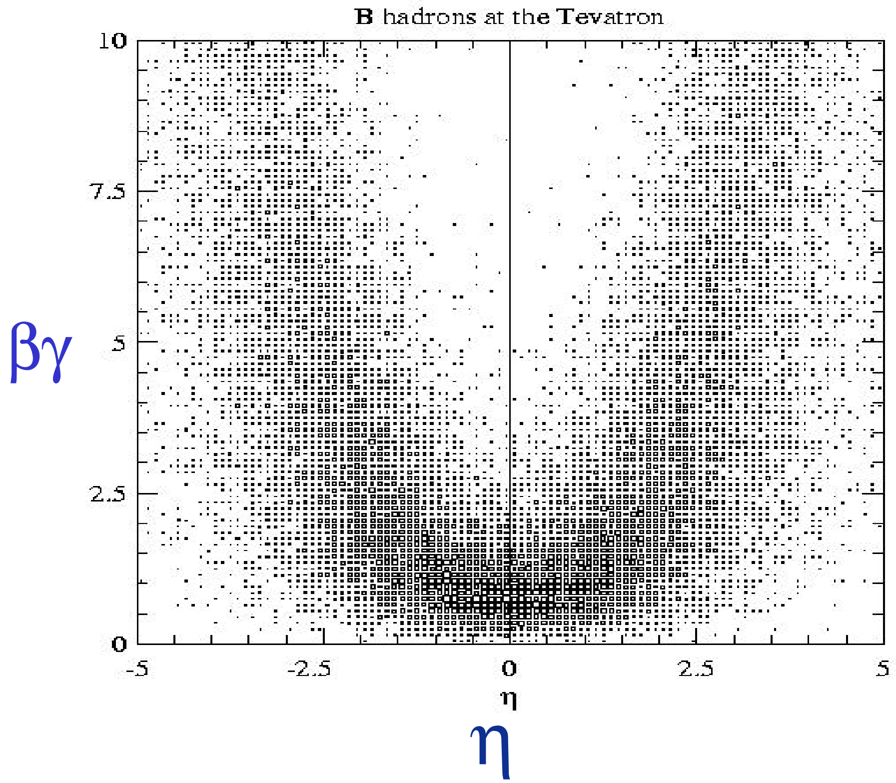
The BTeV Pixel Vertex Detector

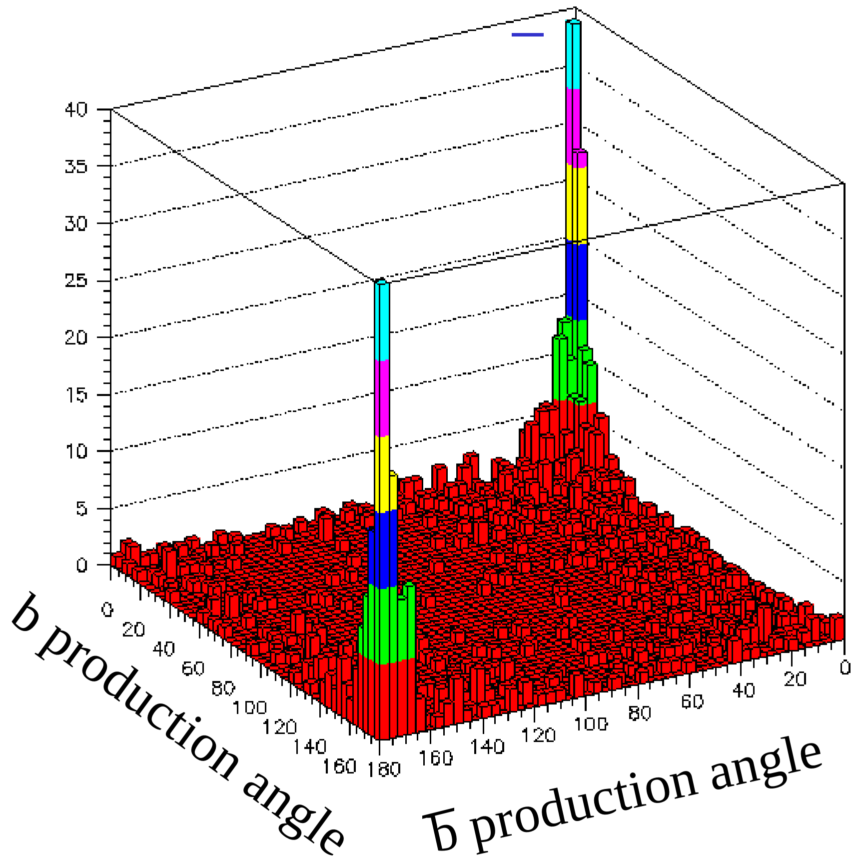
Marina Artuso *for the* ***BTeV pixel group***

Characteristics of hadronic b production

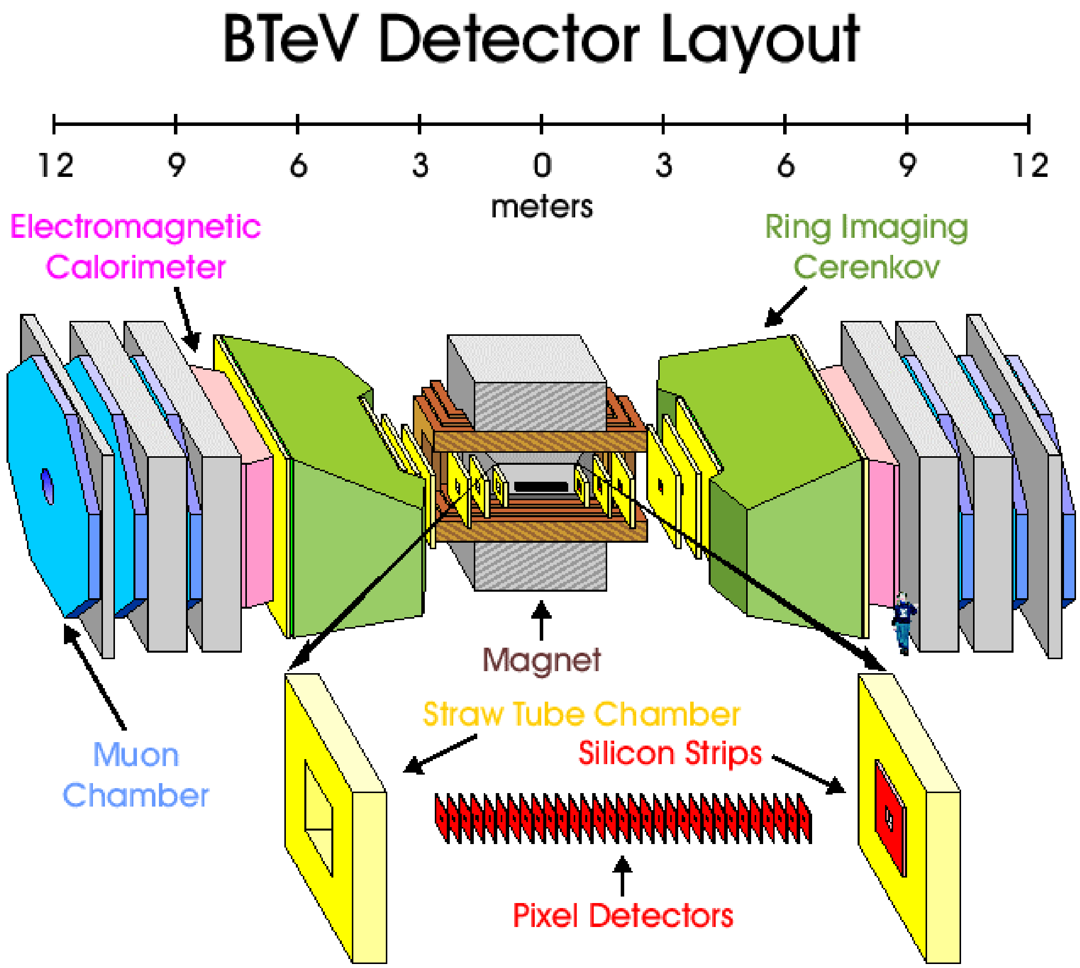
The higher momentum b's are at larger η's



b production peaks at large angles with large bb correlation

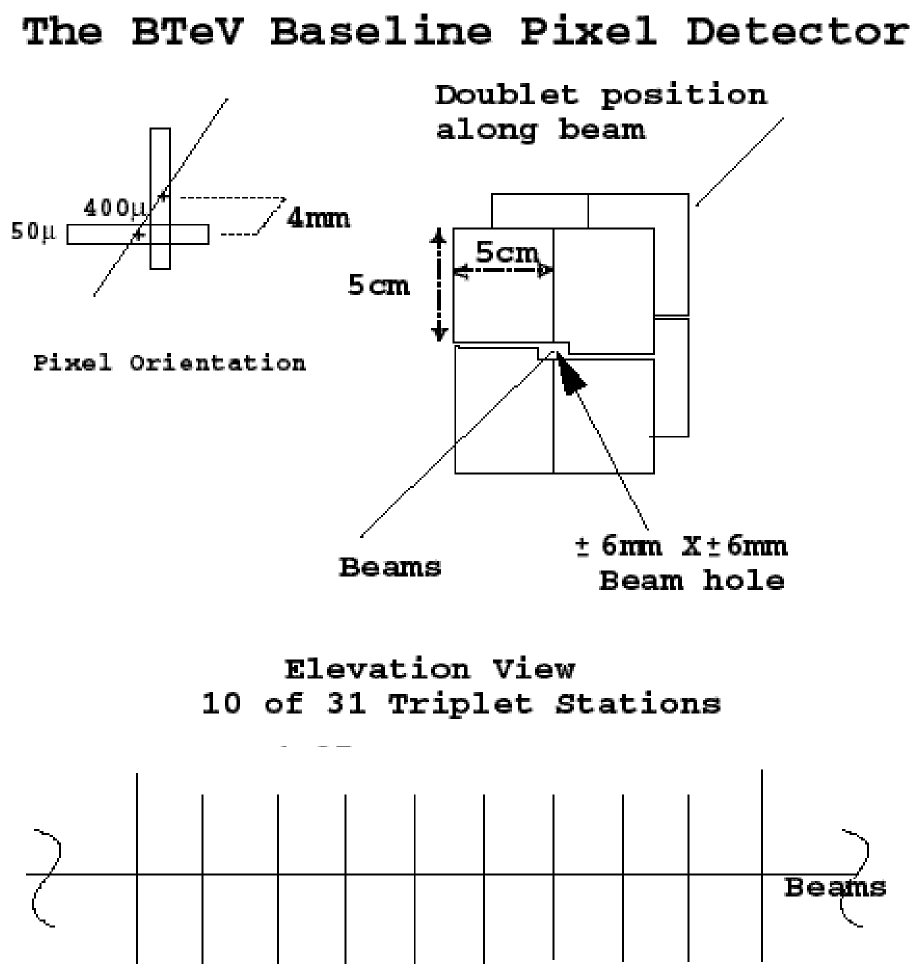


The BTeV Detector



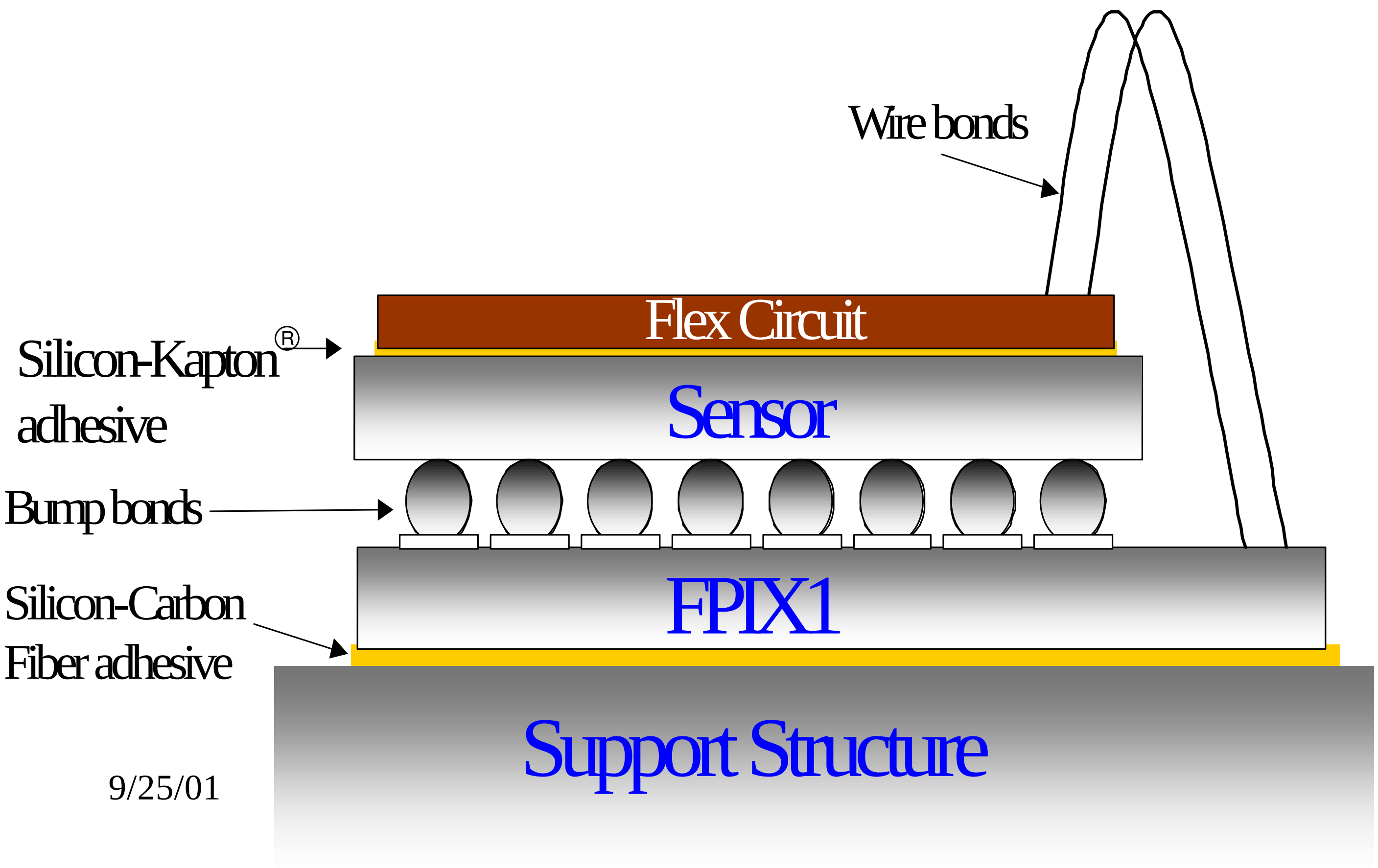
Why pixel?

- Pixels reduce ambiguity problems with high track density & essential to our detached vertex trigger
- Crucial for accurate decay length measurement
- System in secondary vacuum and pixel planes as close as possible to the beam (6mm)
- Radiation hard
- Low noise

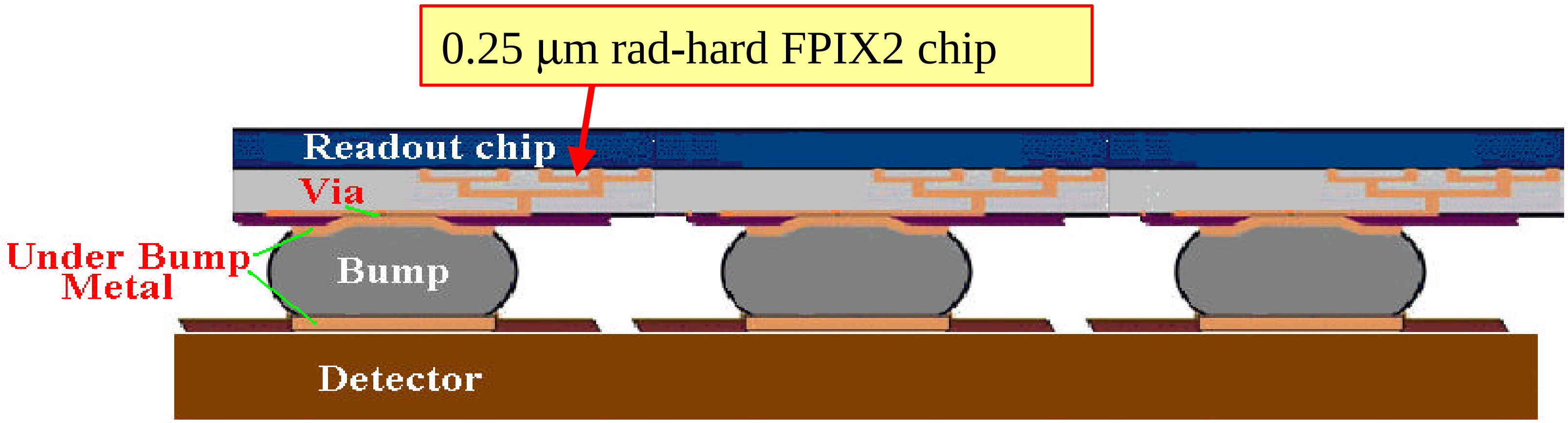


Pixel Module

- Hybrid pixel detector
- Low mass substrate (mechanical support - cooling)
- Flex circuit (control signals, data lines, power)



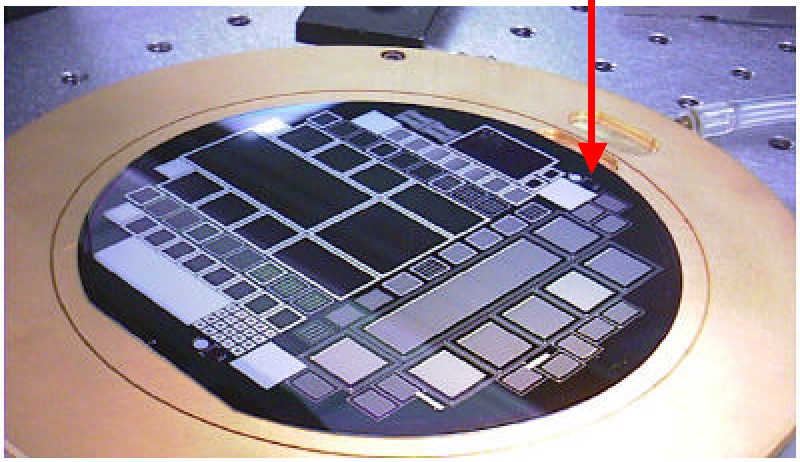
Hybrid Silicon pixel devices



- Independent development and optimizations of readout chip and sensor
- n^+ pixels on n-type substrates: inter-pixel insulation technology under investigation
- Bump-bonding of flipped chip: 2 technologies being considered: Indium (In) and solder (SnPb)

Pixel sensor design

1 of the SINTEF wafers that we are now characterizing



- Now studying:
  - Moderated p-spray sensors (from ATLAS)
  - 1st iteration of sensor submission of our own design: SINTEF submission with a variety of p-stop designs
  - radiation hardness studies just started
  - Next spring we will study the performance with a test beam of irradiated and non-irradiated sensors coupled with BTeV front end devices (FPIXn)

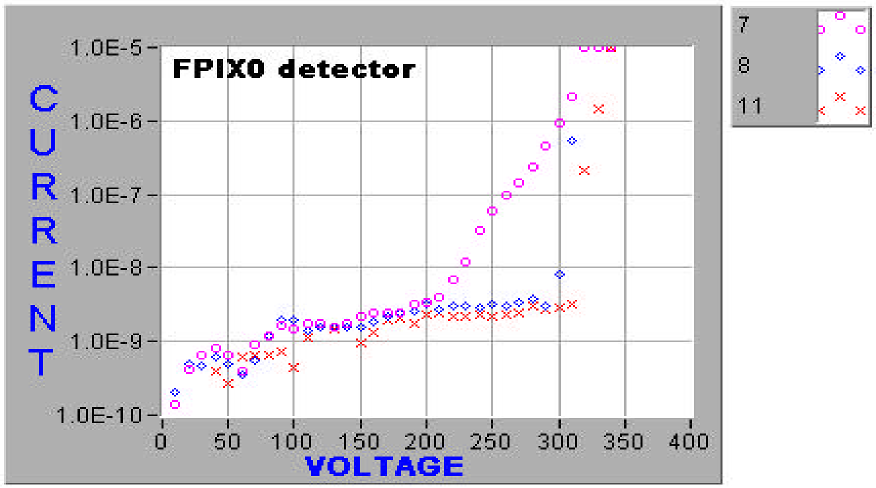
Sensor Development Strategy

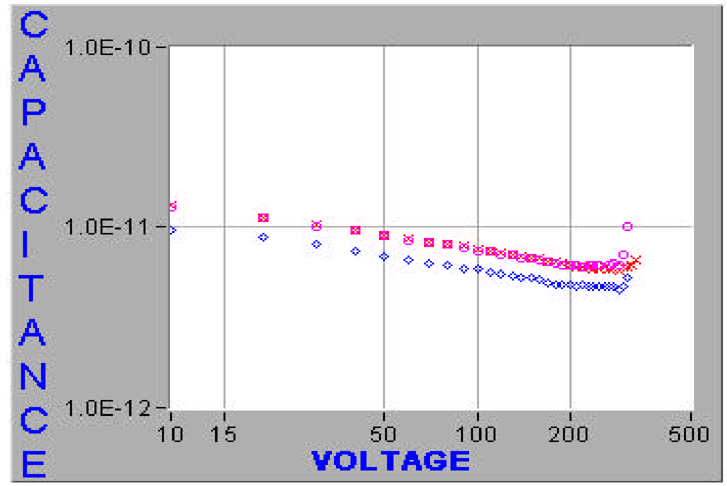
- Detailed experimental study of different design options
- In parallel simulation effort of electrostatic properties and charge signal development with ISE-TCAD
- The goal: identify reliable design that will provide the spatial resolution needed over the course of several years ($\Rightarrow$ radiation hardness is important)

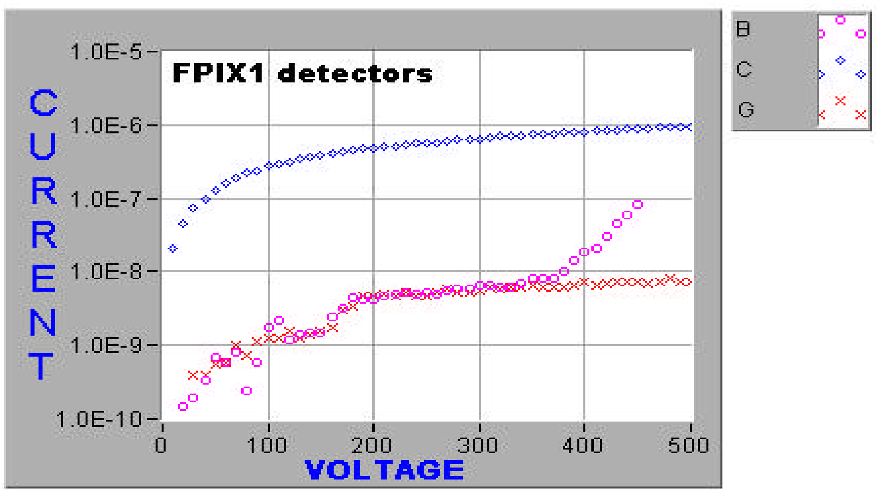
Wafer level Measurements

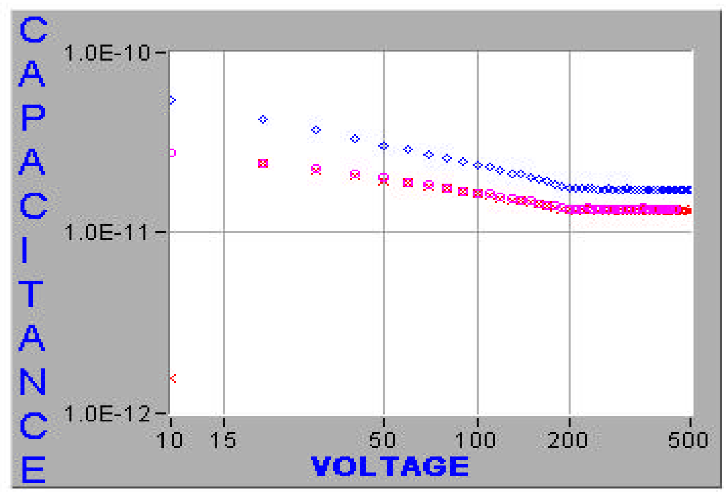
- I-V
- C-V
- Effect of temperature, humidity, test signal frequency, size
- Systematic study of factors affecting the measurement precision

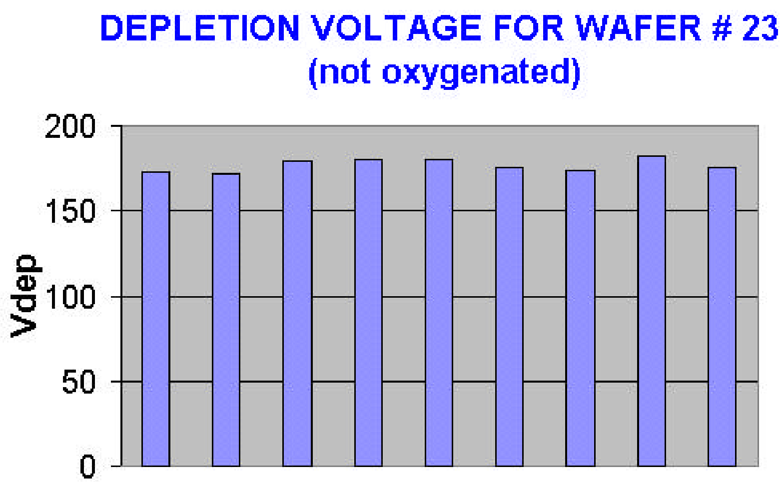
Examples of I-V and C-V characterization of SINTEF prototypes

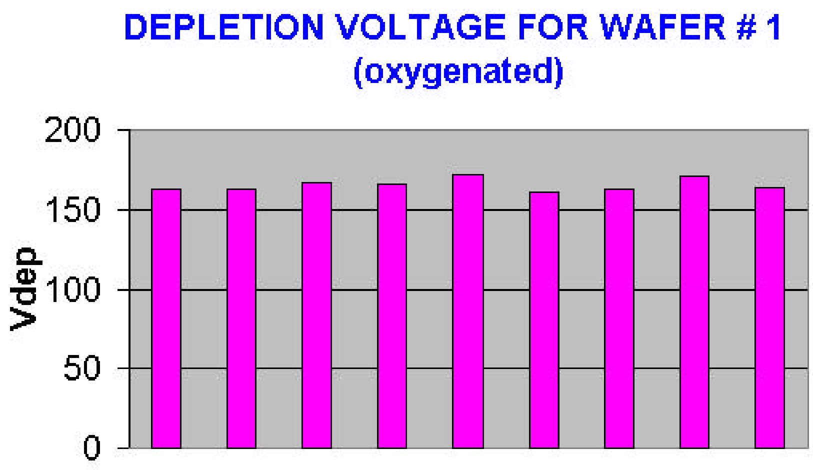




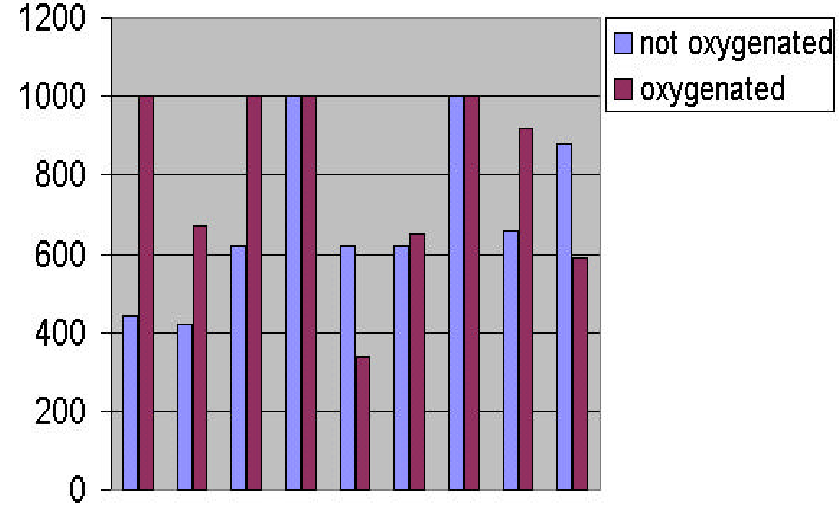








Breakdown voltage



Bump bonding

- Issues
  - Comparison of indium (AIT) and solder bump (MCNC) options
  - Quality assurance, at production and after burn-in tests
  - Effects of thinning front end device wafer⇔goal of 200 μm fpix2 thickness
  - 8” capability of bump bond vendors

First step: studies with dummy detectors

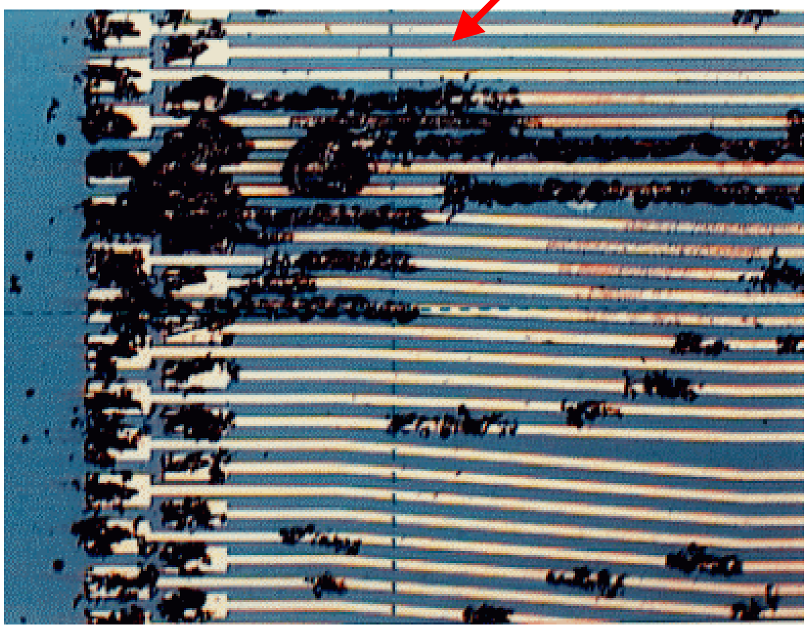
- The strategy: use dummy devices (single flip-chip assemblies of daisy-chained bumps)
  - 30 μm pitch In bumps – 200 chains of 28-32 bumps
  - 50 μm pitch solder bumps – 195 chains of 14-16 bumps
- Chains connected with testing pads at each end: resistance of the chain ⇔ bump quality
- Tests performed:
  - Thermal cycling (-10° C for 144 hr → 100 ° C in vacuum for 48 hrs)
  - Cs^{137} gamma source irradiation to 13 MRad

Rate of occurrence of problems (per bump)

problem	Indium bumps	Solder bumps
A good channel develops high R (5-10 KΩ/bump) in 12 months	2.1×10^{-4}	4.0×10^{-4}
A good channel develops high R after cooling	2.2×10^{-5}	1.4×10^{-4}
A good channel develops high R after heating	2.1×10^{-4}	6.3×10^{-4}

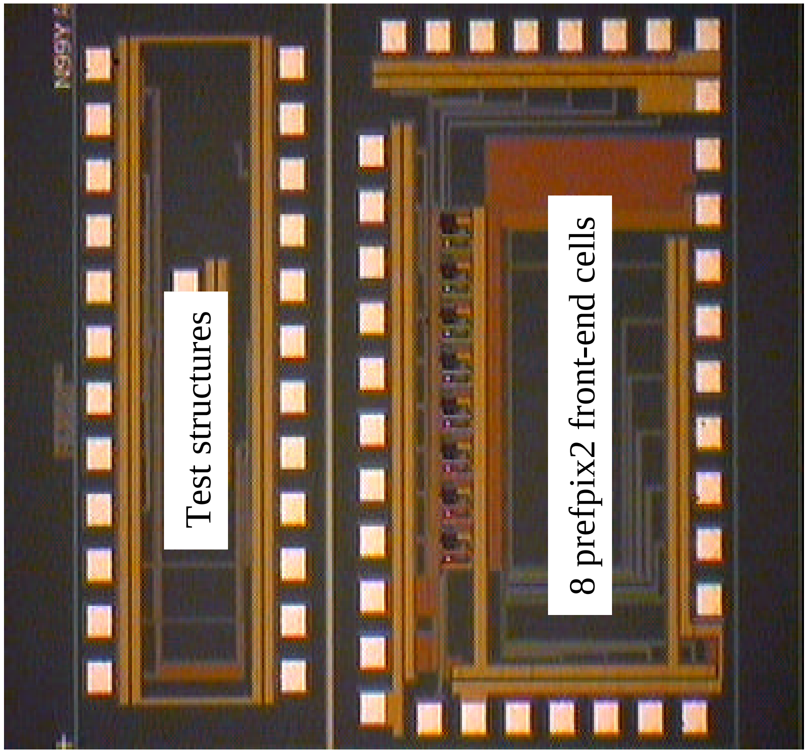
Radiation effects

Al lines after heavy irradiation



- In bumps: almost every 1^{st} channel in group of 4 channels was at high resistance (spurious effect?)
- Solder bumps: Al layer on strips and pads extensively flaky and bubbly after irradiation (accelerate oxidation?) 6/2280 channels broken.

Readout electronics: FPIX2

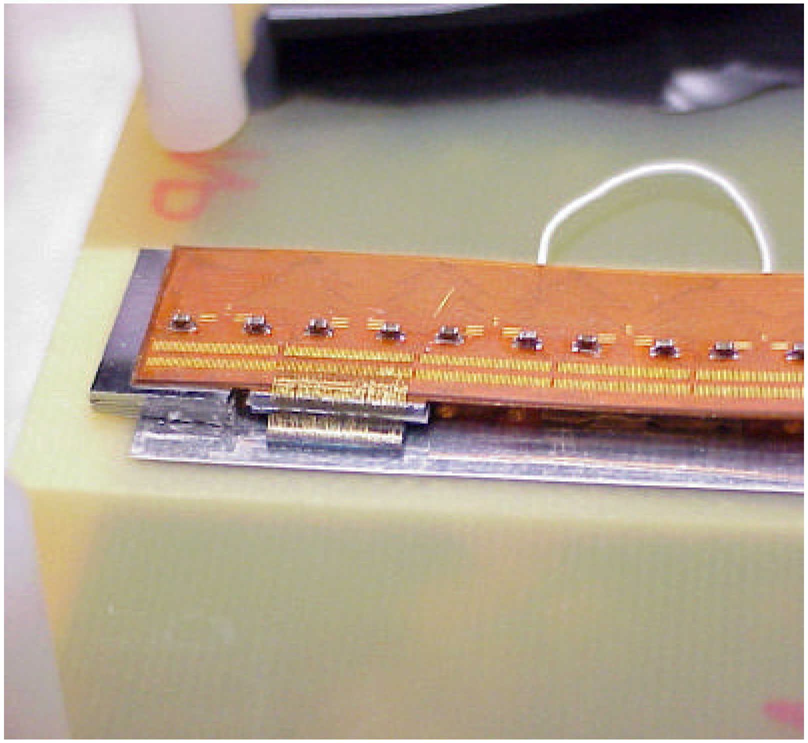


- Low noise
- Low and uniform threshold
- Feedback compensation allows to withstand high I_{leak}
- 3bit FADC in each cell

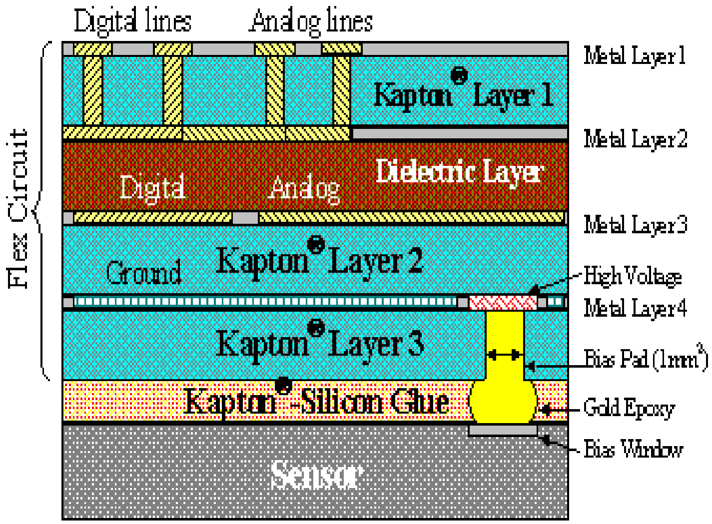
More on this in Gabriele Chiodini's talk

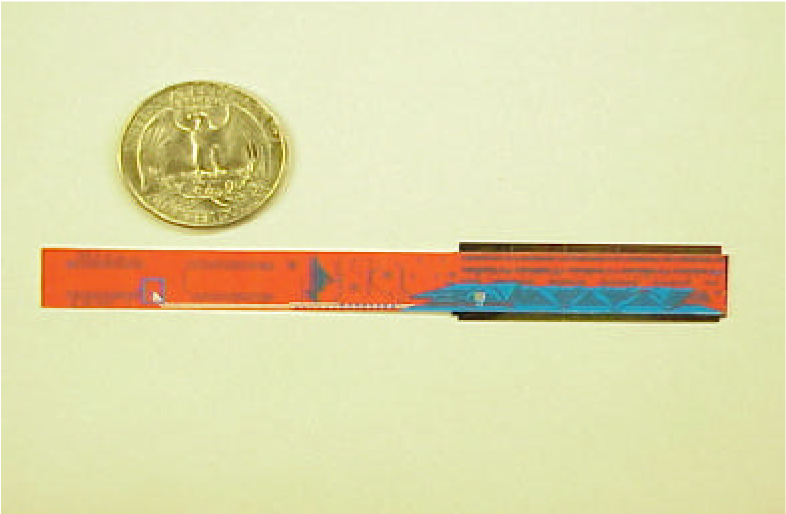
High density flex circuit development

- 15 HDI delivered from CERN; only 4 without defects
- Preliminary performance assessment very satisfactory $\Rightarrow$ design validation
- We need to do more extensive tests and find commercial vendor for large scale production



Performance of the Pixel prototype module





- 1 FPIX1 chip wire-bonded to HDI module with and without sensor bump bonded.
- Noise and threshold dispersion characterization show no degradation with respect to single chip characterization

Performance of the Pixel Prototype Module (in e^-)

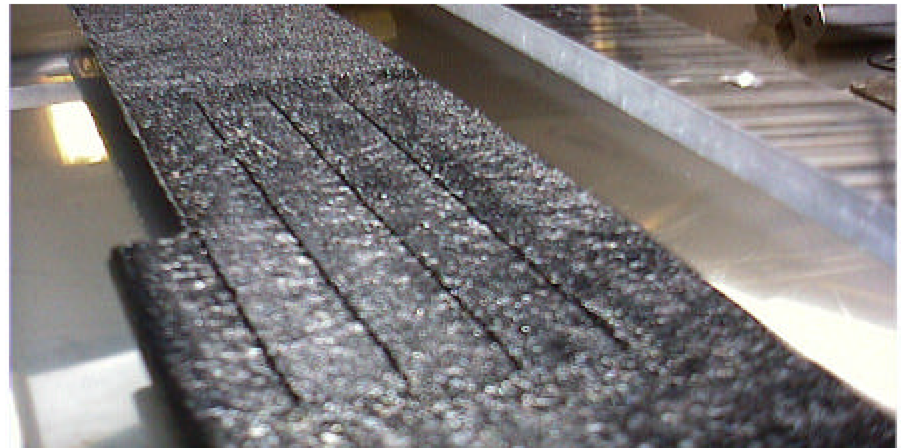
Without sensor				With sensor			
<thr>	σ_{thr}	**<ENC>**	σ_{ENC}	<thr>	σ_{thr}	**<ENC>**	σ_{ENC}
7365	356	75	7	7820	408	94	7.5
6394	332	78	12	6529	386	111	11
5545	388	79	11	5500	377	113	13
4438	378	78	11	4410	380	107	15
3513	384	79	12	3338	390	116	20
2556	375	77	13	2289	391	117	21

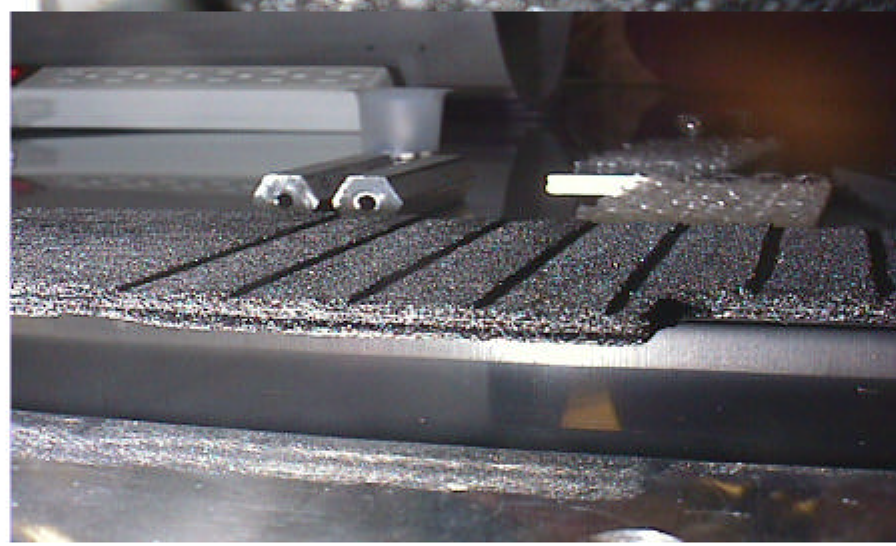
Threshold scan

No degradation introduced by HDI or bump bonded sensor

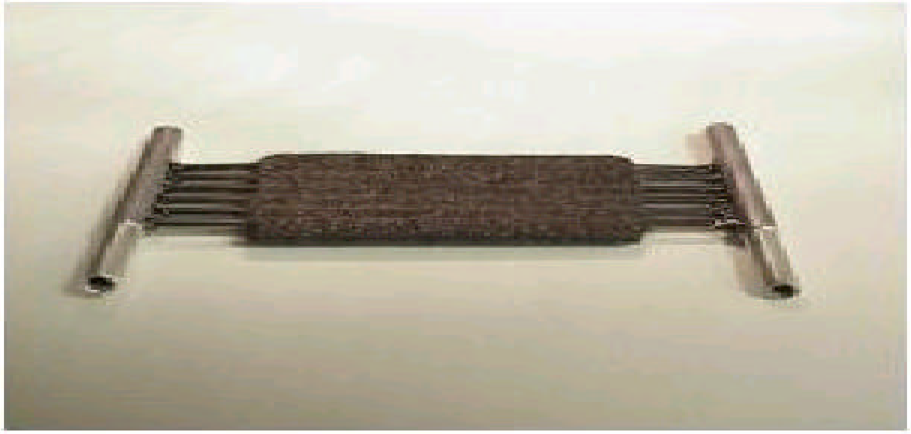
Our baseline mechanical support: Fuzzy Carbon Substrate (with ESLI)

- Light-weight
- Good thermal performance and CTE match to Si
- Problems: fragile, heavy manifold and brittle joint between tube and manifold, difficult to fabricate, sole source
- Back-up involves Be structure but would worse material budget

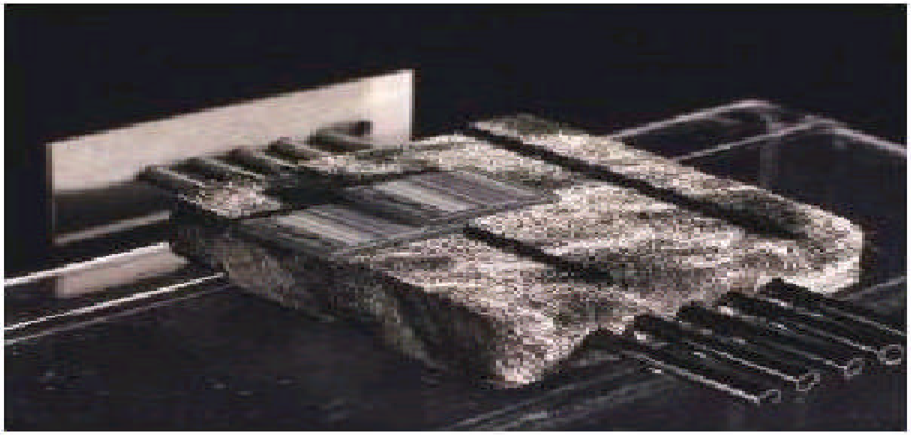




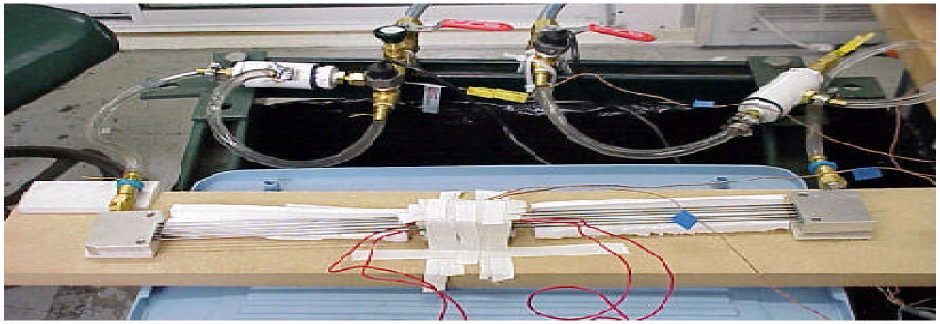
Some prototype devices (ESLI)

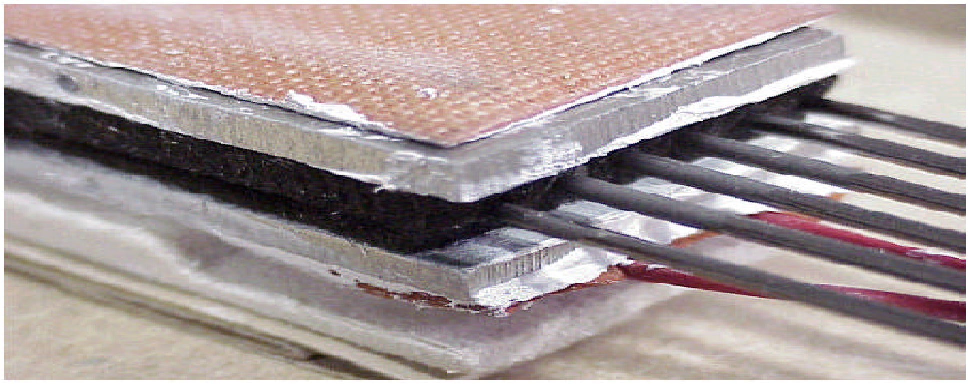


Nonporous carbon tubes



Shingled detector





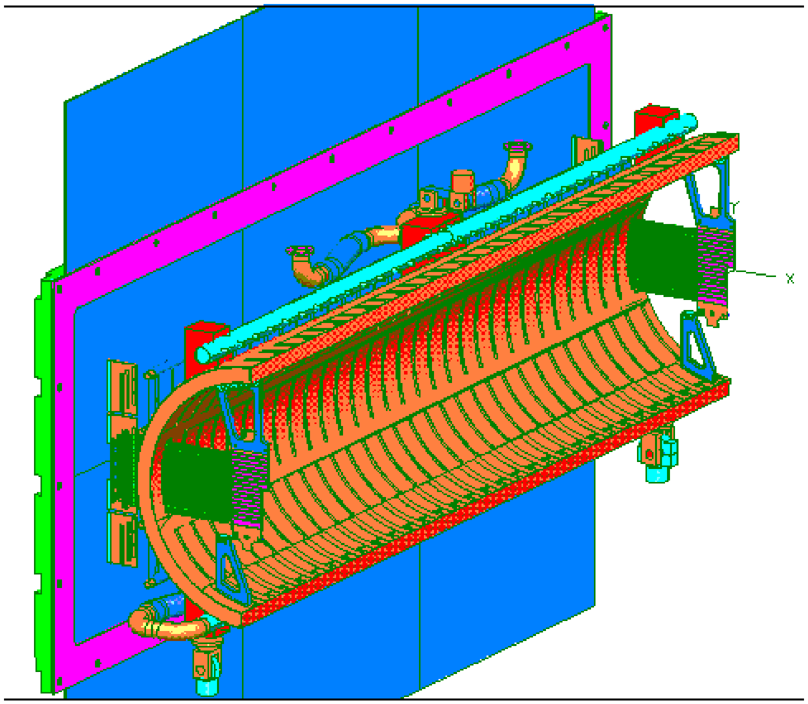
Heat exchanger test heated up by two aluminum plates

System Design Highlights

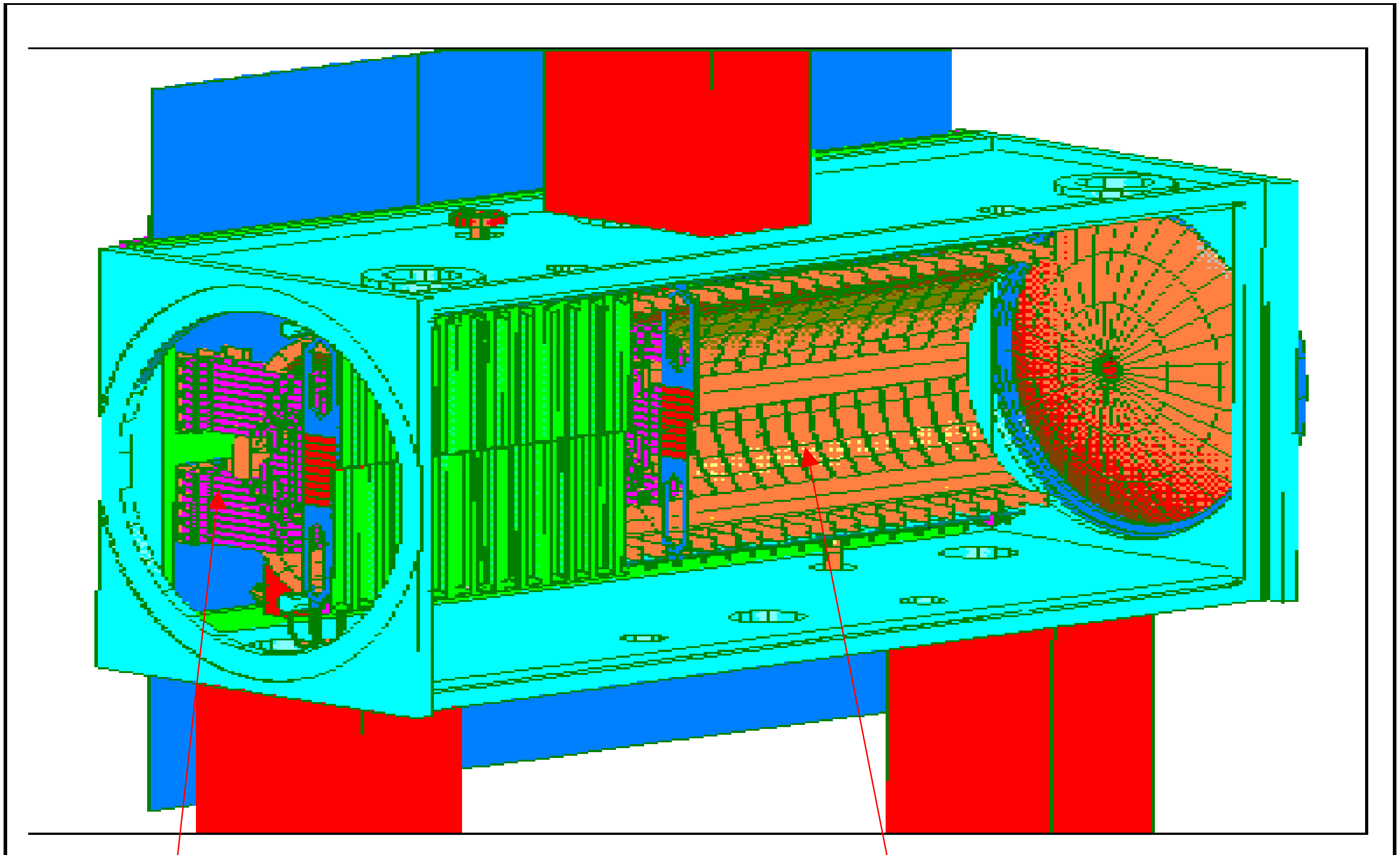
- Pixel sensor telescope needs to be in a secondary vacuum, separated by the beam primary vacuum only by a thin RF shield & is inside a 1.6 T dipole field
  - Must be enclosed in a vacuum vessel
  - Materials used must not outgas and must be non-magnetic
- Sensors must retract from their regular position during injection and machine studies (precision positioning/alignment)

Pixel detector system

- 30 stations (substrates with embedded cooling channels) with 2 pixel planes per station
- Carbon support frame
- Al RF shield
- Cooling system
- Motor drive to move sensors farther from the beam line during injection and beam studies



Pixel Vacuum Vessel

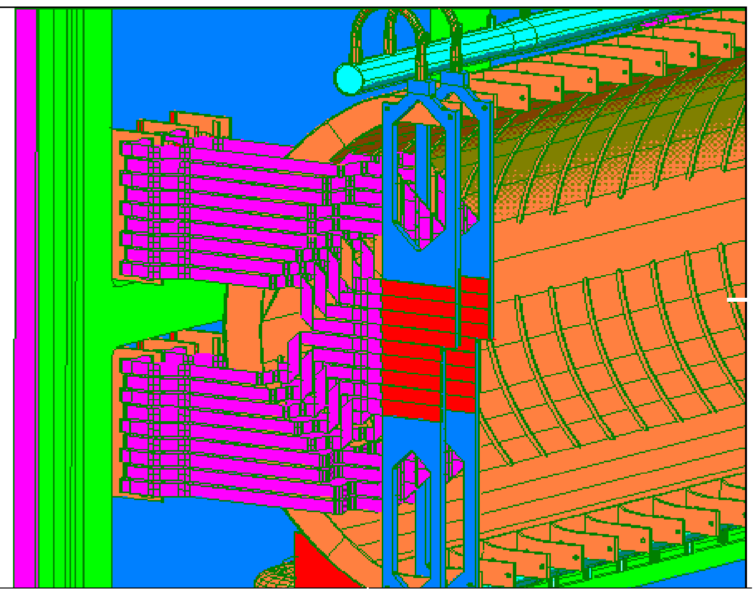


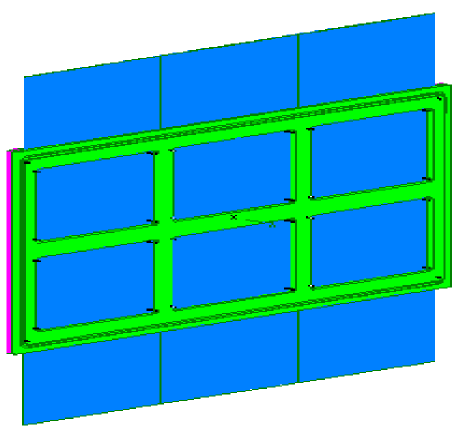
cables

Carbon fiber support frame

Cable Feed -Through

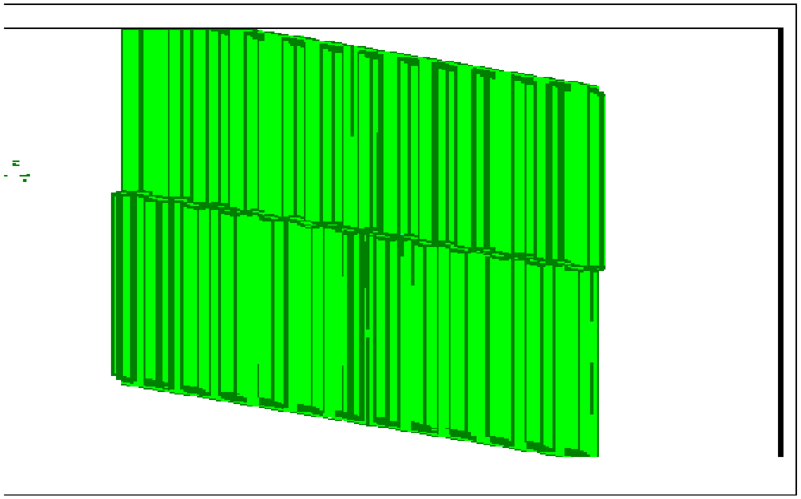
- Use PCB with connectors as vacuum feedthrough
- Large number of cables/connectors
- Large PCB (17x22”), 6 layers now being designed
- This PCB with connectors will be tested in a vacuum system

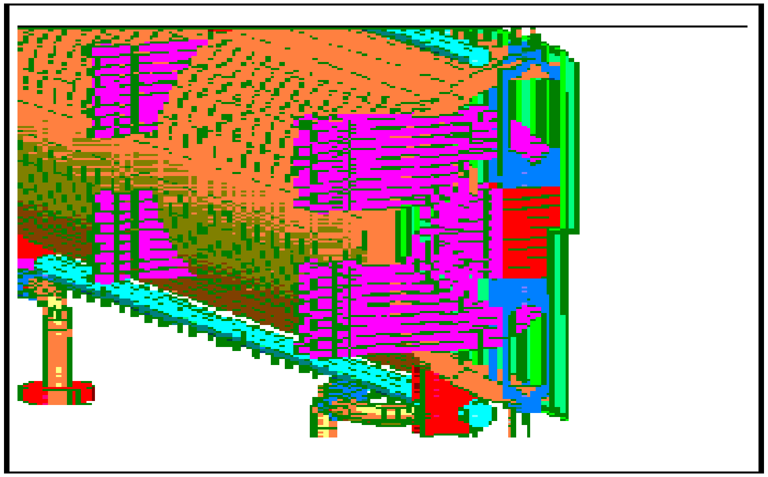




RF shielding

- Same membrane hopefully serve three purposes:
  - RF shielding of the pixel detector
  - Vacuum barrier
  - Image current
- Evaluation in progress





Summary

- Great progress has been achieved in the design of the sensor, front end electronics and module structure of the BTeV pixel detector
- This inner tracking system will be the key element of the Trigger algorithm that will enable efficient collection of a variety of beauty decays & provide a superb tool to challenge the Standard Model