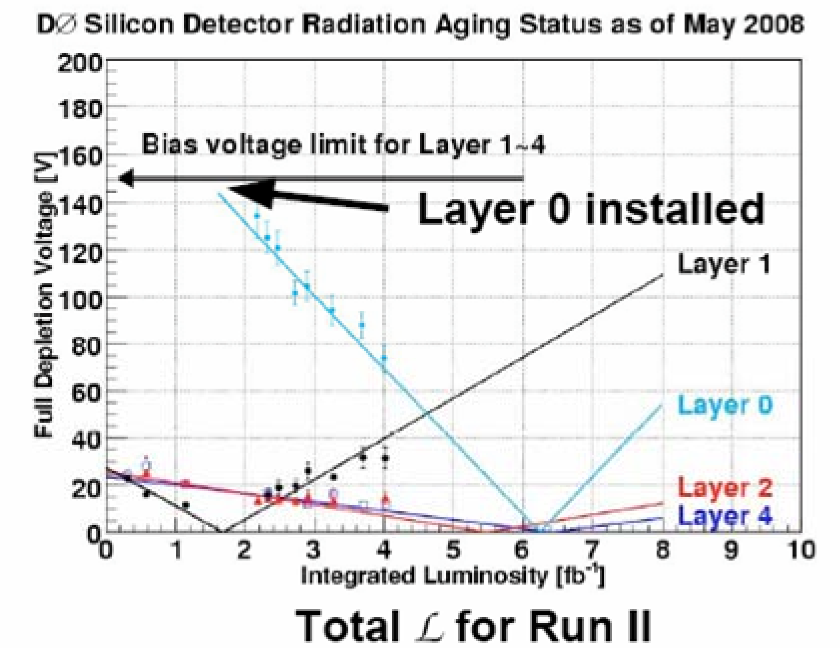


Evolution of

Double-sided Double-metal Noise

- Unexpected behavior for double-sided double metal sensors
- Believed to be a result of charge buildup in thin insulating layer between metal layers
- Position of kink interpreted as V

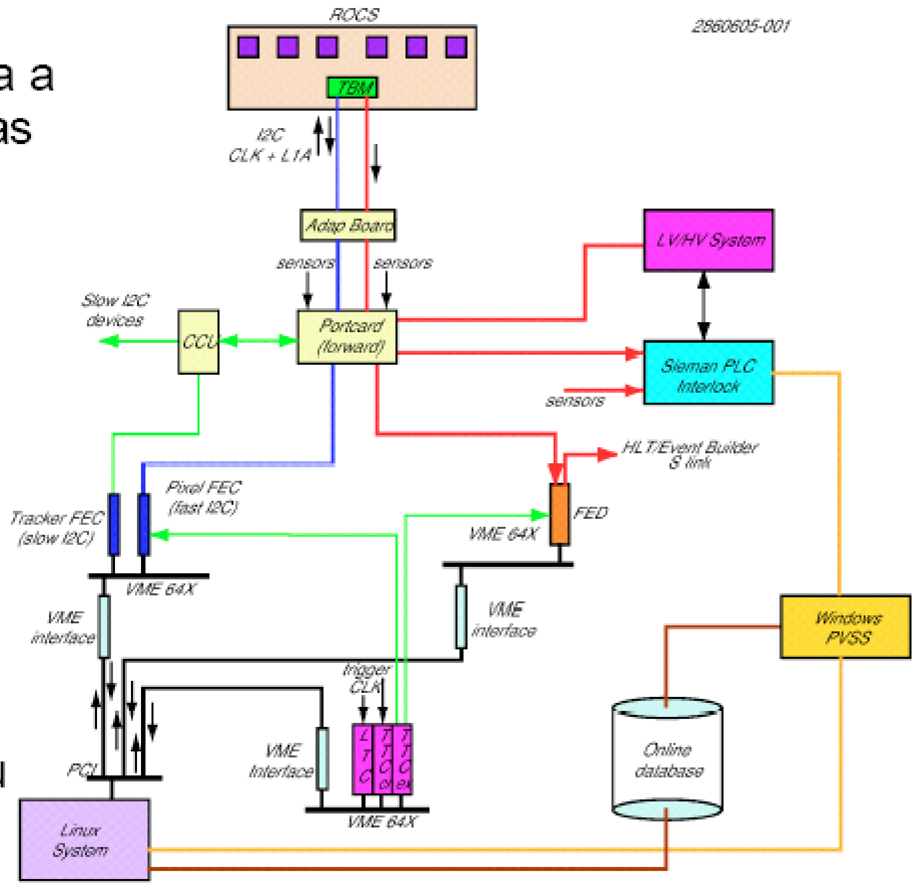




CMS Pixel Commissioning

Finding an Operational Point

- In order to be able to configure and read out data a large number of settings has to be determined
  - ROC settings:
    Timing, Pulse Height,
    Gain settings, Linearity.
  - TBM Gains
  - Delay settings for 40MHz communications
  - AOH bias and gain
  - Address levels in the FED +ADC phase adjustment
- Note that in this design you need to control the charge injection via software



CMS Pixel System has many knobs to turn → non trivial adjustment needed

"Pixel In Box" was extremely usefull to connect to the final DAQ environment

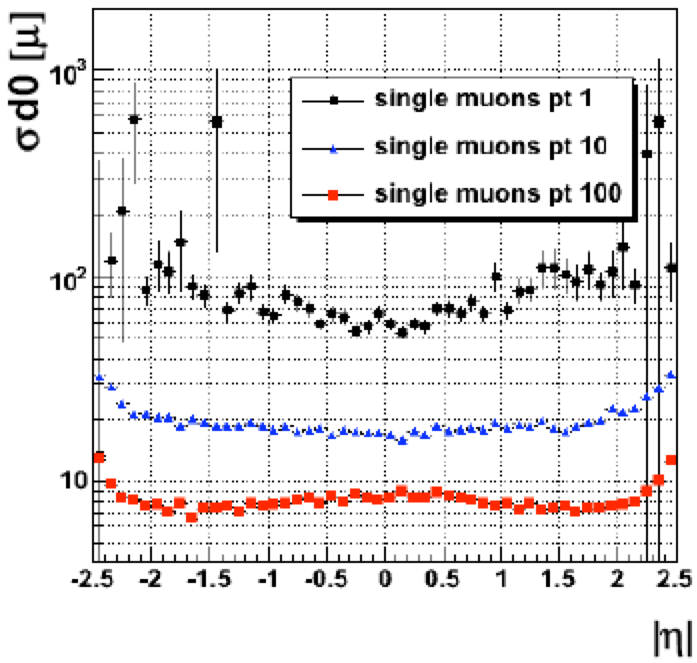
Pixel in a Box

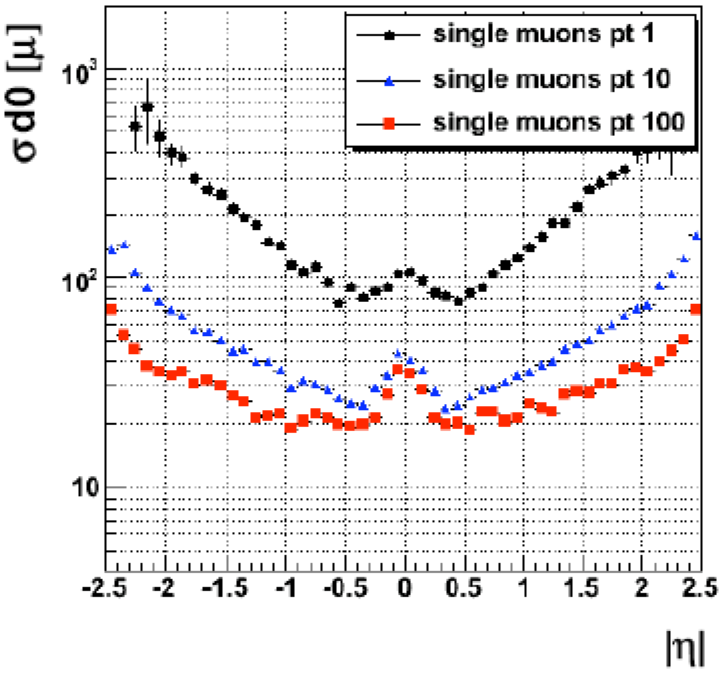
- To test integration with run control and participate in global CMS runs before the full detector was installed we prepared a small test system with one panel.
- Useful to debug run control and other operational issues.
- Installed in CMS from March-July 2008.

CMS Track Reconstruction Performance

Track reconstruction performance

Impact parameter resolution



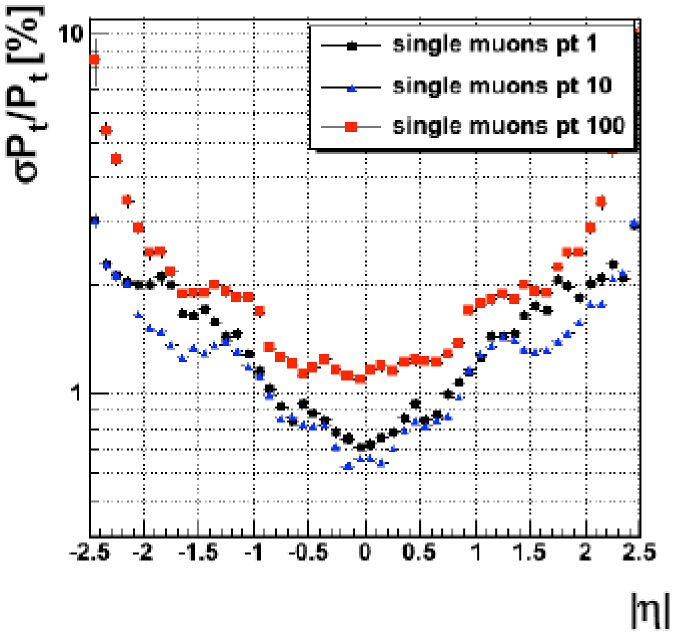


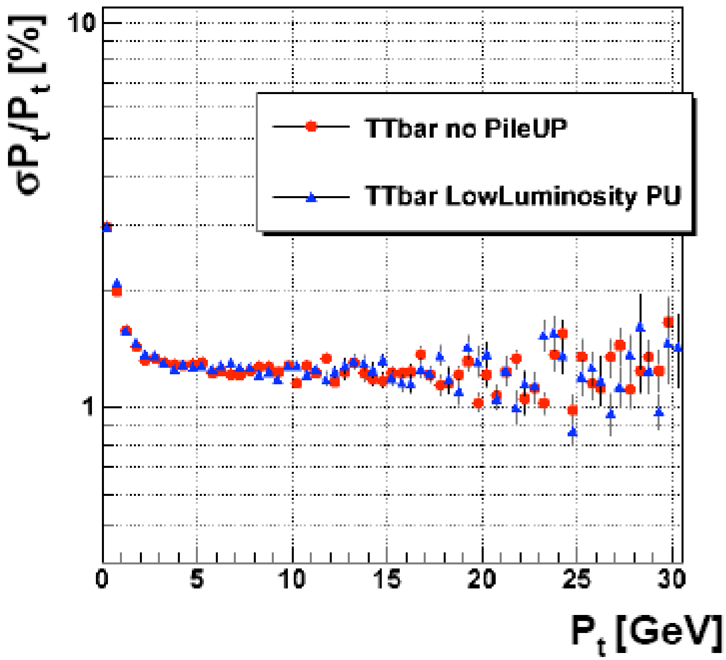
Resolution on transverse impact parameter is expected to be:

~50-60 microns for ~1 GeV particles

~10 microns for 100 GeV particles

Transverse momentum resolution

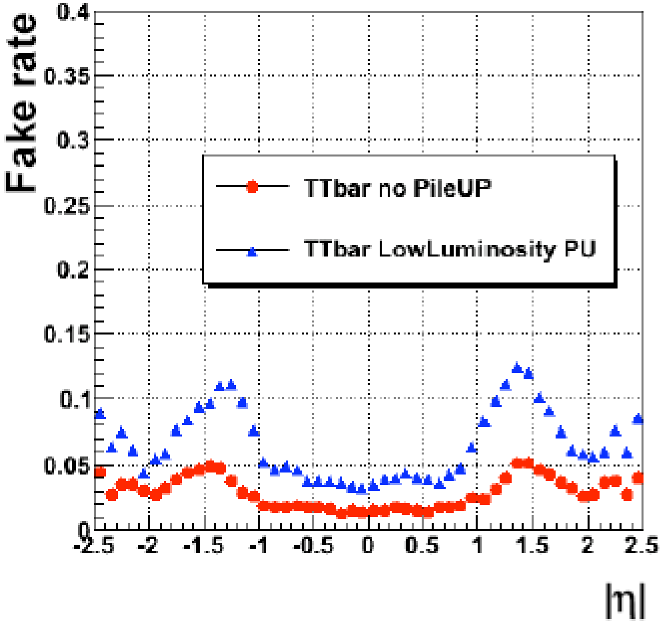


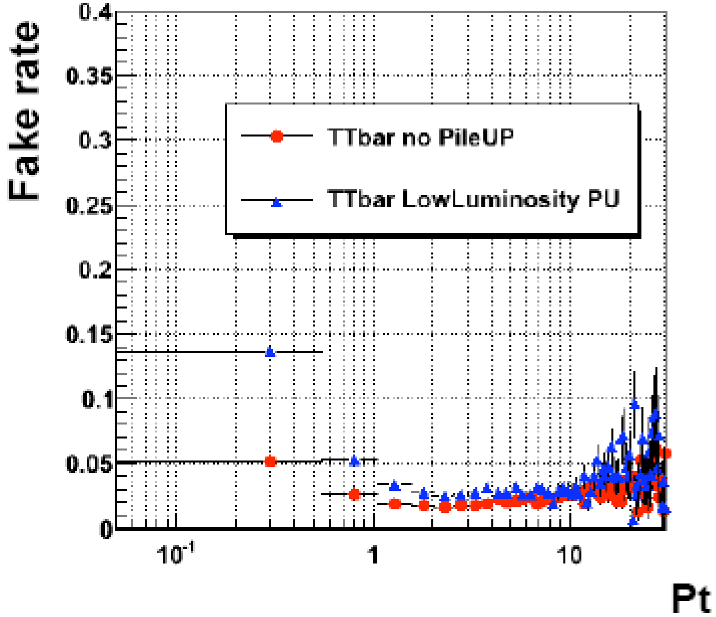


→ CMS tracker has excellent performance !!

but . .. ..

Track reconstruction performance





$$\text{Fake rate} = \frac{\text{(\# tracks NOT associated to simulation)}}{\text{(\# reconstructed tracks)}}$$

A reconstructed track is associated to a simulated one if more than 75% of its hits are "matched" to the ones of the simTrack.

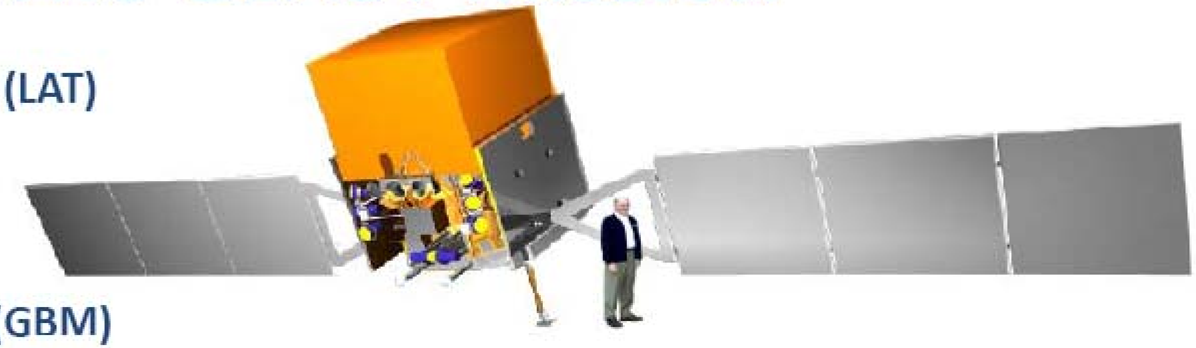
Most of the fakes are in:

- the low pt region
- barrel-endcap transition eta region

→ material budget

The GLAST mission

Large Area Telescope (LAT)
20 MeV - 300 GeV
>2.5 sr FoV



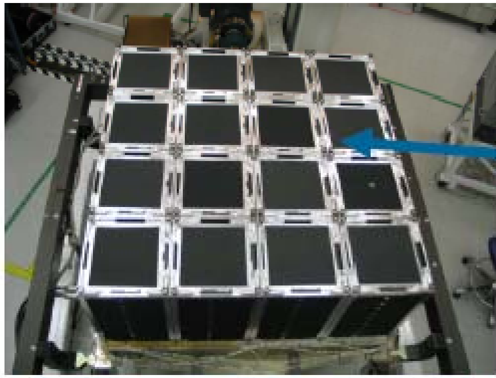
GLAST Burst Monitor (GBM)
8 keV – 30 MeV
9 sr FoV

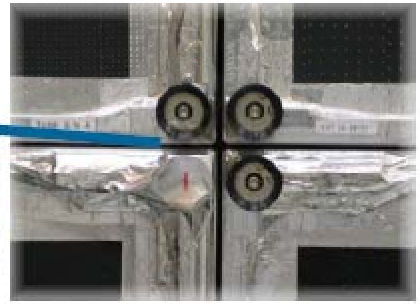
- gamma ray mapping of sky
- large silicon tracker pair spectrometer system in space (~70m^2)
- successfully launched 11. June 2008
- now in phase of commissioning follow by 1 year of observation

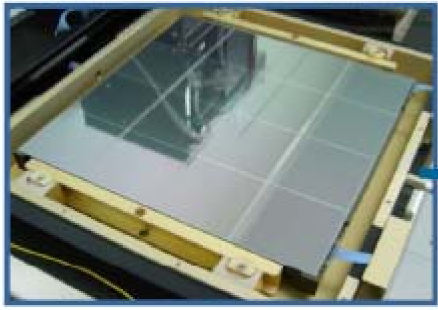
Note: seem to have cooling under control

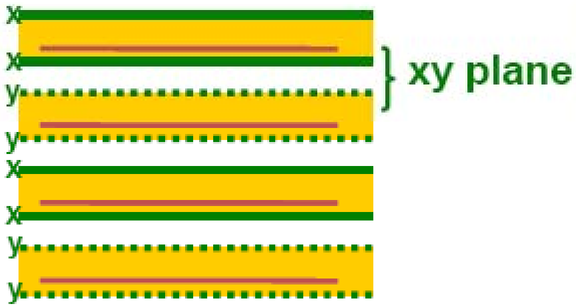
Tracker Design Overview

- **16 tower modules**
  - 37 $\times$ 37cm^2 active cross section/layer
  - 2 mm inter-tower separation in order to minimize the inactive area
  - **70m^2 of Si** (in space!!!)
  - 11500 SSD 8.95X8.95 cm^2,
  - 384 strips - 880,000 channels
  - 440 μm thick
  - 228 μm strip pitch:
- **18 *xy* layers per tower**
  - 19 "trays" structure
    - 12 with 2.7% X_0 W
    - 4 with 18% X_0 W
    - 3 with no converter foils
  - every tray is rotated by 90°
  - W foils are followed by
    - *x,y* plane of detectors
    - 2mm gap between
- **Electronics on sides of trays:**
  - Minimize gap between towers

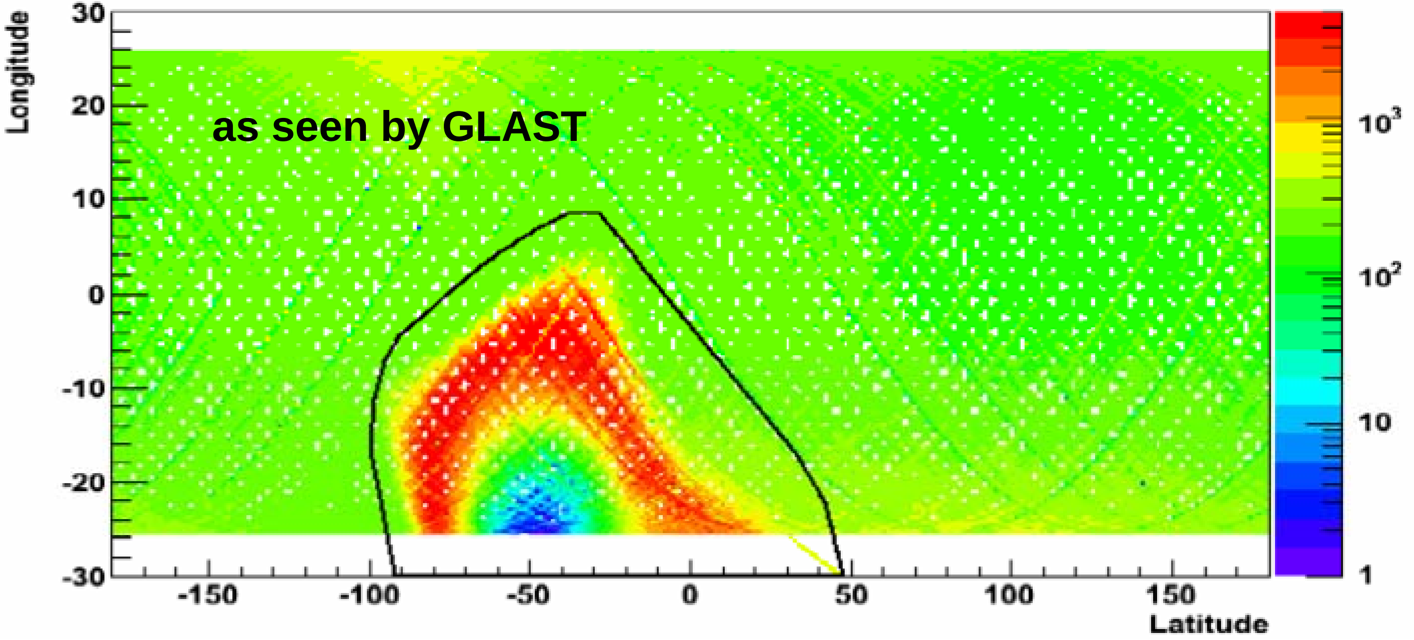


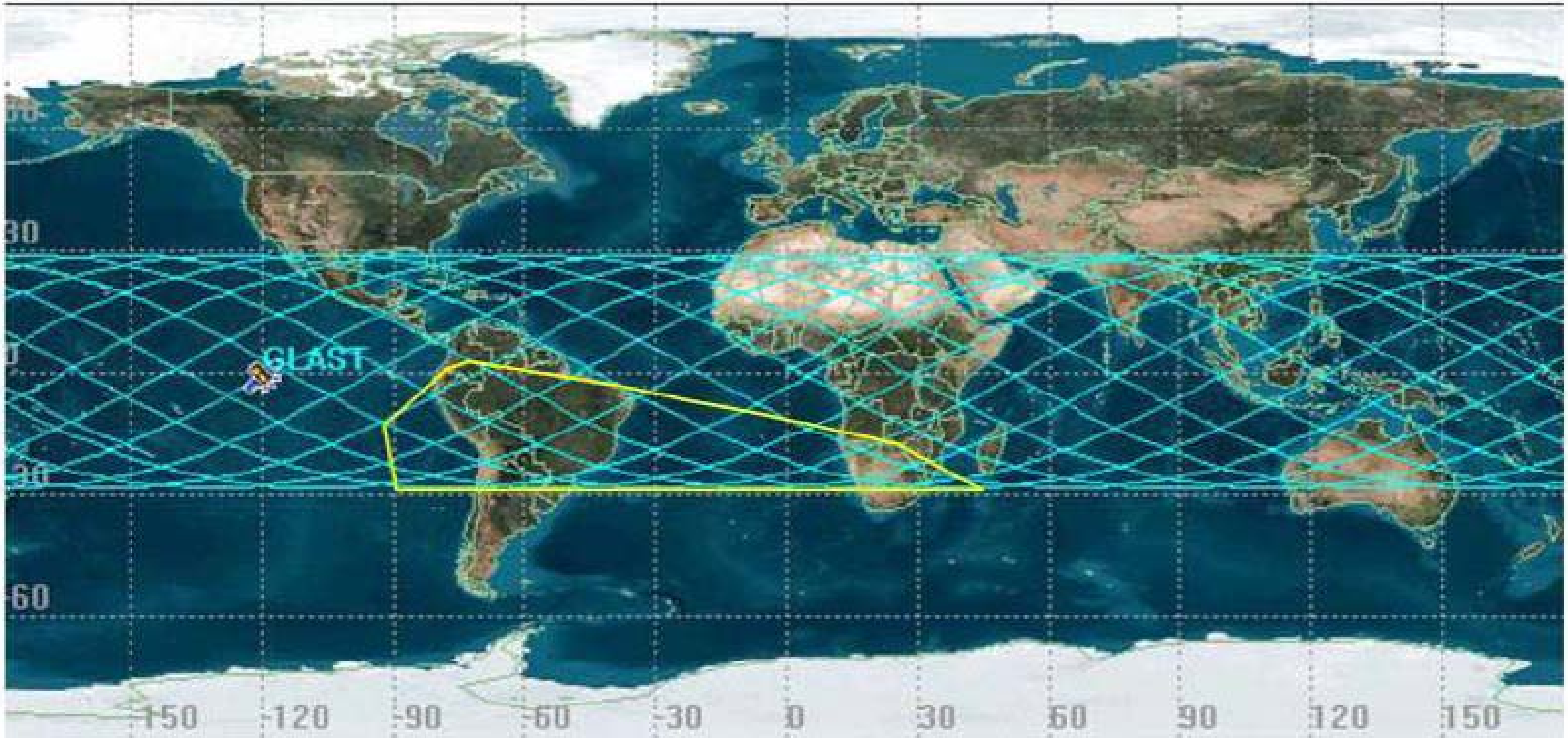






Sout Atlantic Anomaly





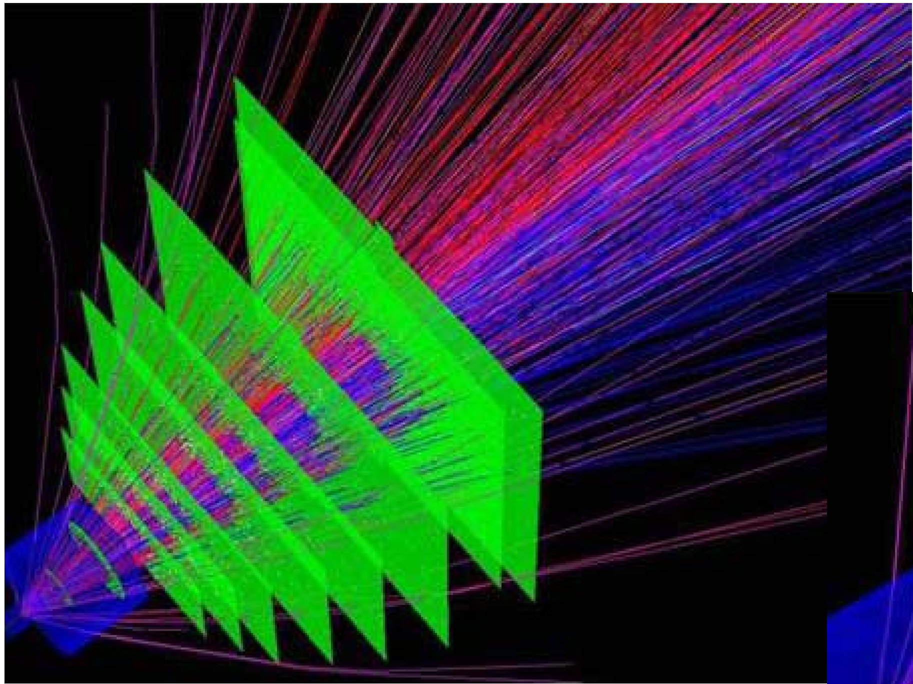
Silicon Vertex Detectors for FAIR

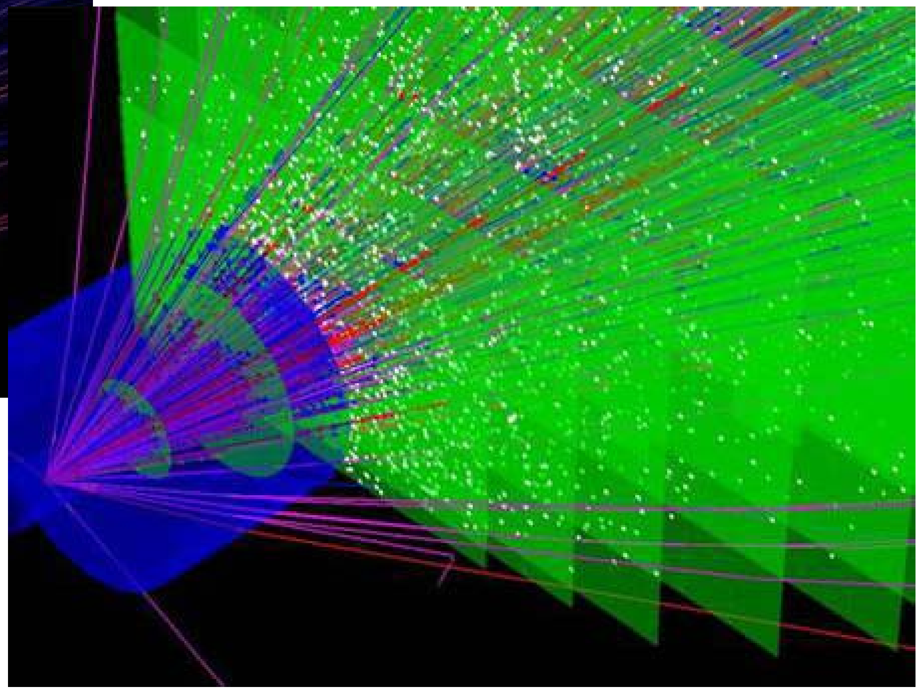
Compressed Baryonic Matter Experiment

the mission ...

... tracking nuclear collisions

- Au+Au interactions, 25 GeV/u, 10 MHz interaction rate
- up to 1000 charged particles/event
- Track densities ≤ 30 cm^{-2}

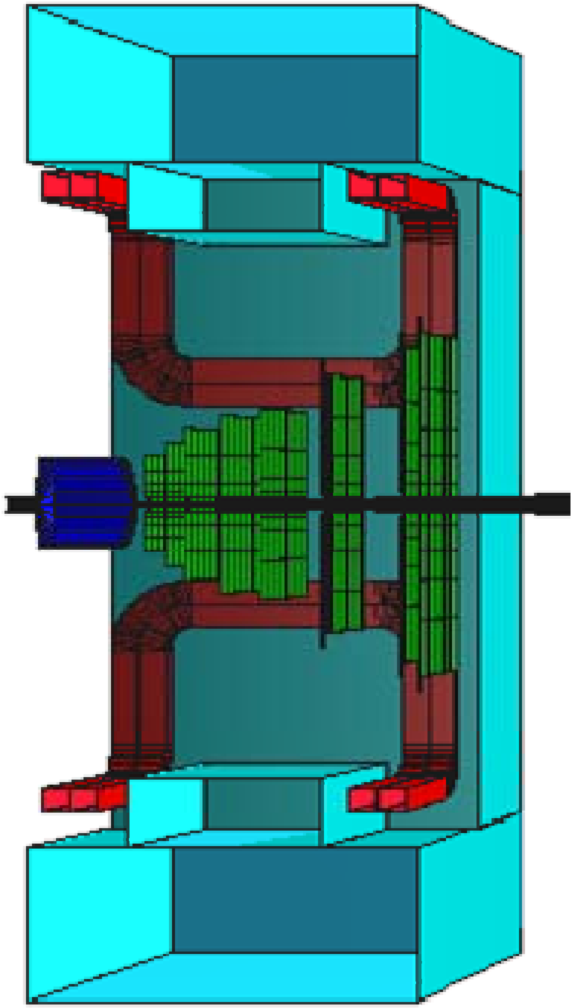




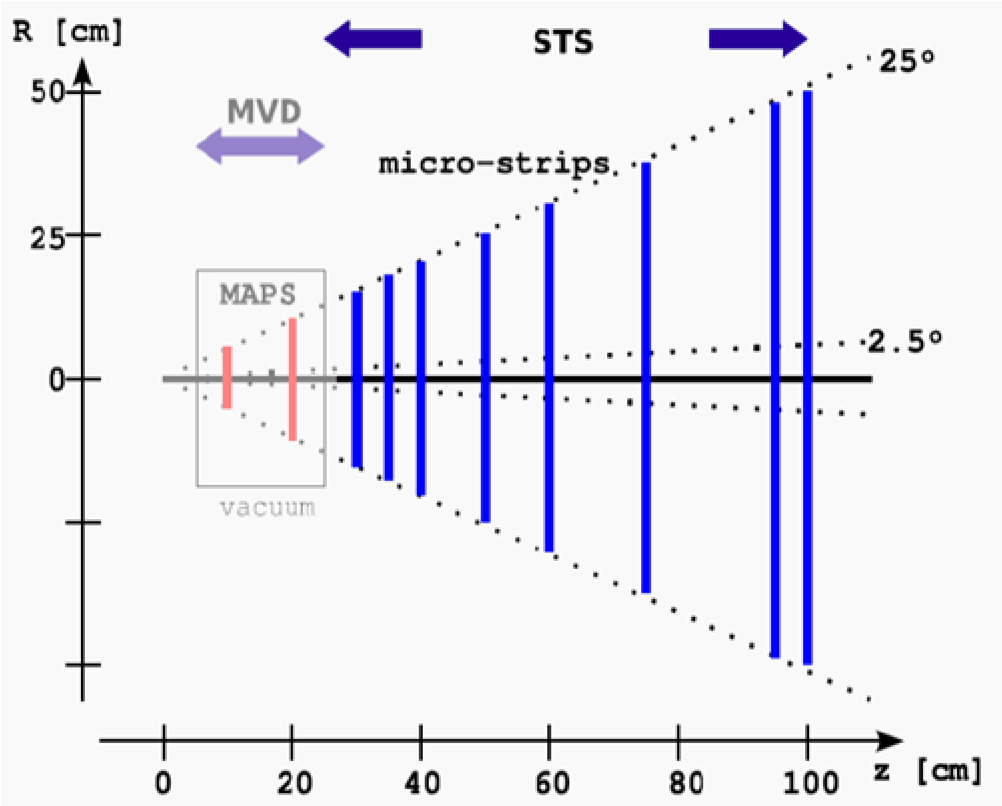
UrQMD generator:
Monte Carlo tracks ...

+ micro vertex detection:
presentation by M. Deveaux

Exploration of a system concept



1 T dipole magnet



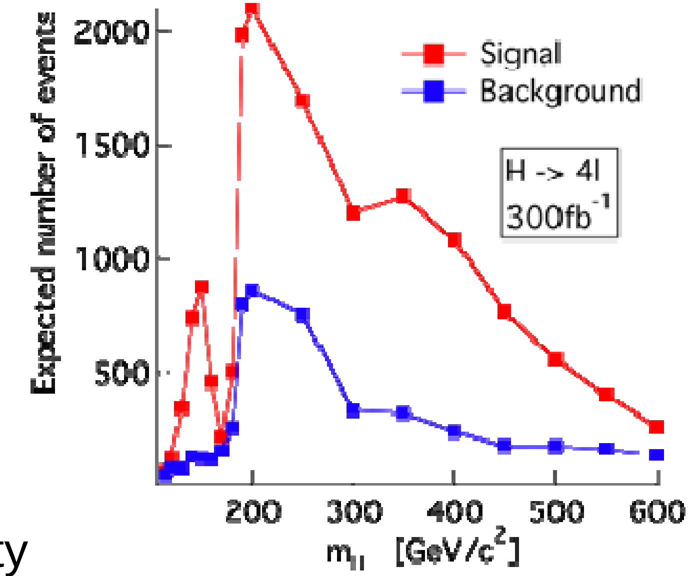
STS: 8 low-mass micro-strip station

Development have started → we look forward for future Vertex Conferences !

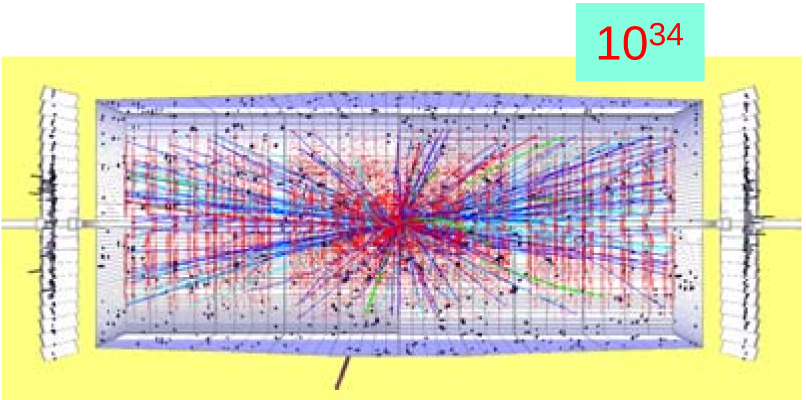
CMS Tracker Upgrade programme

- Limited statistics – eg:
  - and time to reduce errors

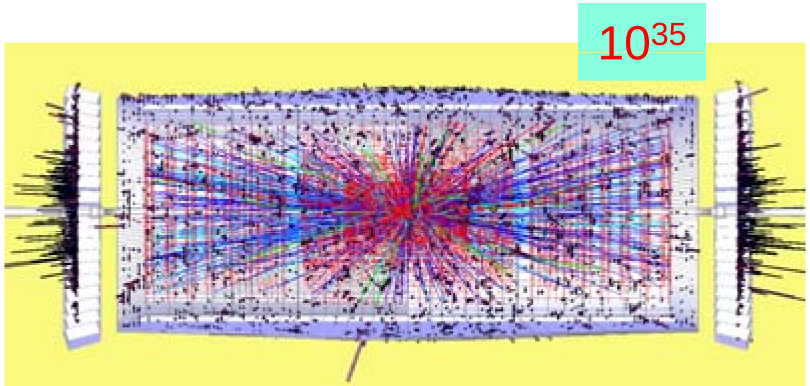
- However, the environment is very challenging:



- H→ZZ → μμee, M_H= 300 GeV vs luminosity



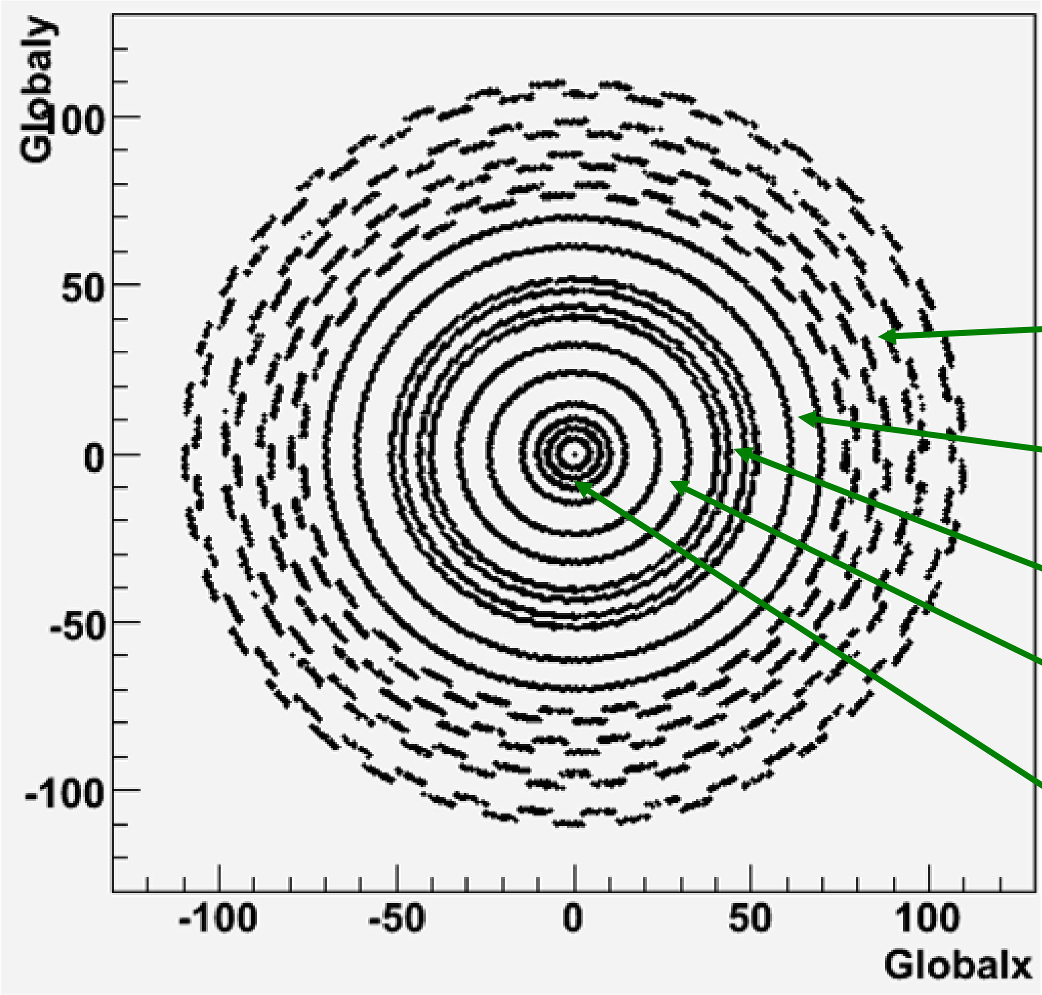
Full LHC luminosity
~20 interactions/bx



Proposed SLHC luminosity
~300-400 interactions/bx

Different Strawman layout now under study

- A working idea from Carlo and Alessia **Strawman A**
  - Take current Strawman A and remove 1 “TIB” and 2 “TOB” layers



Strawman A r-phi view
(RecHit ‘radiography’)

4 TOB short strips
Remove 2

2 TOB strixels
Adjust chn count

2 TIB short strips
Remove 1

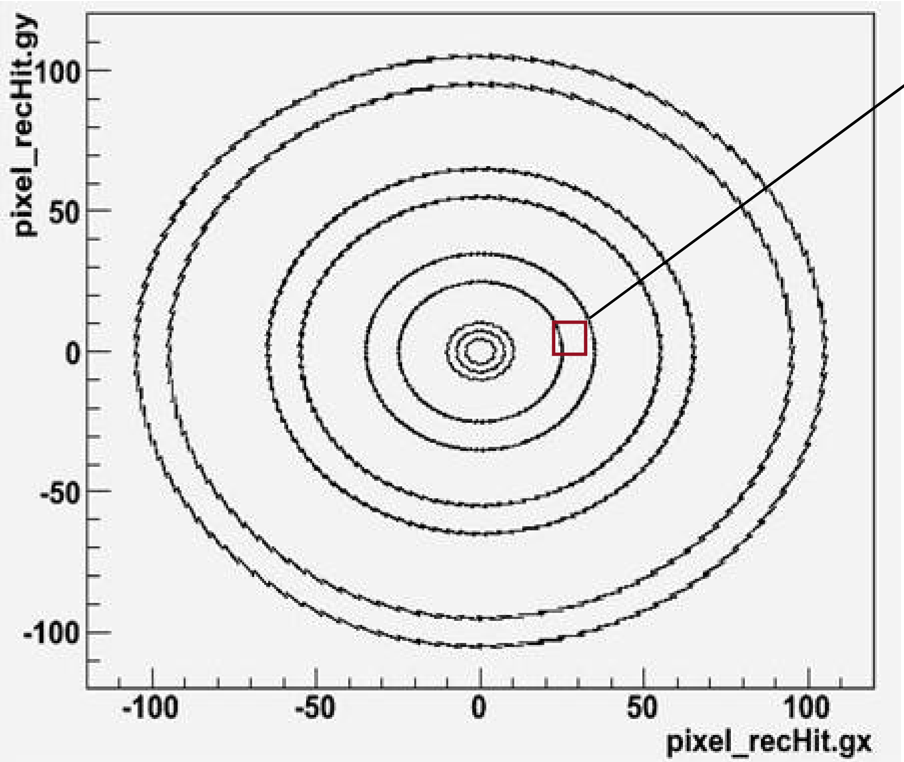
2 TIB strixels
Adjust chn count

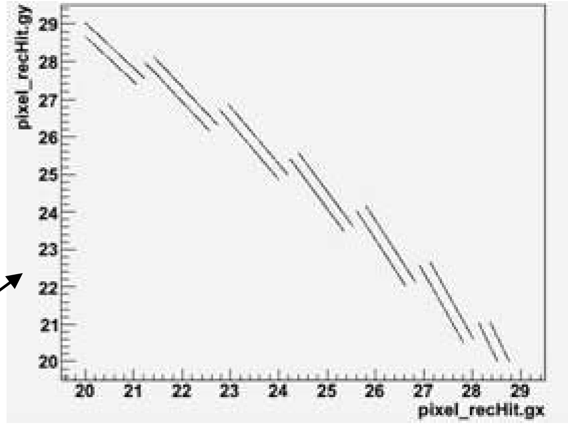
4 inner pixels

Strawman B

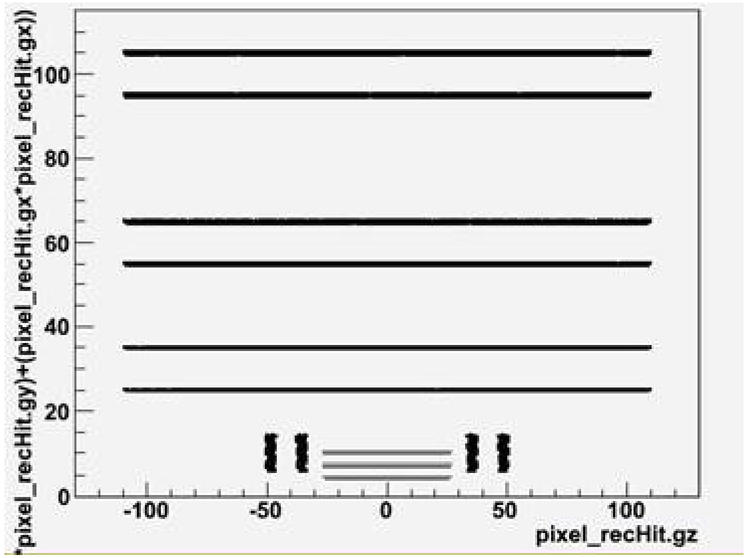
- Adjust granularity (channel count) of Strawman B layers
  - Keep the TEC for now until someone can work on the endcaps

Strawman B r-phi view
(RecHit ‘radiography’)





r-z view



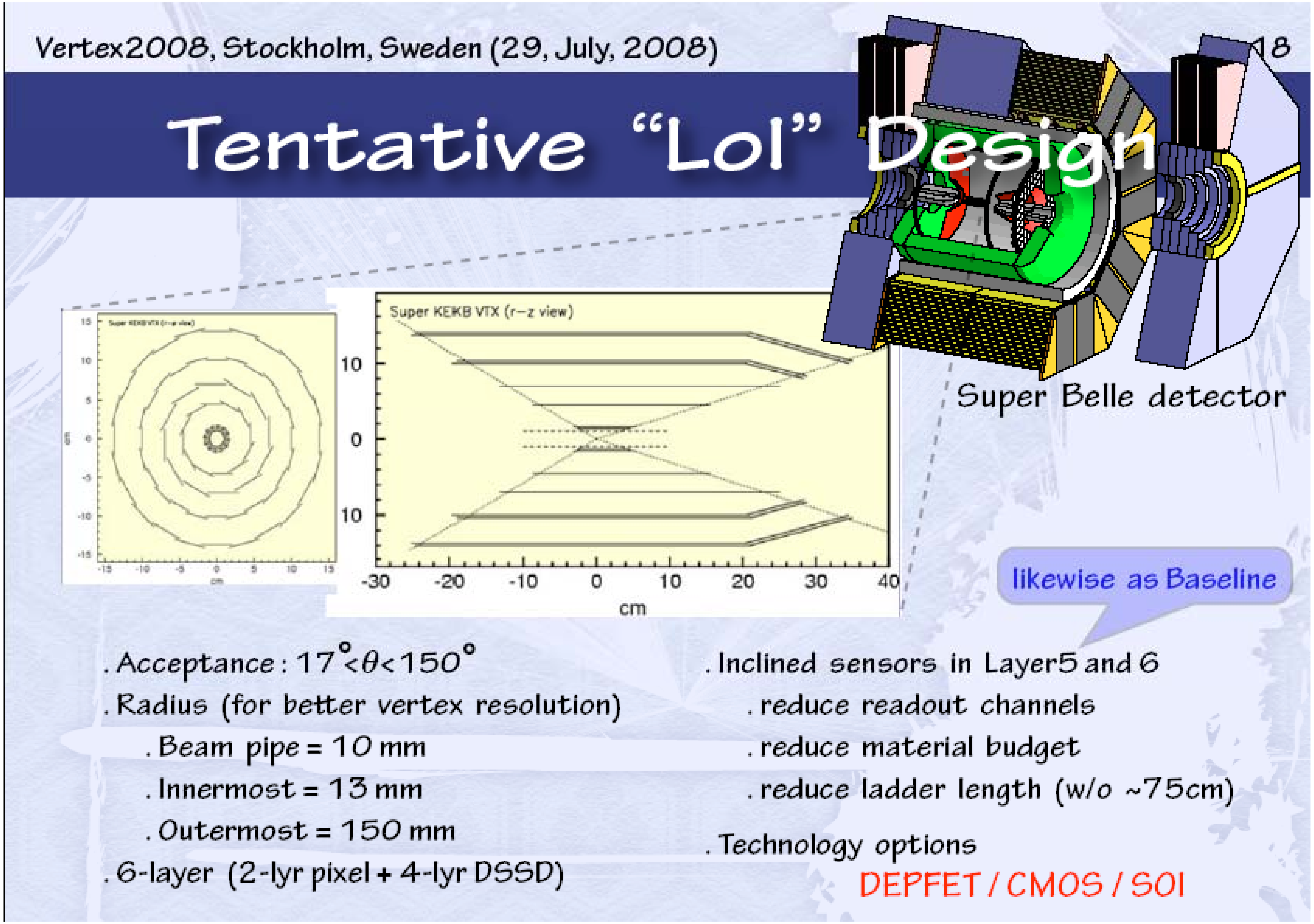
LHCb Upgrade

- Upgrade LHCb detector such that it can operate at 10 times design luminosity of $\mathcal{L} \sim 2 \times 10^{33}$ $cm^{-2}s^{-1}$
- Accumulate ~100 fb^{-1} without detector replacement

→ **looking to use hybrid pixel detectors for VELO replacement**

→ **adapt FPIX chip development for former BTeV experiment**

Super Belle B-factory Vertex Detector



Technology options

	DEPFET	CMOS (CAPS/MAPS)	SOI
Material budget	20 ~ 100μm (adjustable)	<~50μm (sensitive area 5~10μm)	50~100μm (could be <~50μm)
Size	limited by wafer (50×75 mm^2)	limited by reticle (21×21 mm^2)	limited by reticle (21×21 mm^2)
Power consumption	small (0.5w) (reset switcher chip: Voltage swing > 8V)	small	small
Rad.-hardness (3MRad/yr ?)	tested < 1MRad (up to 8MRad?: irradiation test)	intrinsic rad. hard (must be > 30MRad)	tested > 30MRad
10kHz trig. rate	estimated ~1% ineff.	? (CAP3 too slow)	not proved
Availability	MPI only (already used in other exp.)	R&D in progress	R&D in progress

Readout Chip for outers

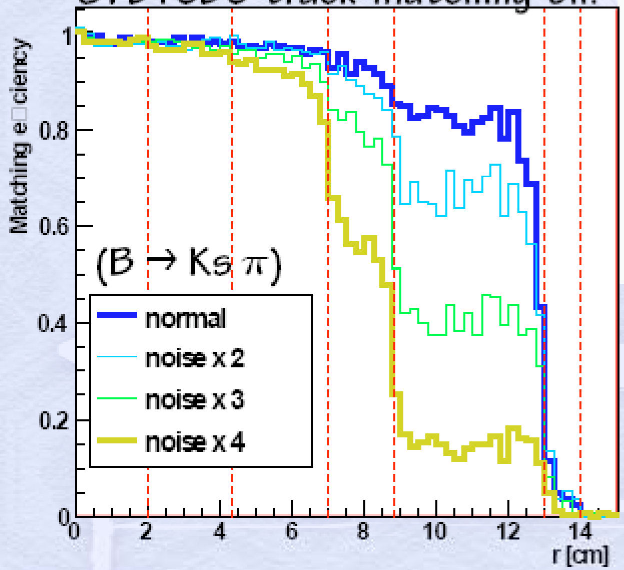
High trigger rate (~10kHz) : Pipeline readout → APV25

beam BG tolerant : Shorter shaping time is preferred, but not critical

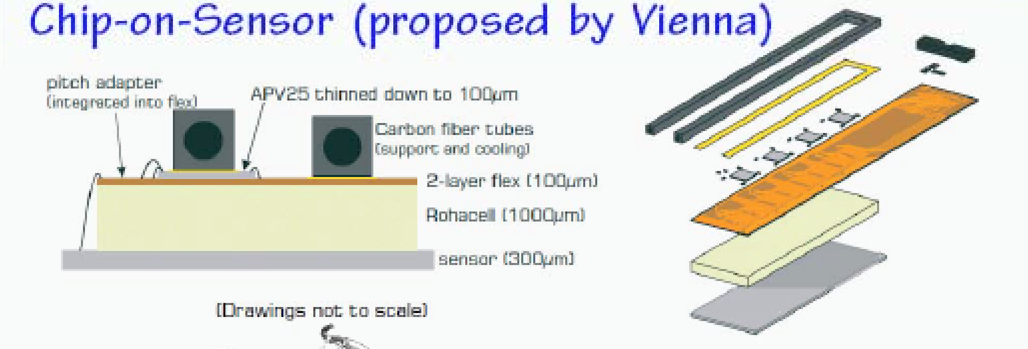
longer sensor + APV25 → worse S/N (VA1TA~16 for outer layer)

R=16cm   17°< θ < 150°

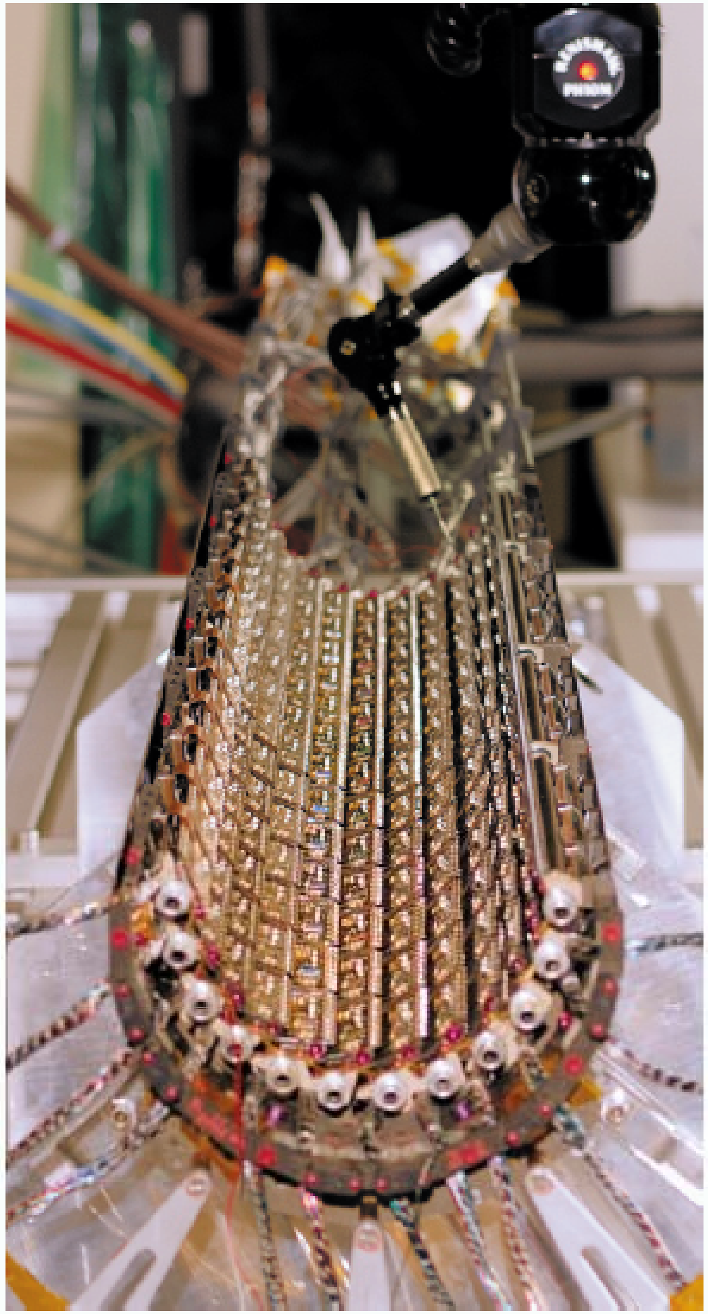
SVD+CDC track matching eff.



Chip-on-Sensor (proposed by Vienna)



FE Electronics for the B-Layer replacement or SLHC in ATLAS



Vertex2008

July 28–August 1, 2008,
Utö Island, Sweden

Roberto Beccherle
[on behalf of the ATLAS Pixel Collaboration]
Email: Roberto.Beccherle@ge.infn.it

B-Layer replacement options

A. Replace the Pixel Detector with a simpler 2 hit system with present technology (case of disaster) is not realizable (collaboration to build it, spares not available)

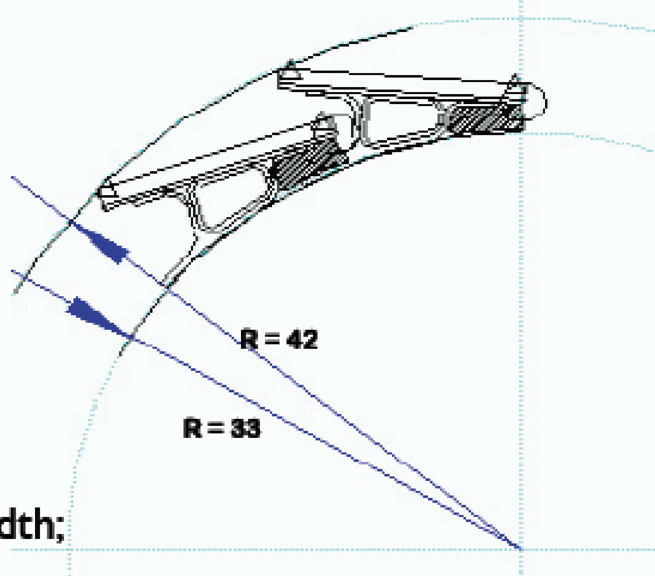
B. Insertion of a smaller b-layer and a smaller beam pipe inside the existing detector.

✦ Insertable B-Layer with present technology:

- Possible fall-back from preferred solution.

✦ Insertable B-Layer with new technology:

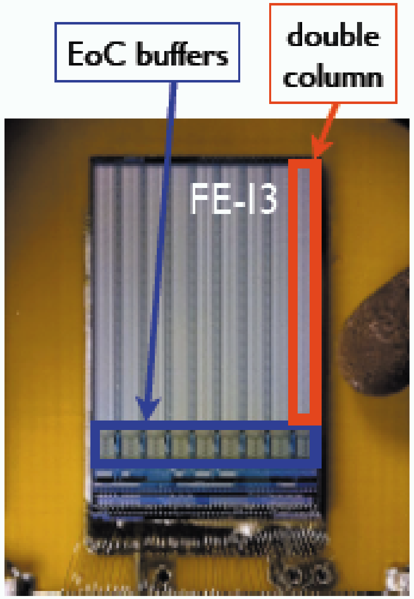
- Seems feasible (Requires new smaller beam-pipe).
- 16-staves not shingled b-layer.
- New chip design (FE-I4): Live fraction, I/O bandwidth;
- New Sensor design: Increase radiation hardness (400 fb^{-1} between 2013 and 2016) due to the smaller radius and the ramping up of LHC luminosity.

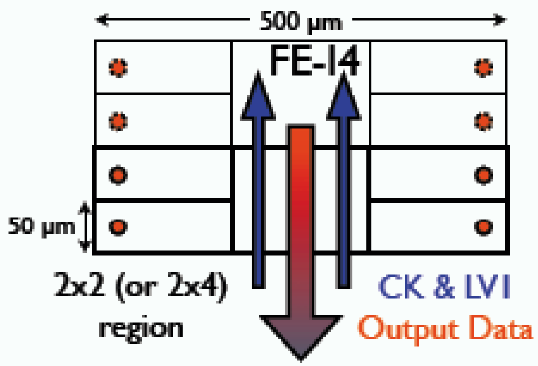


- R&D and prototyping in 2009 – construction 2010-2012;
- The critical part is the very short R&D time available for the new design.

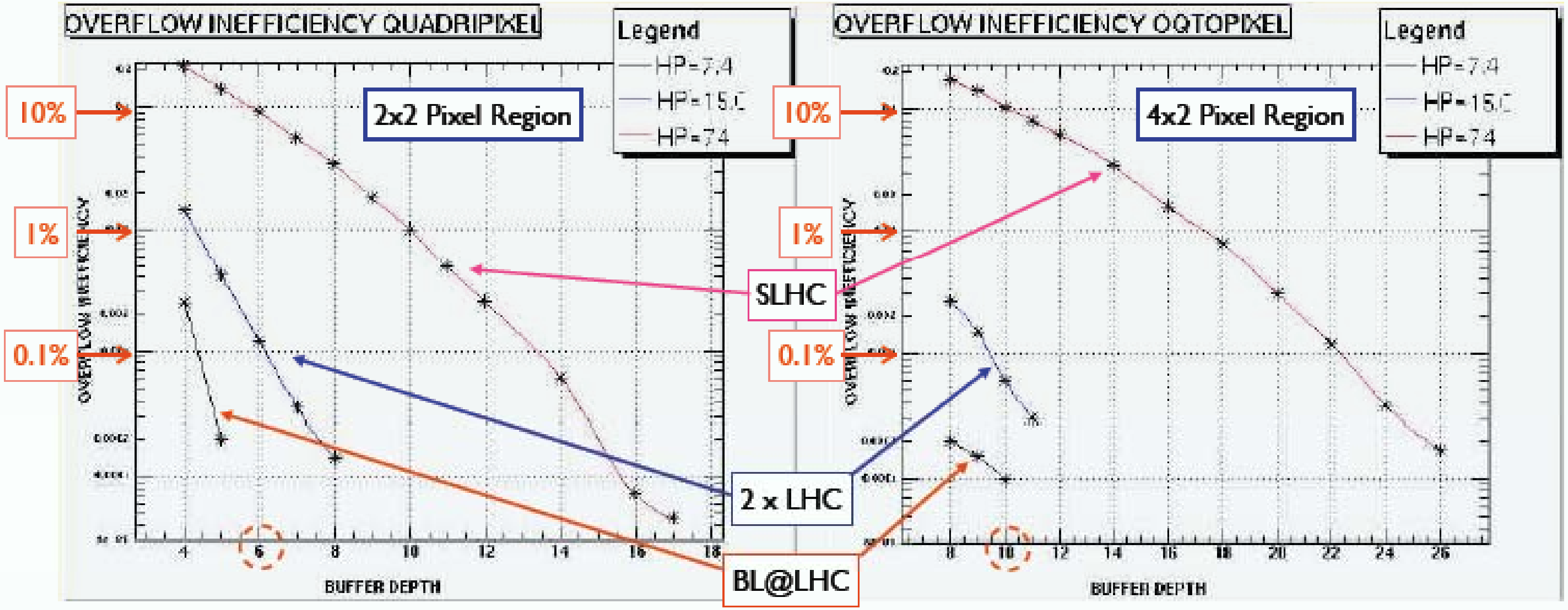
Need for a new architecture

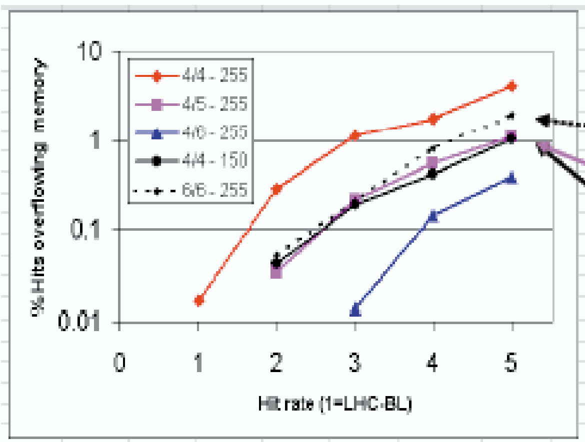
- Double column bus occupancy and the number of EoC buffers implemented as in FE-I3 and power consumption do not scale well with size and higher event occupancy. All data is processed and copied to the EoC buffers, but only < 1% gets triggered!
- The basic idea is to store all the information as long as posible locally in the Pixel region and to transfer to the periphery only the amount of information that has really to be transferred off chip.
- We still want to keep the Time over Threshold option, as in FE-I3.
- Storing all information directly in the pixels is also not feasible as one buffer per pixel would surely not be enough, and two would not fit.
- Therefore the idea is to put together "as many pixels as possible" forming "local regions" of pixels that can share buffers and logic in order to optimize the overall number of needed buffers.
- There has to be a compromise between the number of pixels grouped together which leads to a lower number of buffers, but a higher complexity in the routing and combinational logic needed to deal with the common region.





Local Buffer depth effects





Larger region

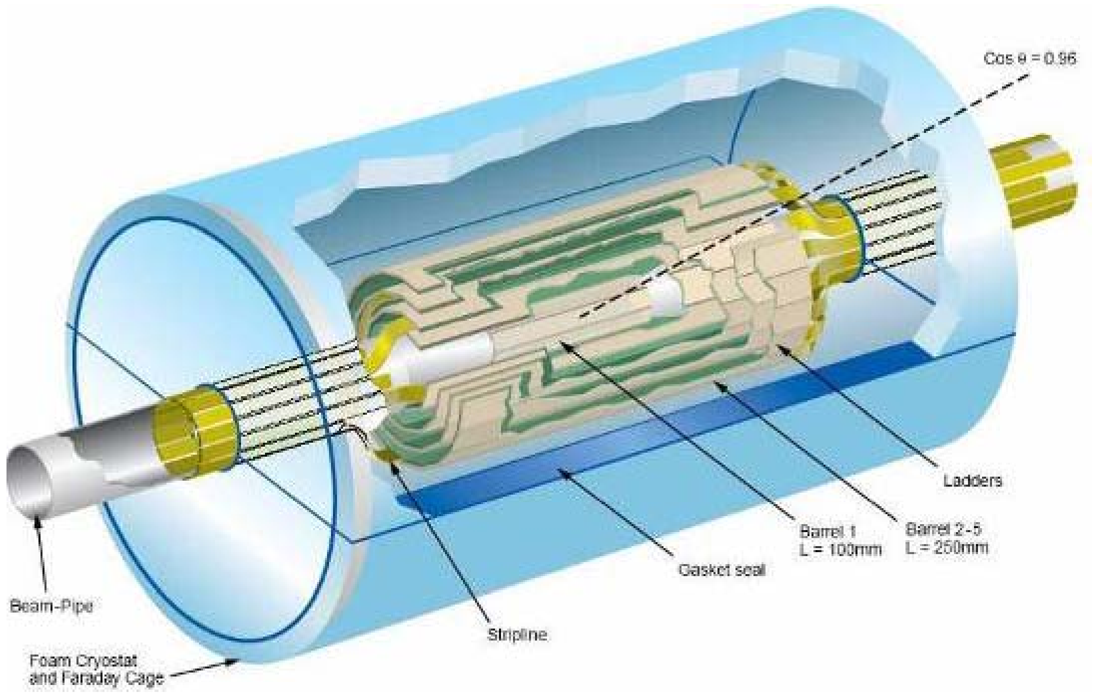
More Buffers

Faster Erase

- Inefficiency as function of Local Buffer Depth.

Simulation work is critical in order to understand correct scaling of most available parameters.

ILC vertex detector



- **Precision measurement of jet energies is not enough: which are b-jets, charm-jets or light quark jets? For the heavy quark jets, which are quarks and which anti-quarks? Latter is most cleanly established by measuring the 'vertex charge', pioneered with considerable success by SLD**
- **Achieving the required performance is the task of the most expensive ILC detector R&D topic – currently 9 options are being pursued**

VXD technologies

- All approaches aim for ~3 μm precision and <40 μm 2-hit resolution

- Target material budget is ~0.1% X_0 per layer

- They vary from single-bunch time stamping to time integrating with special compensating features

- List them in approximate order of adventurousness – one or two are more likely to be candidates for second generation upgrades

FPCCD – Yasuhiro Sugimoto *(Takubo-san, this wkshop)*

•CCD with 5 μm pixels, read out once per train; 20 times finer pixel granularity instead of 20 time slices

CPCCD – Andrei Nomerotski

•Fast readout of CCD aiming for 50 μs frame rate

•Main novel features are column parallel readout, with bump-bond connections on 20 μm pitch to readout chip including amp, analogue CDS, ADCs, sparsification and memory

CMOS MAPS (MIMOSA) – Marc Winter

•3T architecture, limited to NMOS transistors in pixel

DEEP n-well – Valerio Re *(Francesco Forti, this wkshop)*

•Full CMOS in pixel, collecting signal charge o nthe deep n-well that houses the NMOS transistors (triple-well process)

CAP – Gary Varner

•CMOS MAPS, with signal storage (after charge-to-voltage conversion) on in-pixel capacitors

DEPFET – Laci Andricek

•Signal charge stored on ‘internal gate’ – unique in-house technology

Chronopixels – Dave Strom

•Goal is to time-stamp (single bunch) by pixel functionality that can fit into a 10 μm pixel (full CMOS wirh 45 nm design rules)

Vertically integrated pixel detectors (SOI & 3D) – Ray Yarema *(Grzegorz Deptuch, this wkshop)*

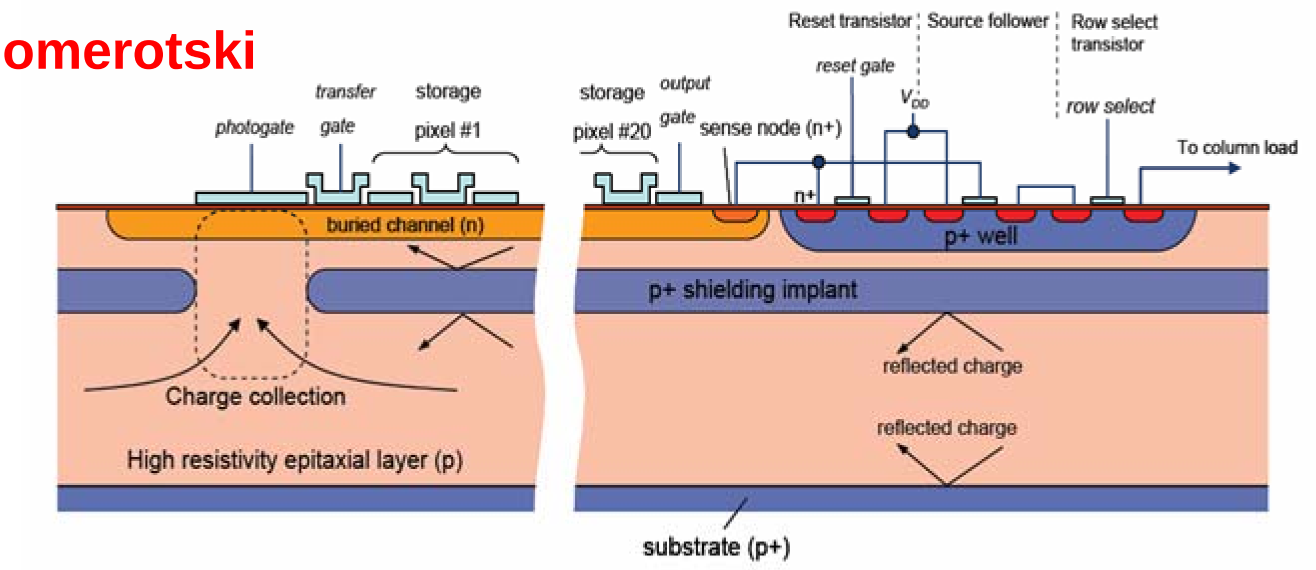
•An impressive strategy to be liberated from the constraints of CMOS by developing tiered systems

ISIS – Andrei Nomerotski

Collection pixel

not equal

Read out pixel



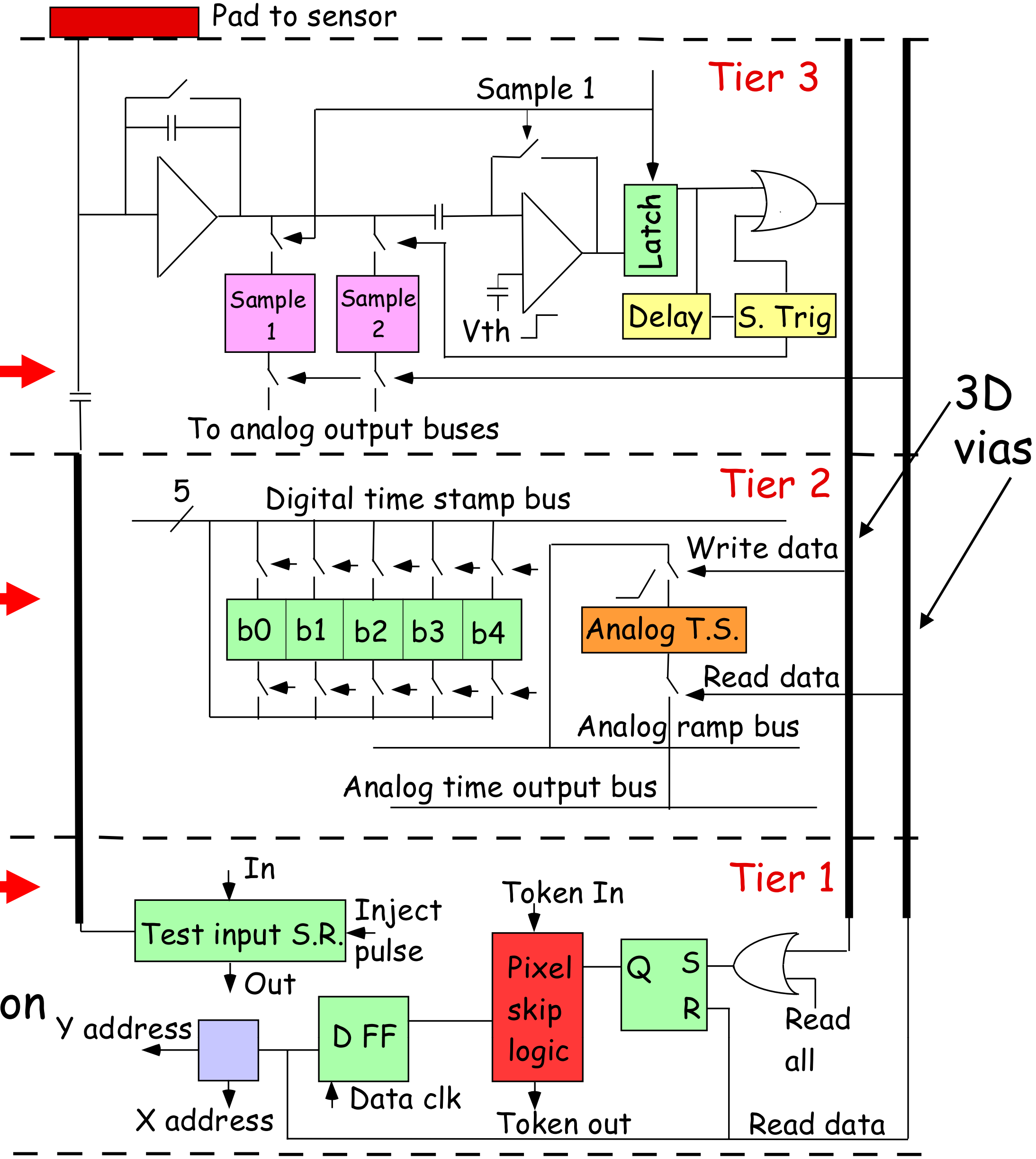
Vertical Integration of Integrated Circuits & Pixel Detectors

VIP: distribution between layers

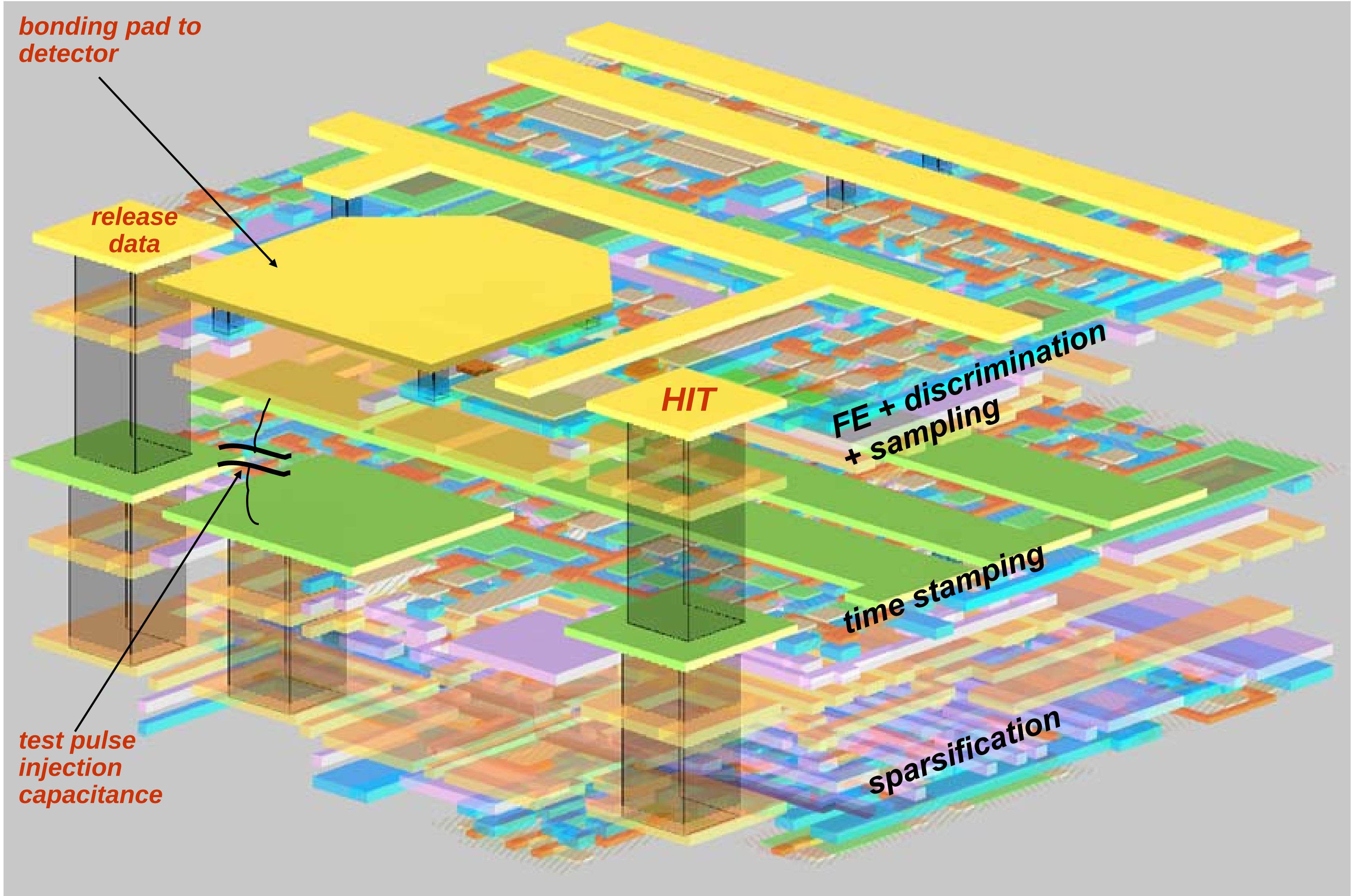
38 transistors — Tier 3 analog

72 transistors — Tier 2 Time Stamp

65 transistors — Tier 1 Data sparsification



VIP: layout view with 3D Design Tool by Micro Magic:

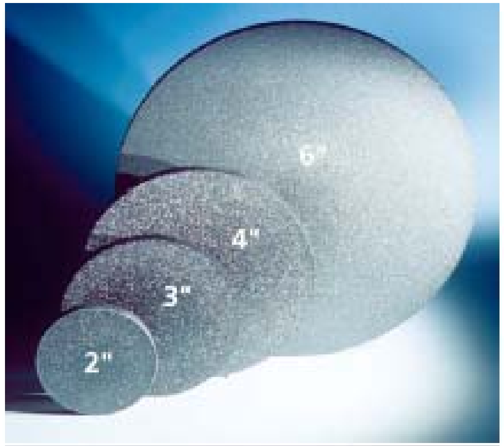


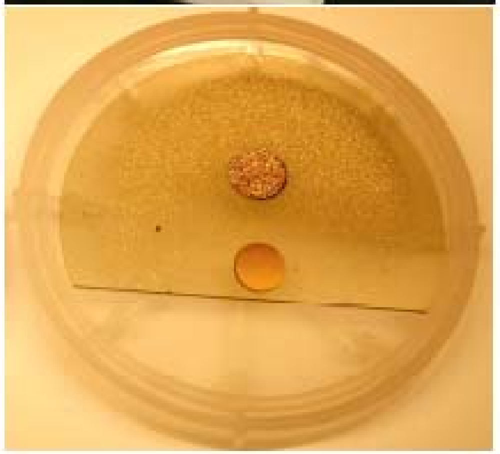
First chips have been manufactured !!! → yield could improve when going to bulk CMOS

New Manufacturers Developing Detector Grade Diamond

Status:

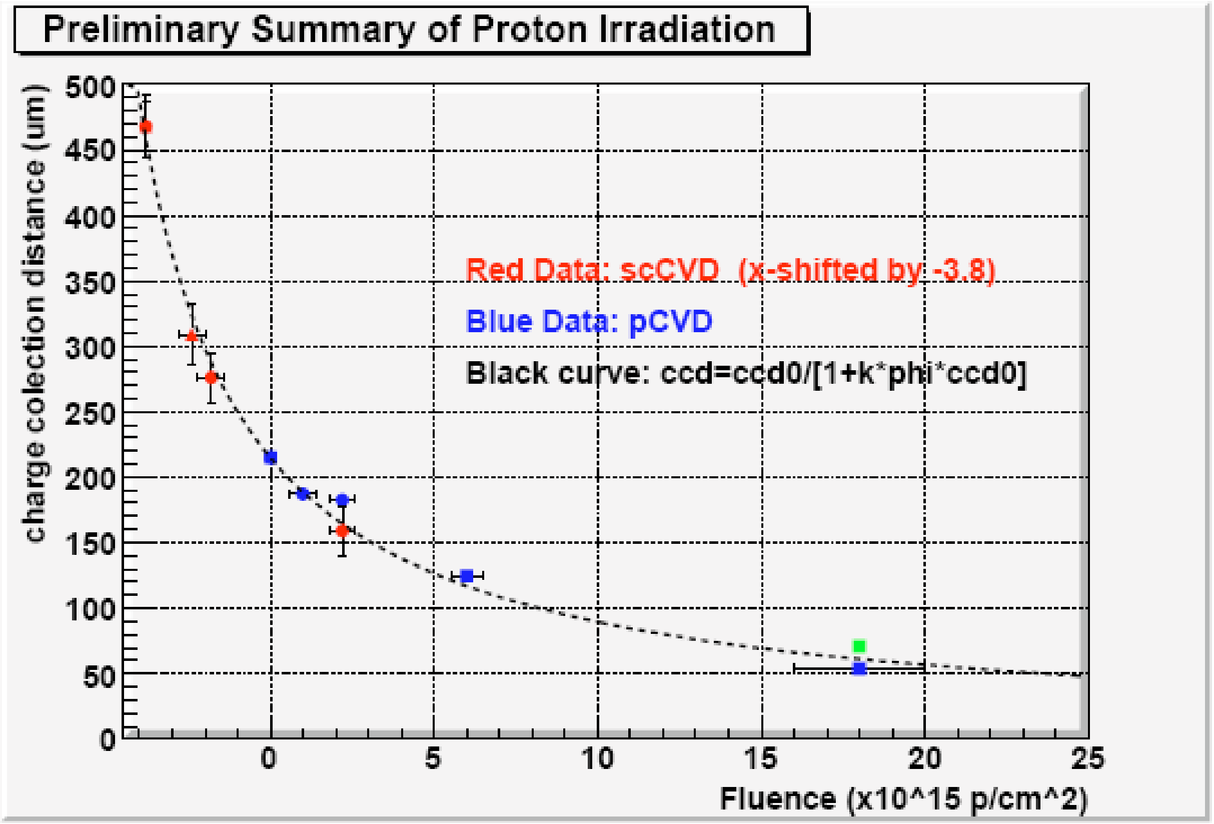
RD42 has begun working with two companies (Germany, US) to develop detector grade diamond material





- First samples from companies show charge collection distance $\sim 100\mu m$

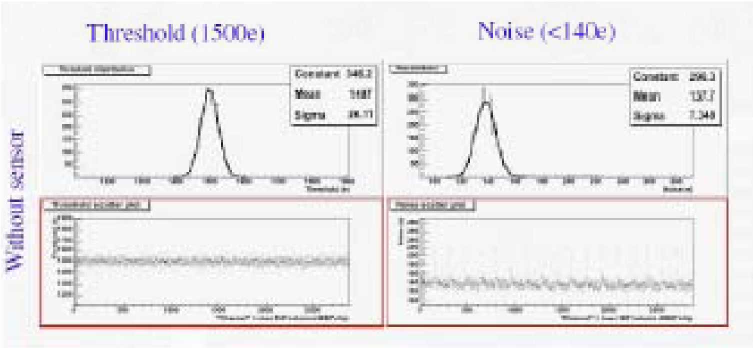
Proton Irradiation Summary - preliminary:



Preliminary summary of proton irradiation results for pCVD (blue) and scCVD diamond (red) at E=1V/μm up to 1.8×10^{16} p/cm^2 (~500Mrad).
pCVD and scCVD diamond follow the same damage curve:
$1/\text{ccd} = 1/\text{ccd}_0 + k\,\phi$.

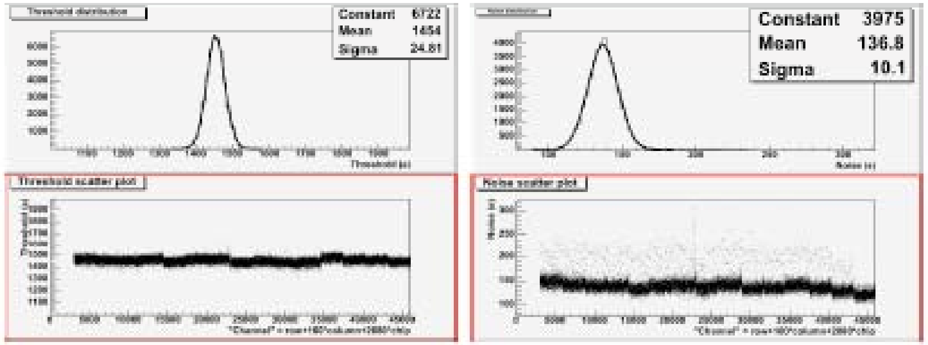
The ATLAS pixel module - Noise, Threshold

Bare Chips

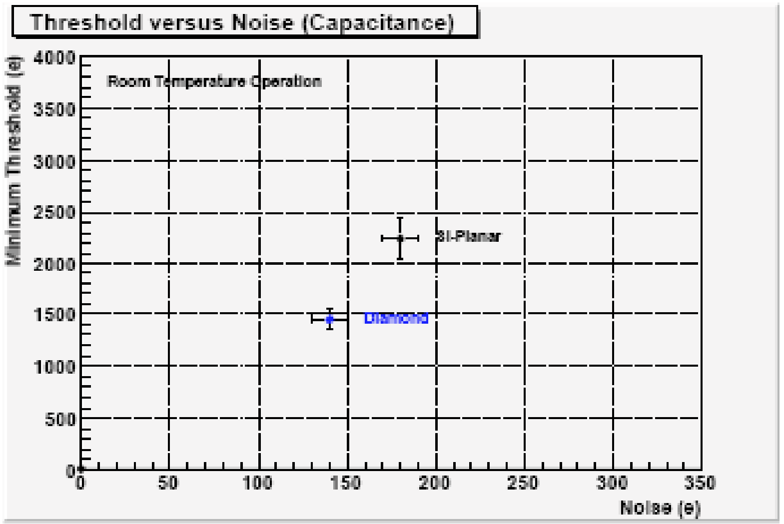


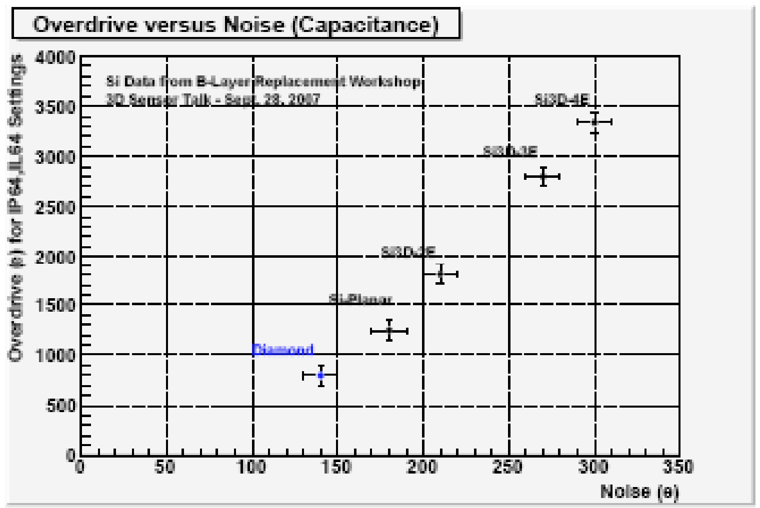
Noise $\sim$ $140e$, Mean Threshold $1500e$, Threshold Spread $\sim 25e$.

with Diamond Detector



Noise $\sim$ $137e$, Mean Threshold $1454e$, Threshold Spread $\sim 25e$.

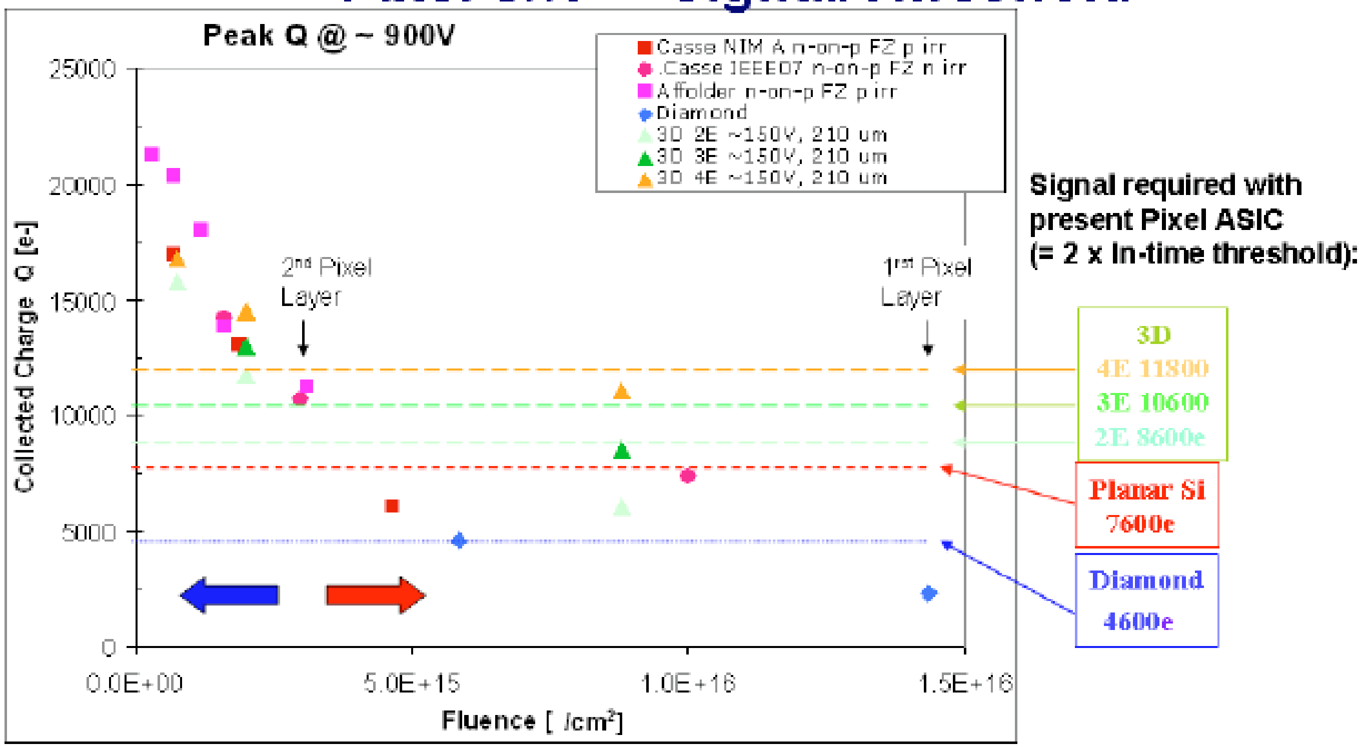




Radiation Hardness Comparison

Signal/2x In-time Threshold (from H. Sadrozinski Jun08 ATLAS talk):

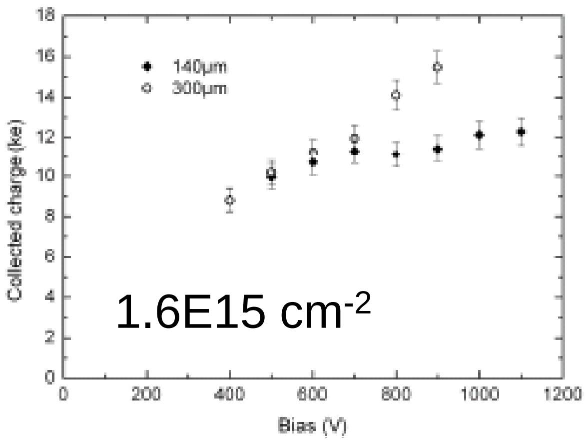
Pixel S/N -> Signal/Threshold

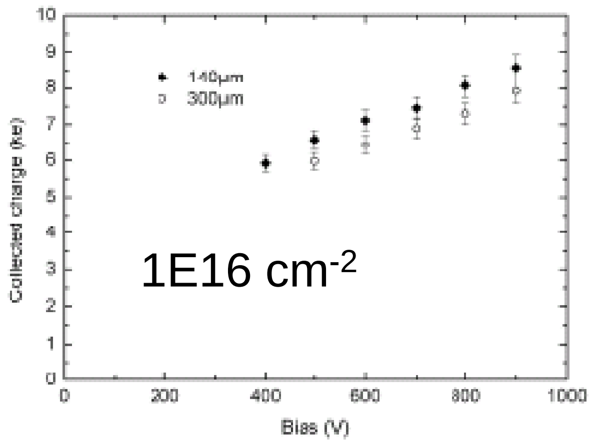


Need to optimize FEE

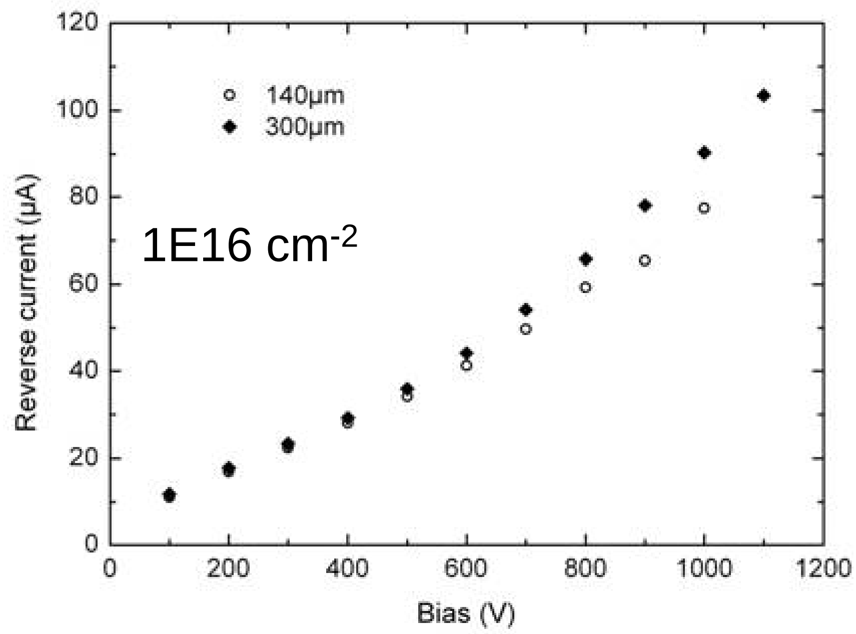
Marginal performance for innermost Pixel Layer

Charge Collection Efficiencies Studies in Silicon



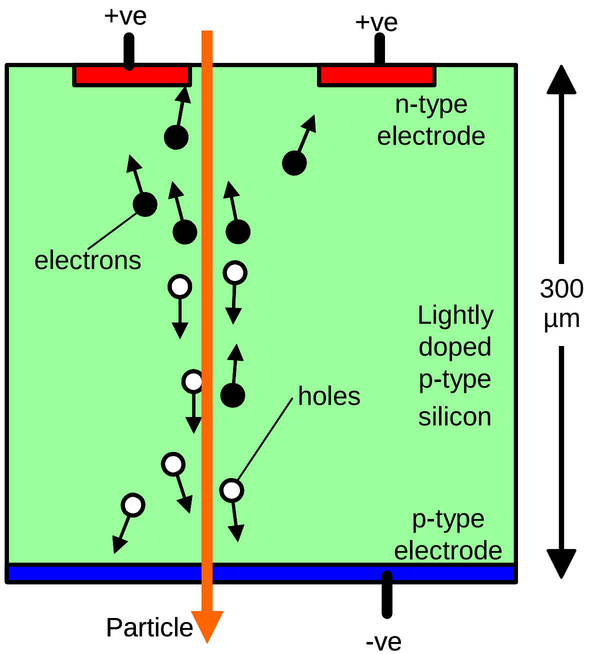


One comment on thin devices

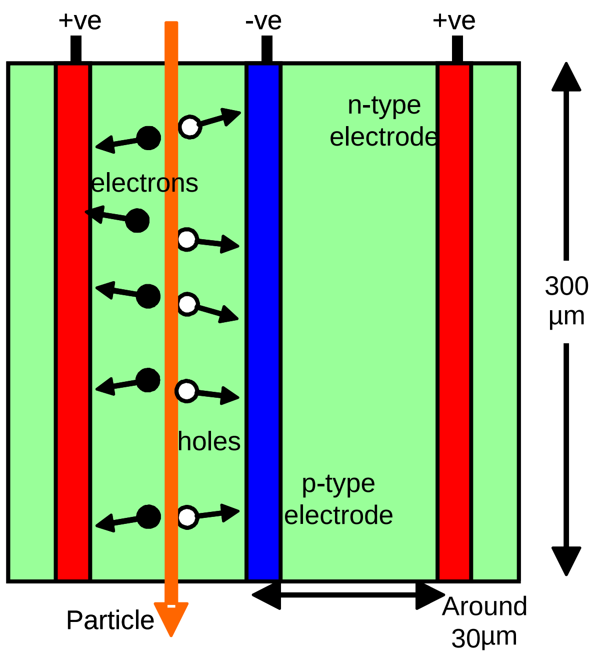


SLHC we will dissipate as much power to sensor as to ROC

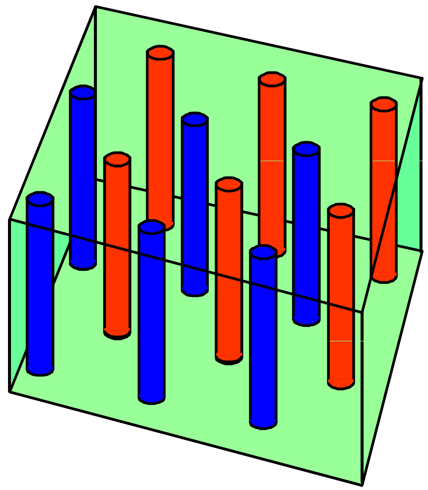
3D Detector Structure



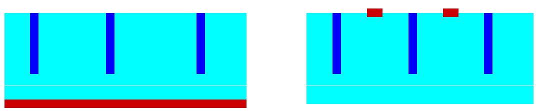
Planar



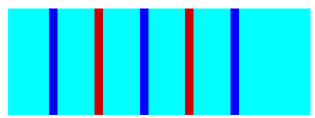
3D



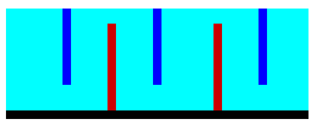
Single Sided Single Type Columns (semi-3D)



Single Sided Double Type Columns (classic 3D)



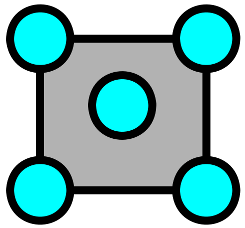
Double Sided Double Type Columns (new 3D)

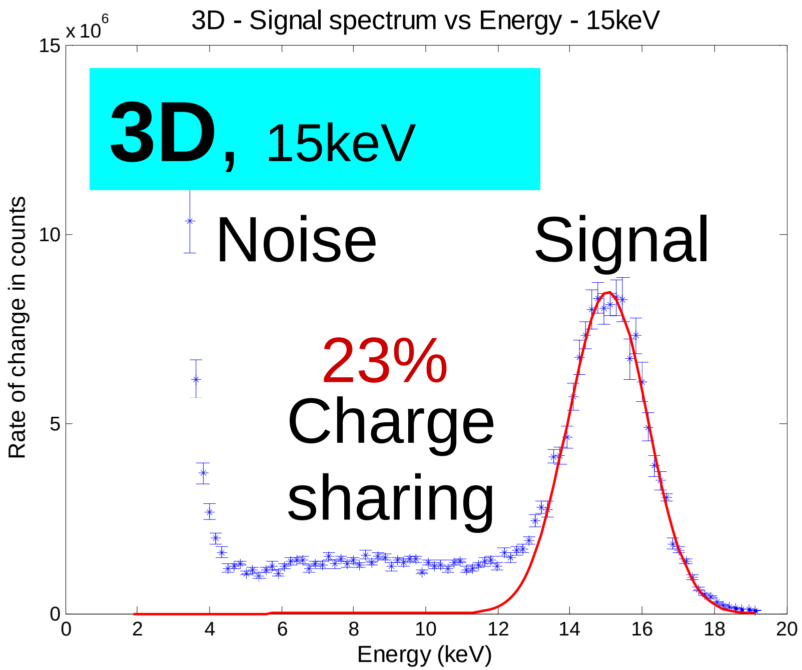


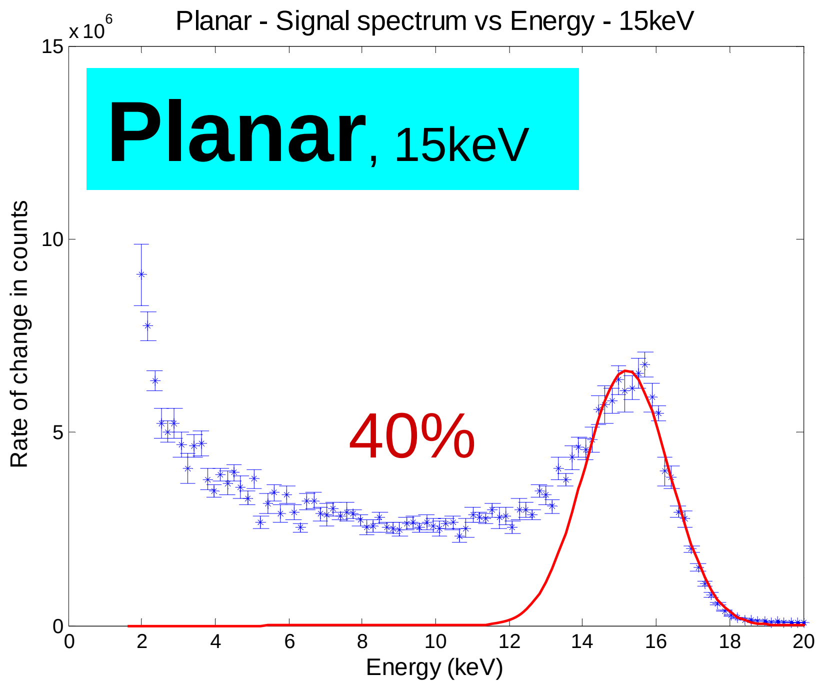
Spectral scan

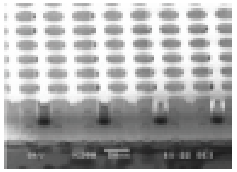
Medipix application   55um pixel size

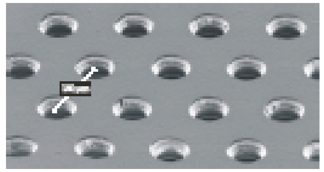
- Monochromatic beam
- Threshold scanned through signal into noise
- **Charge sharing reduced in 3D detector**
  - self shielding geometry





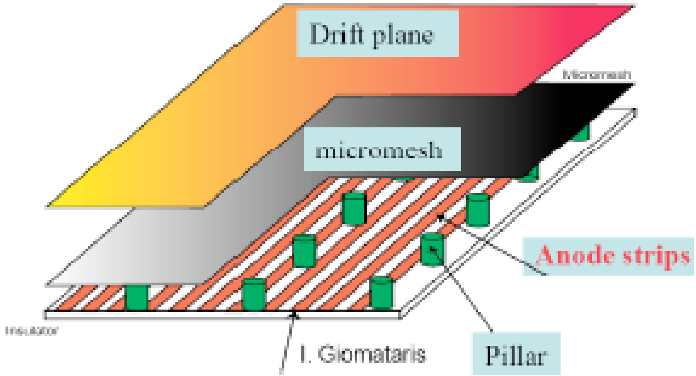


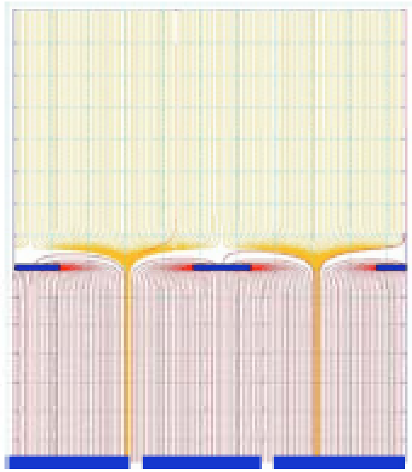




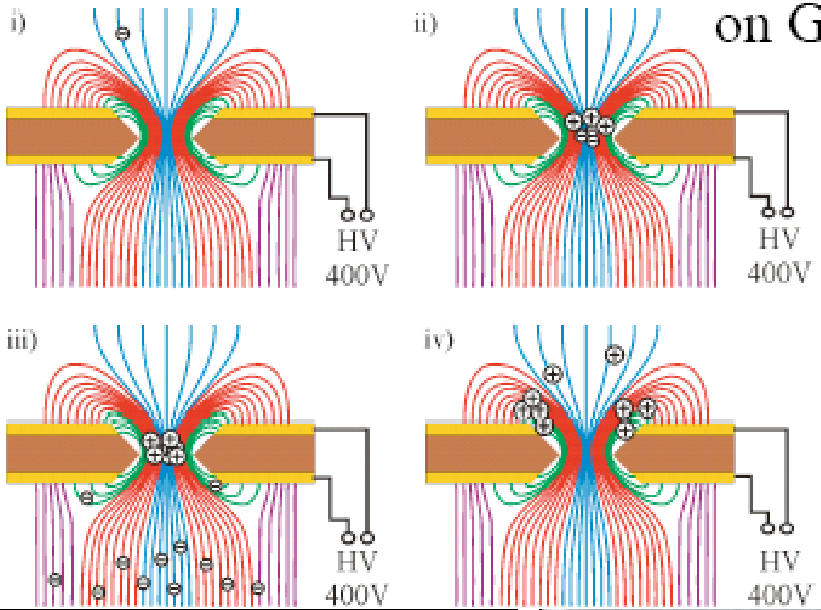
The 2 Favorites: Micromegas & GEMs

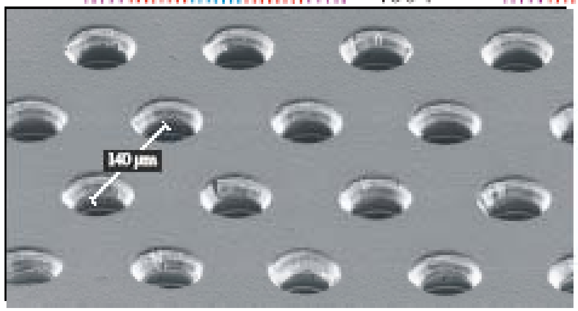
- 1996 first publication of MM

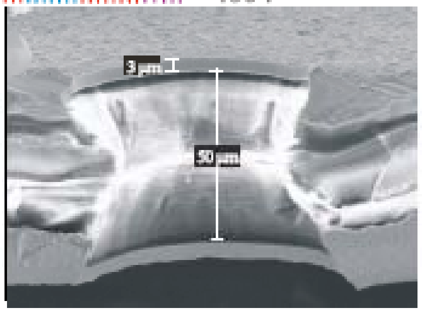


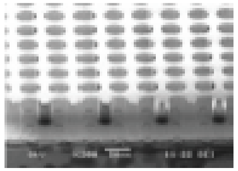


- 1997 F. Sauli publishes first paper on GEMs

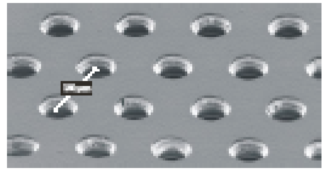


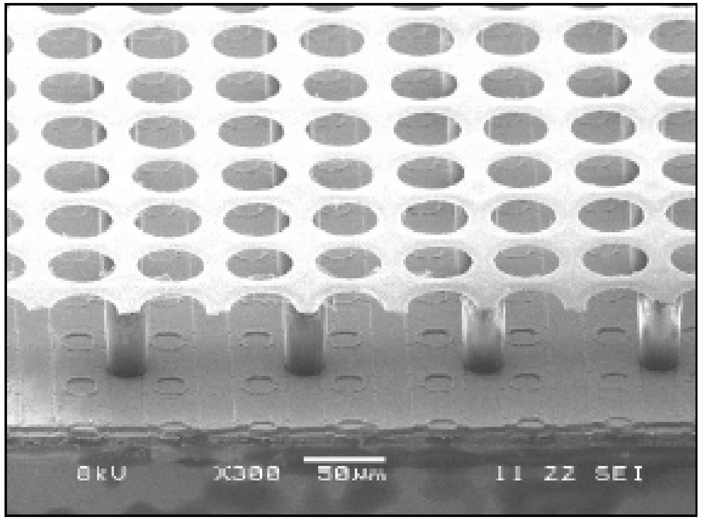


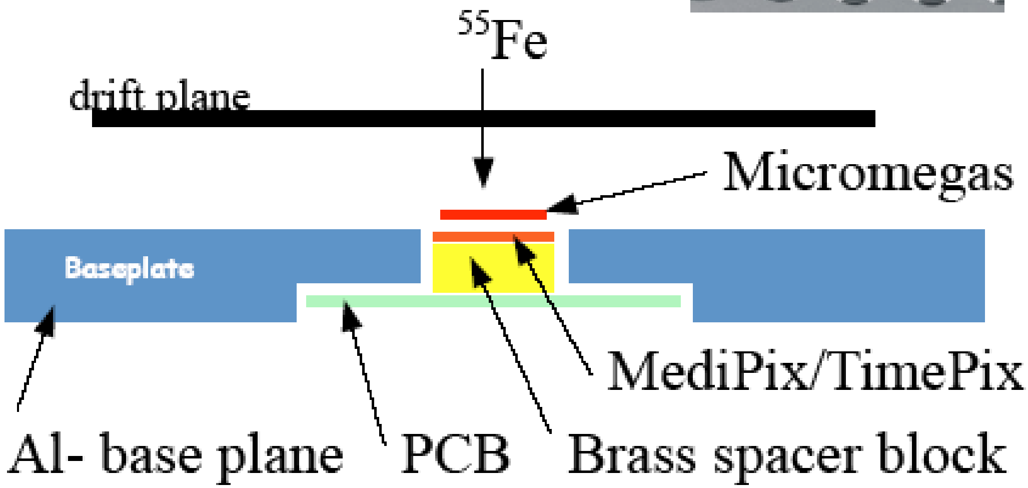


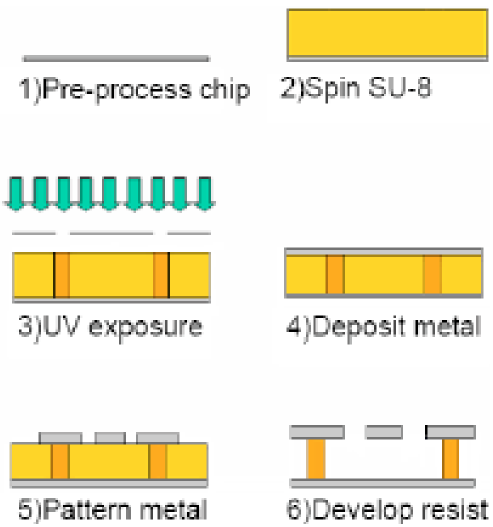


InGrid

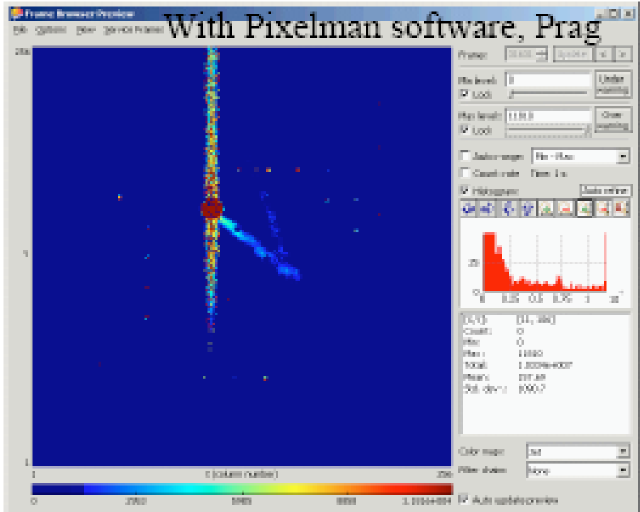








IMT Neuchatel:
15 or 20 µm highly resistive aSi:H protection layer (~10^{11} Ω·cm)
MESA+: InGrid



chip survives several 1000 discharges induced by Thorium

Summary & Conclusion

- The conference was just like the weather → fantastic

- I would like to thank and congratulate all the speakers for their excellent talks

- Most of all, I would like to thank Richard Brenner his people that made this conference such a success.

- I wish everyone a good return and a successful continuation of their work, hoping that it can be reported and shared in VERTEX conference to come.