A Walking Tour of the STAR Heavy Flavor Tracker

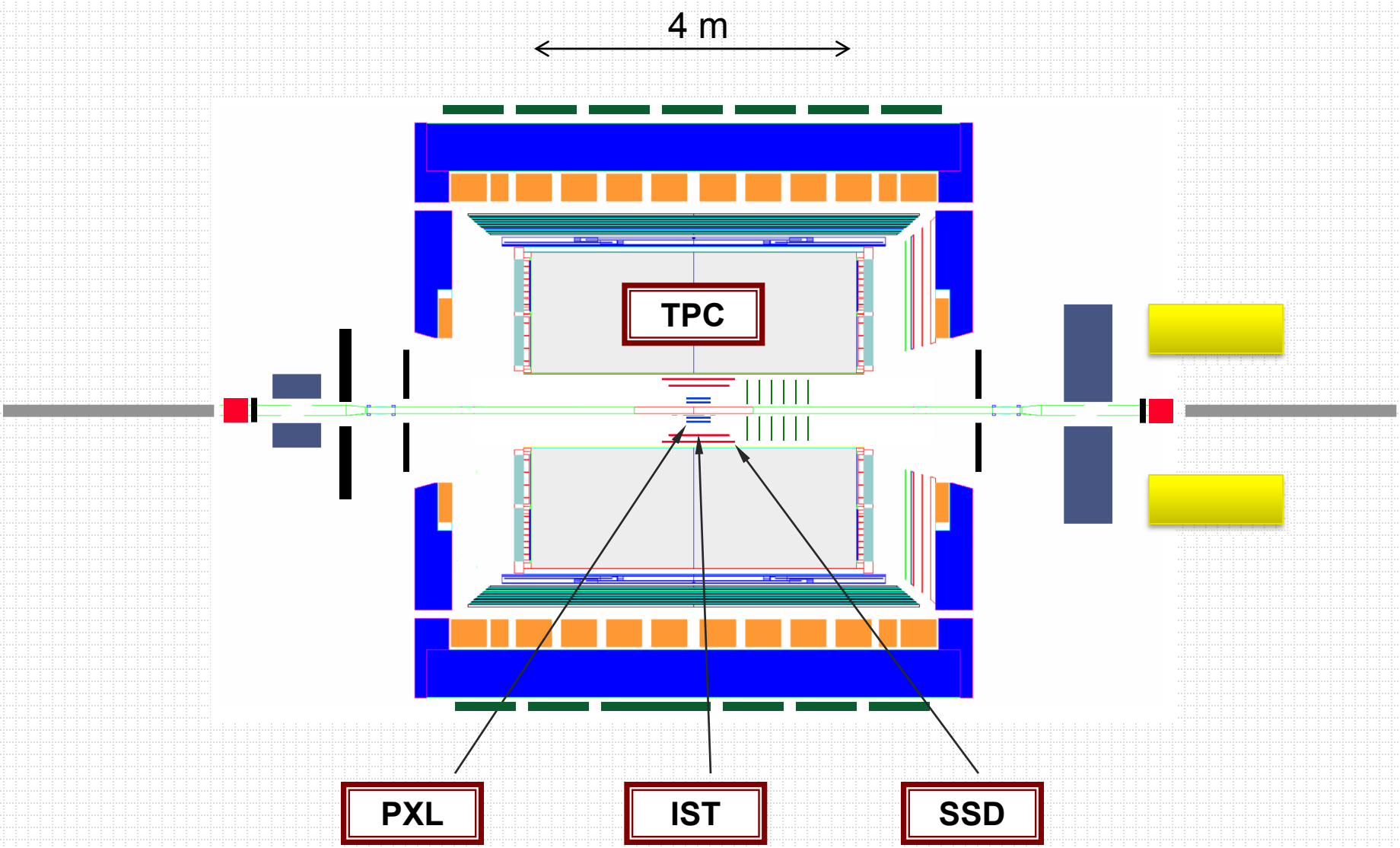
Detector Layout, Mechanics and Cooling

Jim Thomas

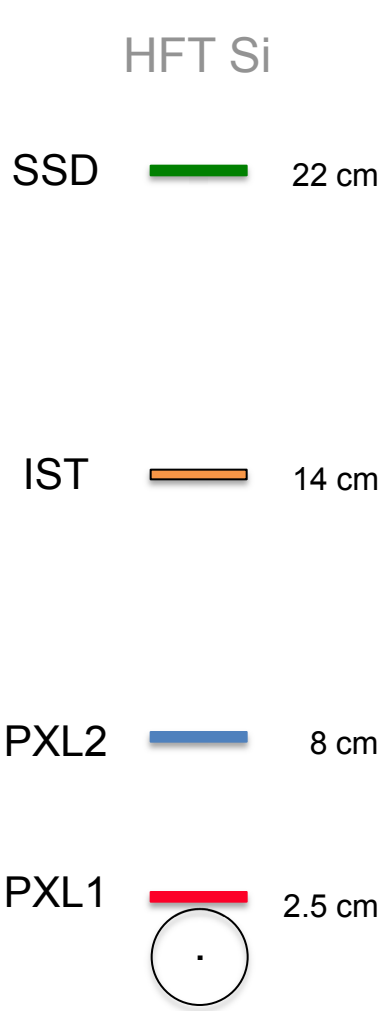
Lawrence Berkeley National Laboratory

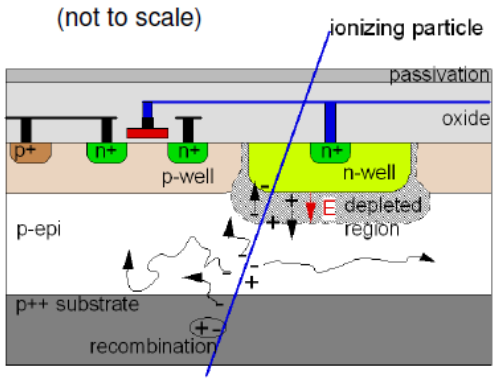
May 29th, 2011

The Heavy Flavor Tracker: Location inside the TPC

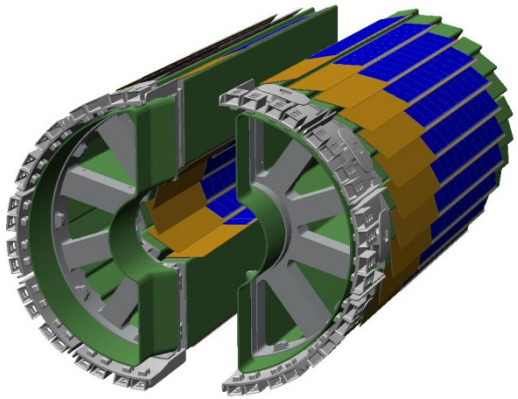


The HFT – Pixel Technology





Now using high resistivity Si which allows for a biased depletion region (previously relied upon diffusion to collect the charge)



- **Unique Features**
  - **20.7 x 20.7 μm pixels**
  - **100-200 μsec integration time**
  - **436 M pixels**
  - **0.37% X/X_0 per layer**
  - **Install and Replace in 8 hours**
- **News**
  - **Change in process: now using HighResistivity Si**
  - **Better signal to noise and higher radiation tolerance >300 kRad**
  - **Don't have to replace the detector every year**

PXL Requirements and Design Choices

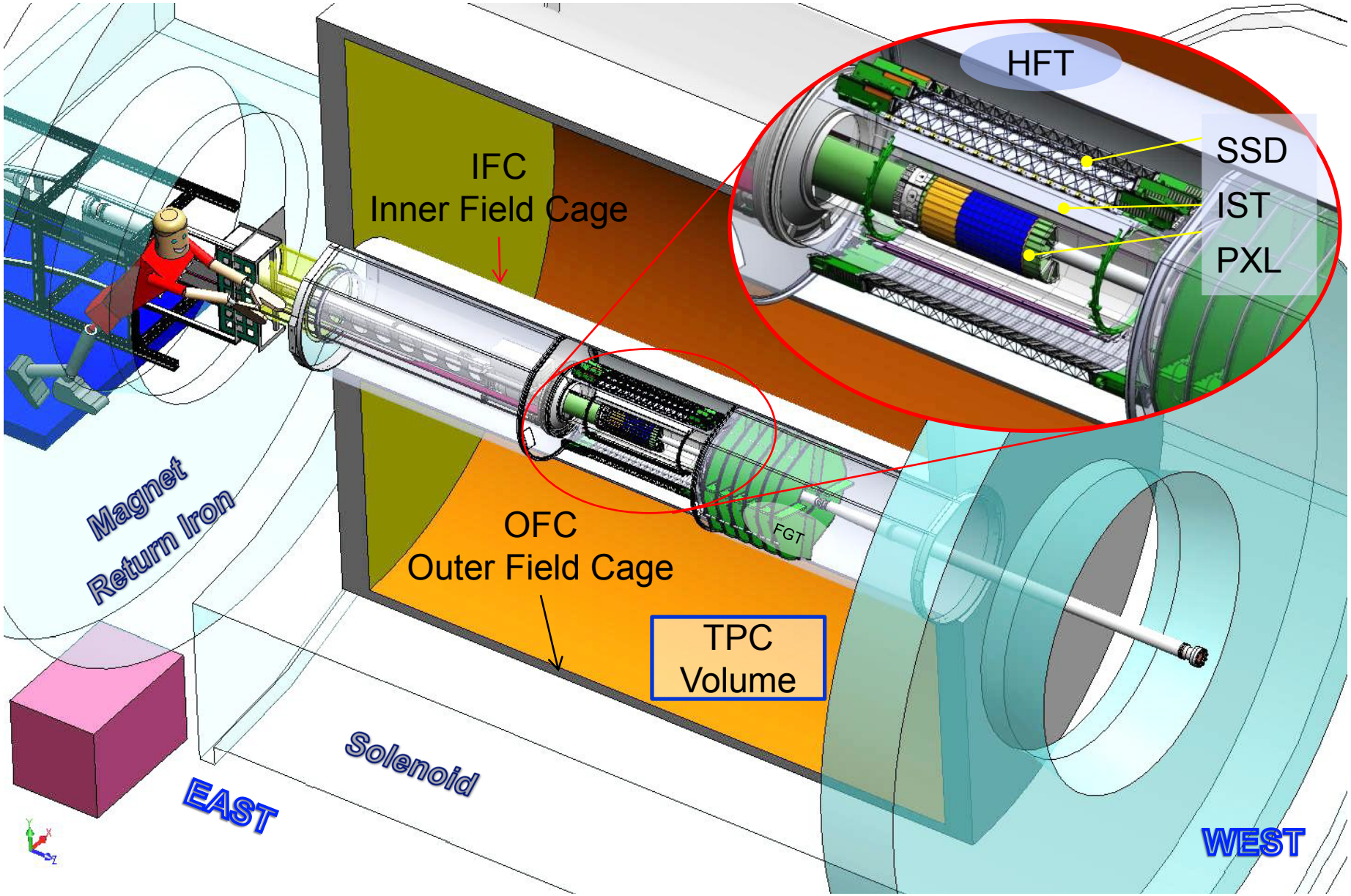
Requirements

- -1 ≤ Eta ≤ 1, full Phi coverage (TPC coverage)
- ≤ 30 μm DCA pointing resolution required for 750 MeV/c kaon
  - Two or more layers with a separation of > 5 cm.
  - Pixel size of ≤ 30 μm
  - Radiation length as low as possible but should be ≤ 0.5% / layer (including support structure). The goal is 0.37% / layer
- Integration time of < 200 μs
- Sensor efficiency ≥ 99% with accidental rate ≤ 10^{-4}.
- Survive radiation environment.

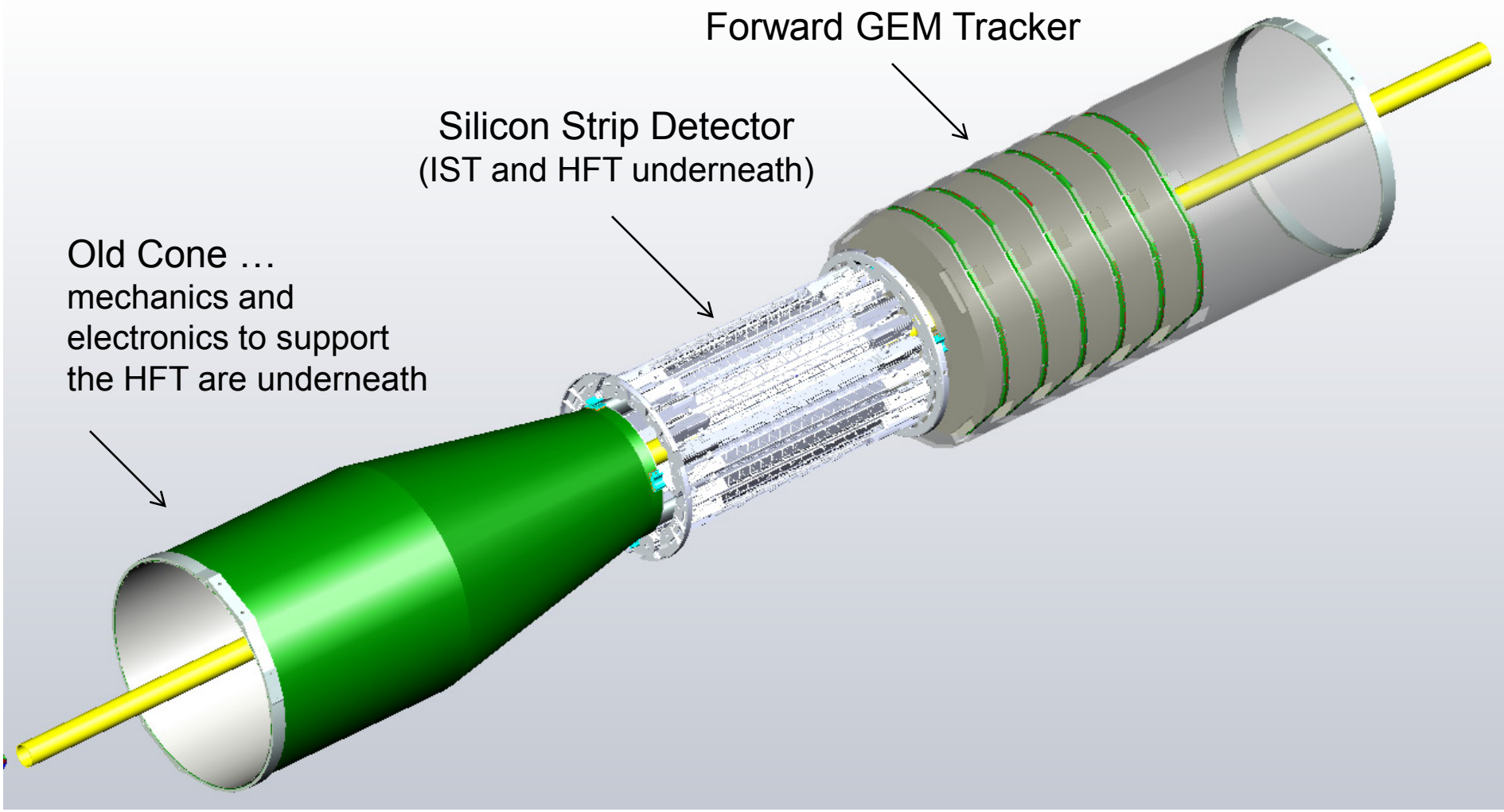
Design Choices

- Air cooling
- Thinned silicon sensors (50 μm thickness)
- MAPS (Monolithic Active Pixel Sensor) pixel technology
  - Sensor power dissipation ~170 mW/cm^2
  - Sensor integration time <200 μs (L=8×10^{27})
- Quick extraction and detector replacement (1 day)

Exploded view of the HFT inside the TPC

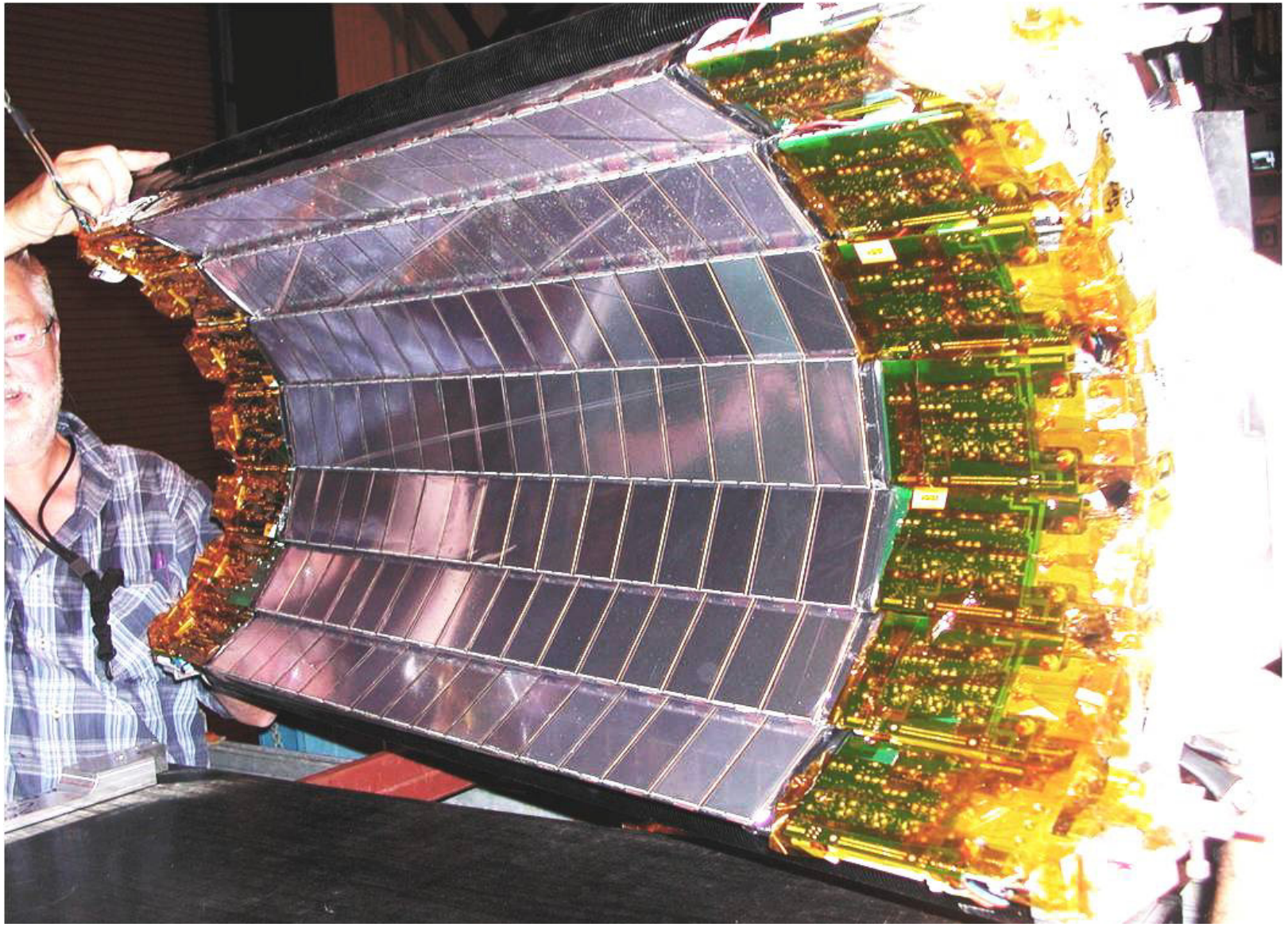


The “cone” assembly is removable (annually)

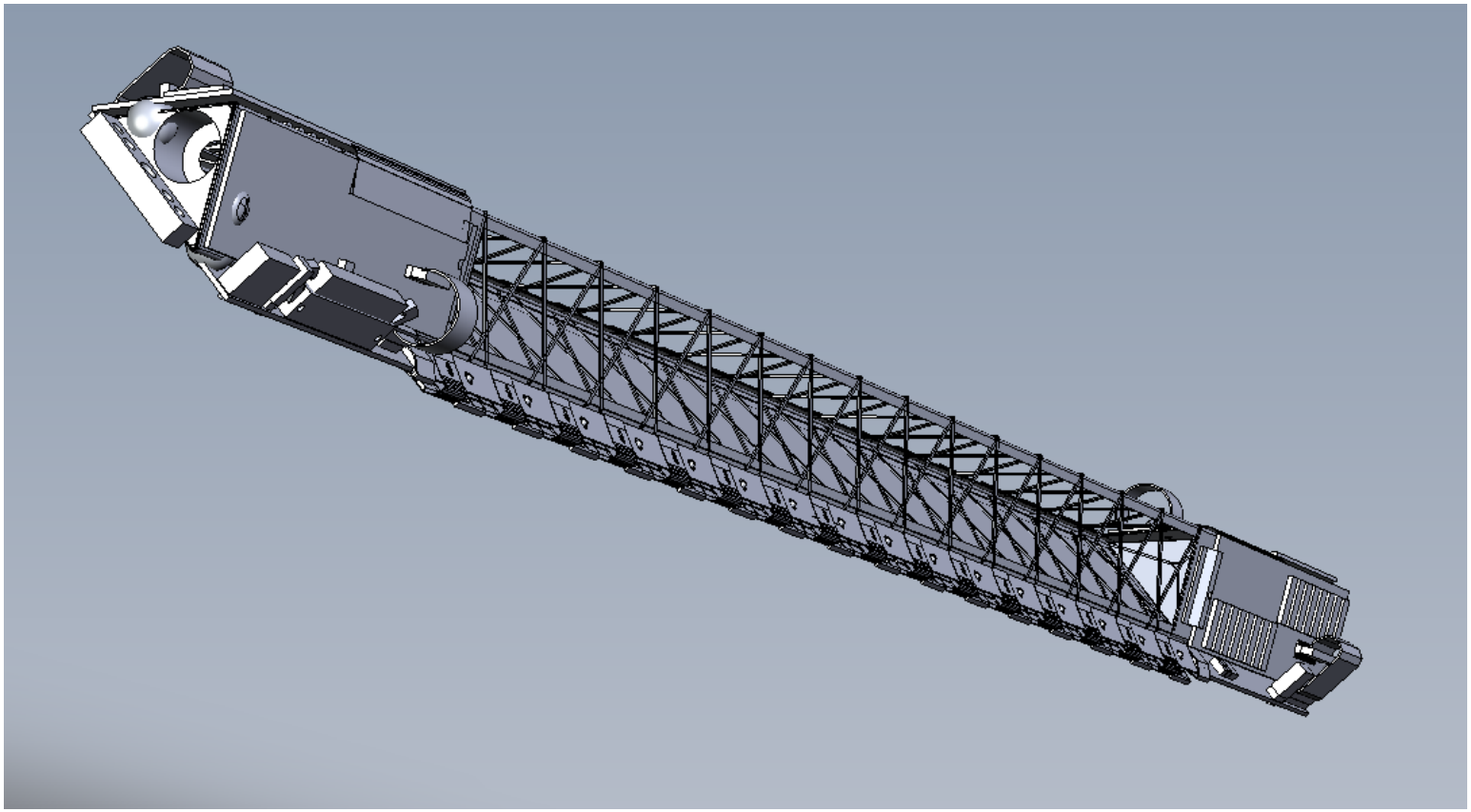


This is an old diagram … in the new design, the cones are symmetric

The Silicon Strip Detector at 22 cm radius

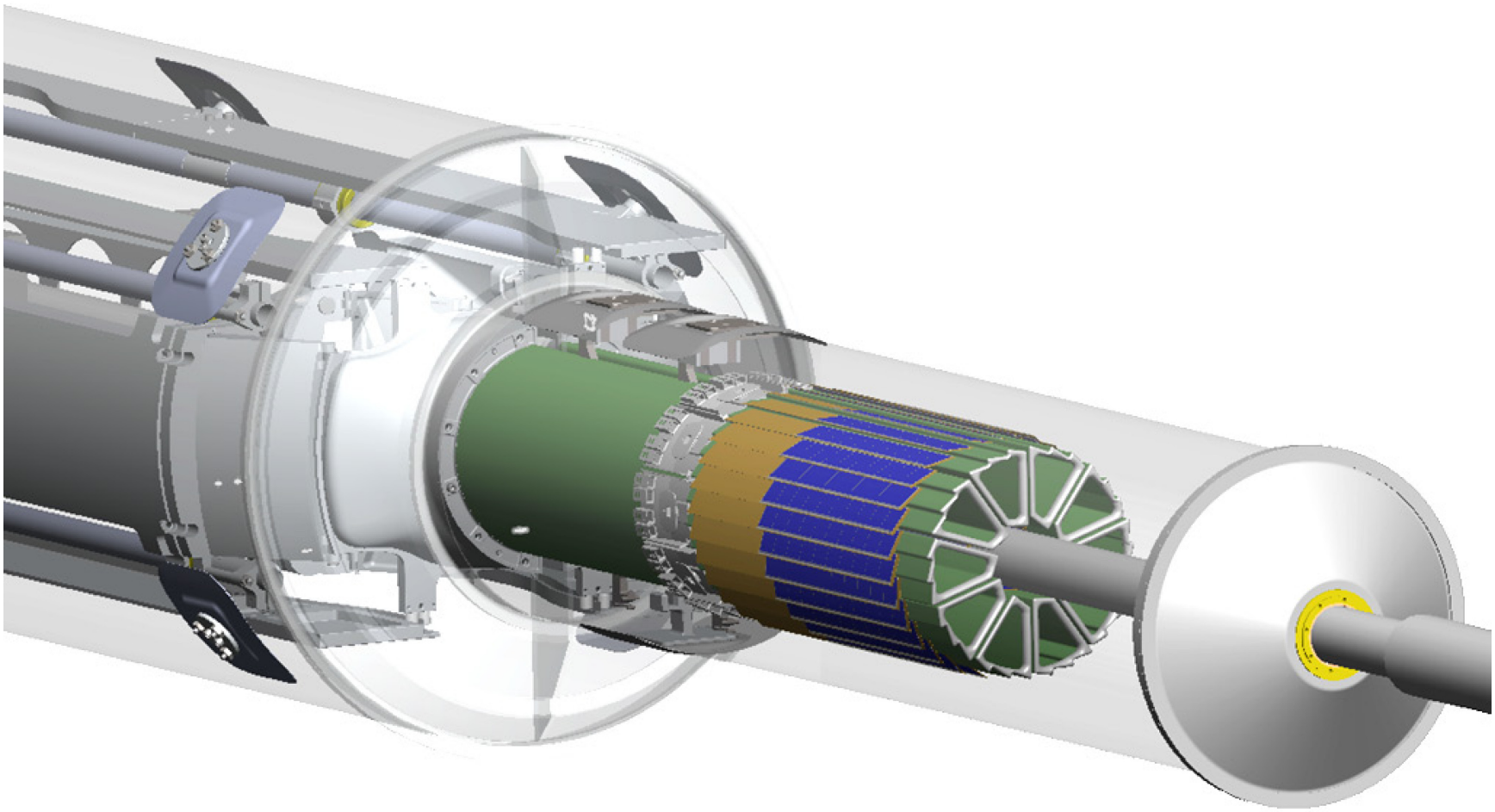


The Silicon Strip Detector – an existing detector

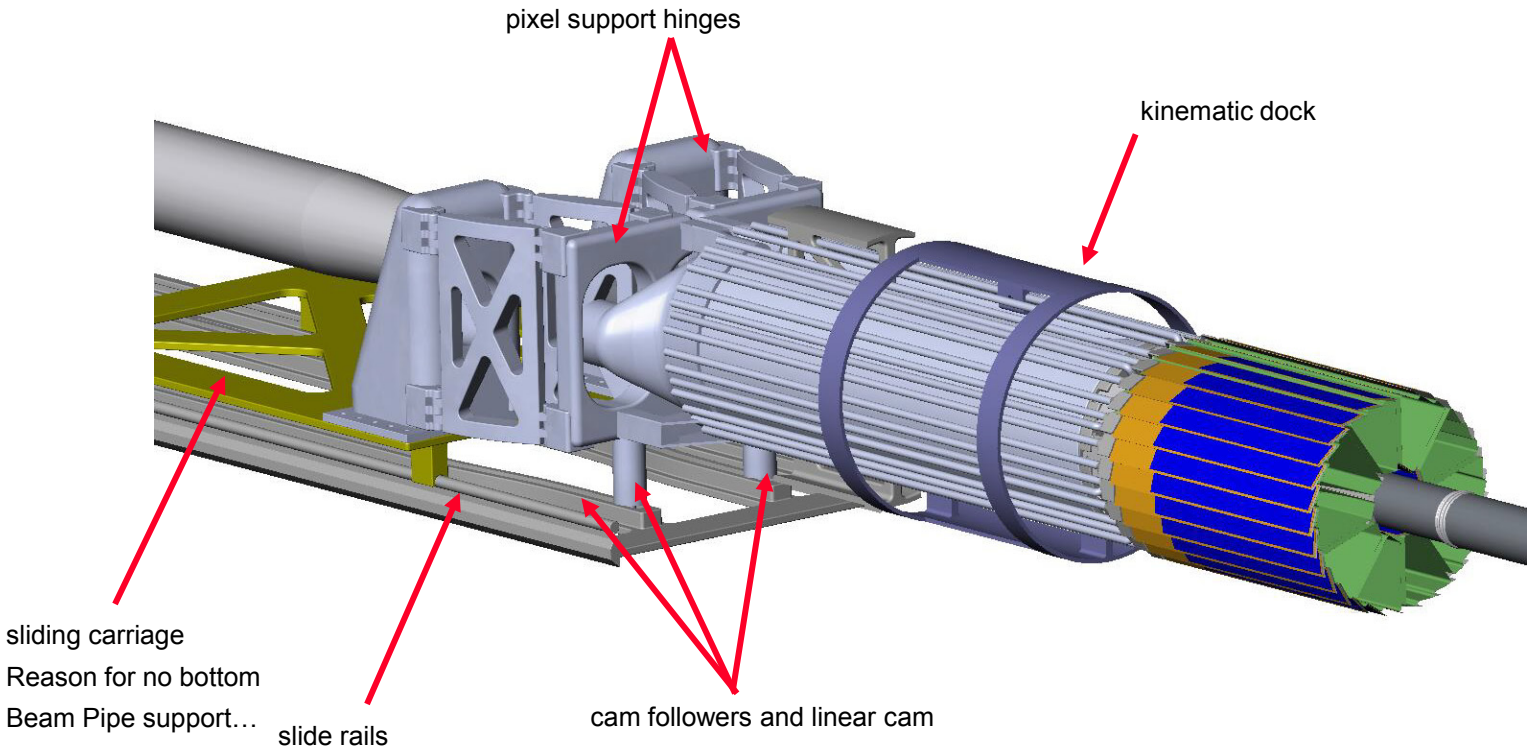


- 20 ladders located at a radius of 22 cm
- Double sided Si strips, 95 μm pitch, 4 cm long, crossed at 35 mrad
- The electronics on each end of the ladder are to be upgraded
- Readout Goal: > 1 kHz for all detectors in the HFT

The Pixel Detector lies beneath the SSD and IST

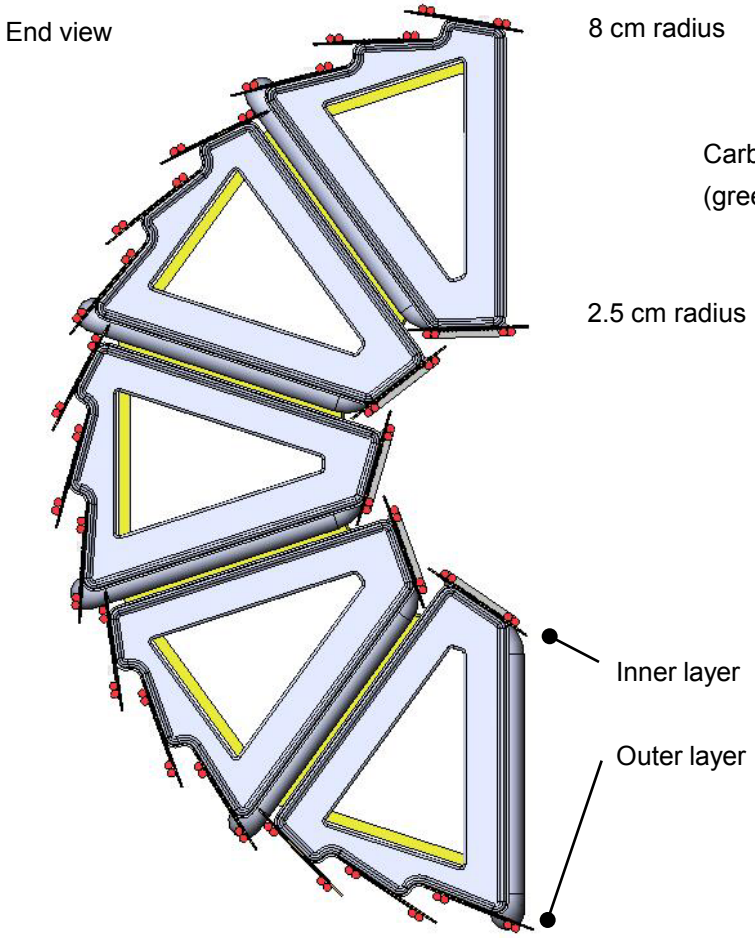


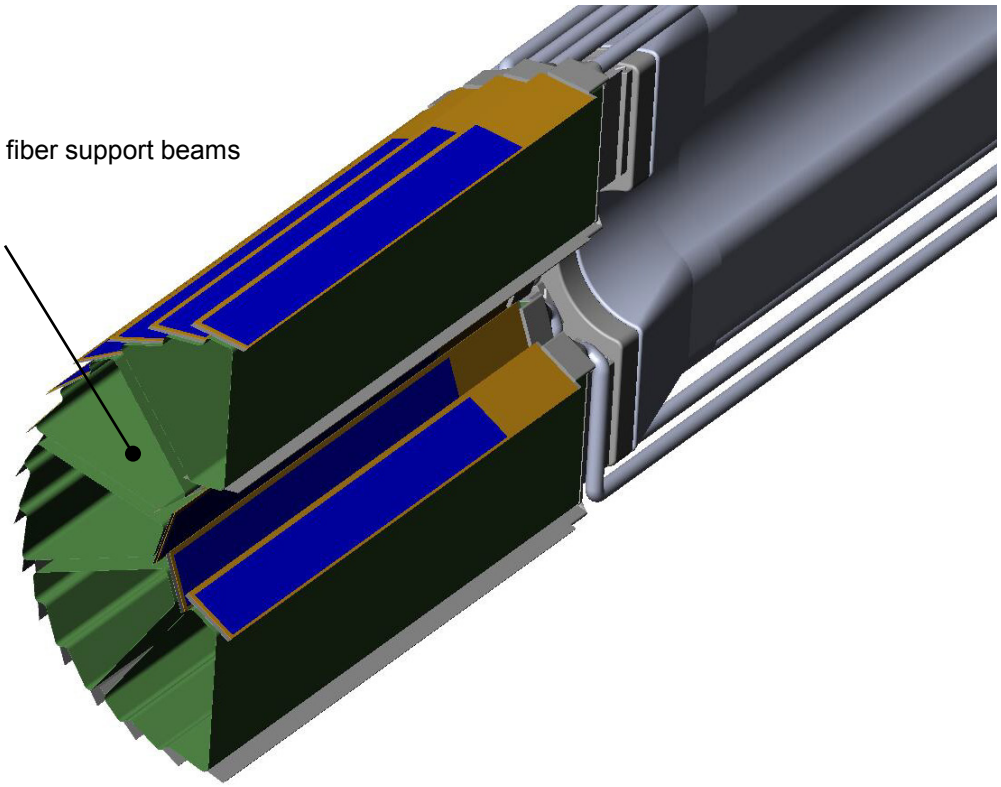
Hinge detail

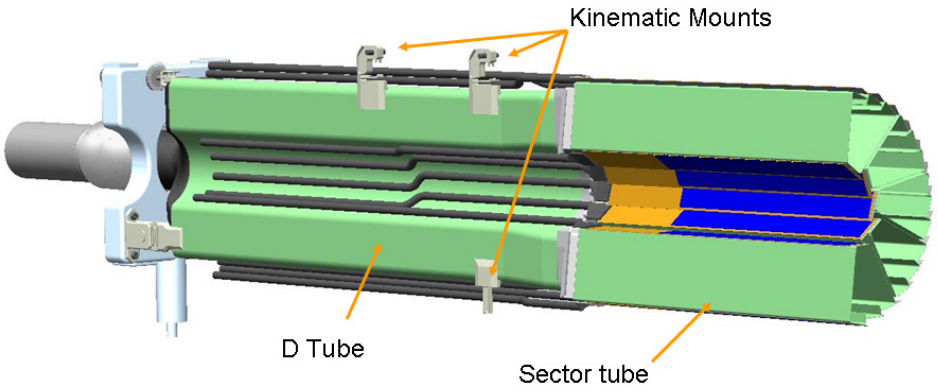


- **Parallelogram hinges support the two detector halves while sliding**
- **Cam and follower controls the opening of the hinges during insertion and extraction**
- **Detector support transfers to kinematic dock when positioned at the operating location**

Pixel support structure near the vertex

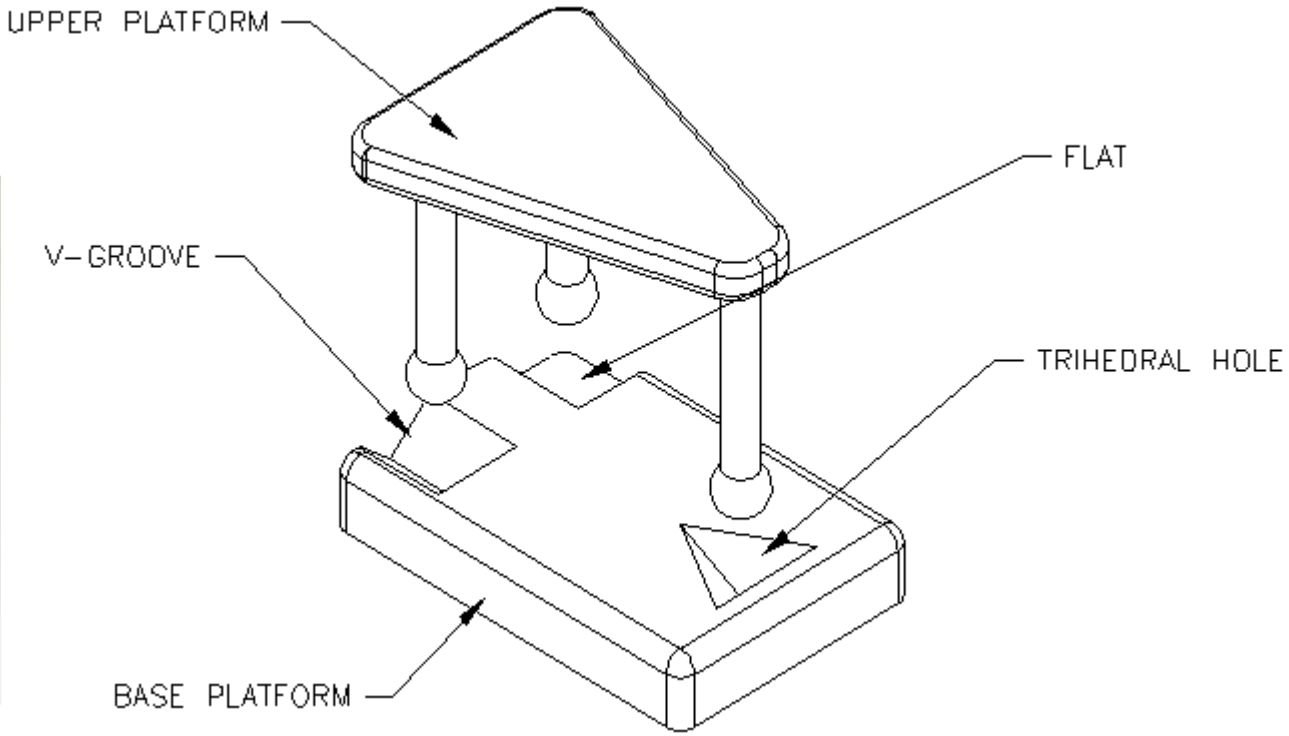






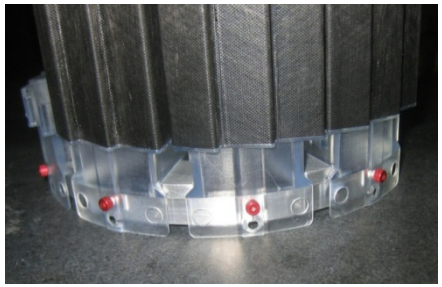
Two “D” sectors form the heart of the PXL detector. The two halves separate in order to allow for easy access, removal and repair.

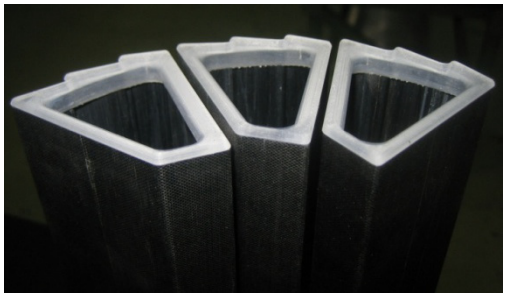
Kinematic Mounts

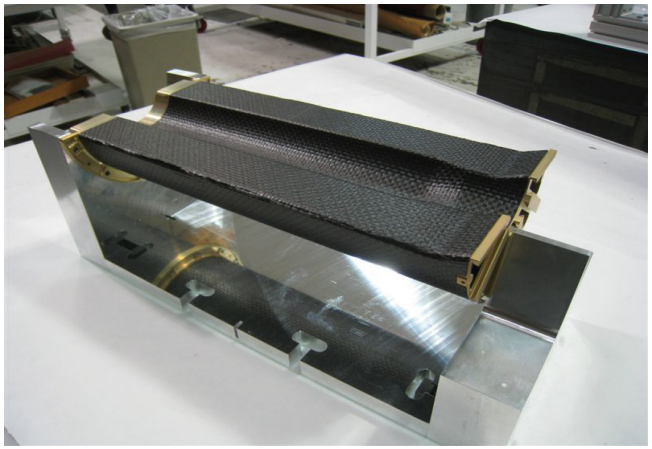


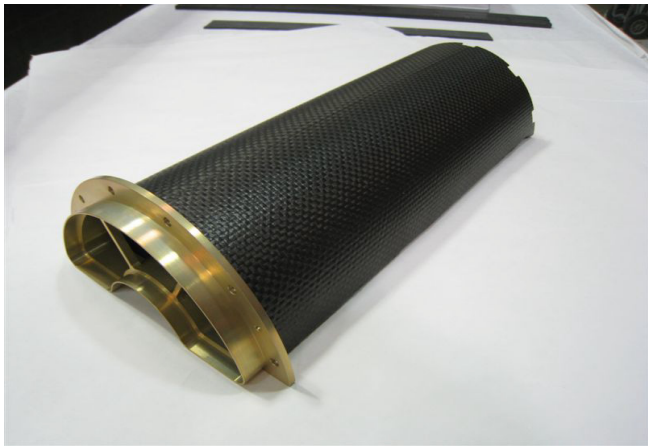
- **Kinematic mounts exploit the fact that three points define a plane**
- **Obvious 'perfect' alignment with four spheres ⇒ 3 points of contact**
- **Reproducible position to 10 μm, often used on optical benches**
- **More typical design on the right … the difficult part is to maintain enough pressure on the points of contact to hold their position**

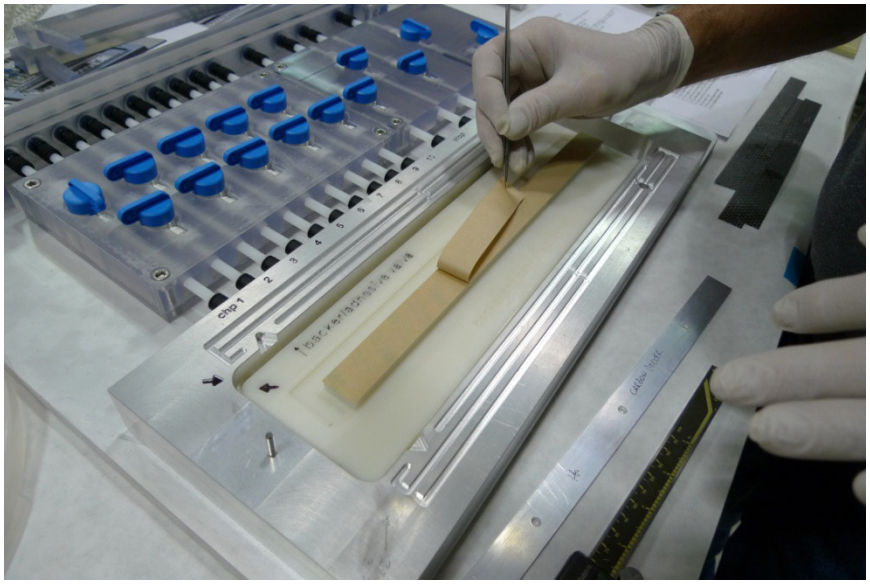
HFT PXL status – fabrication and tooling

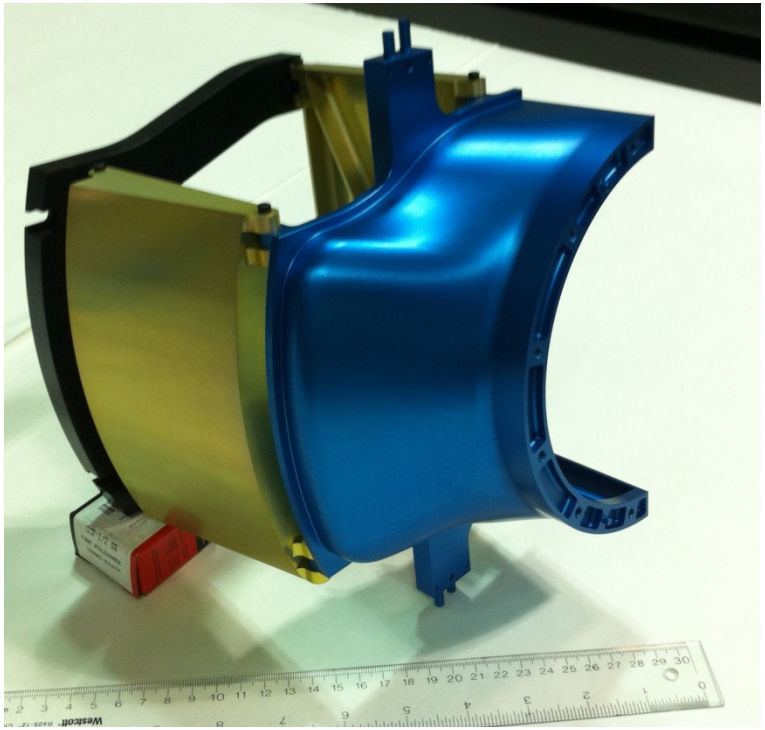




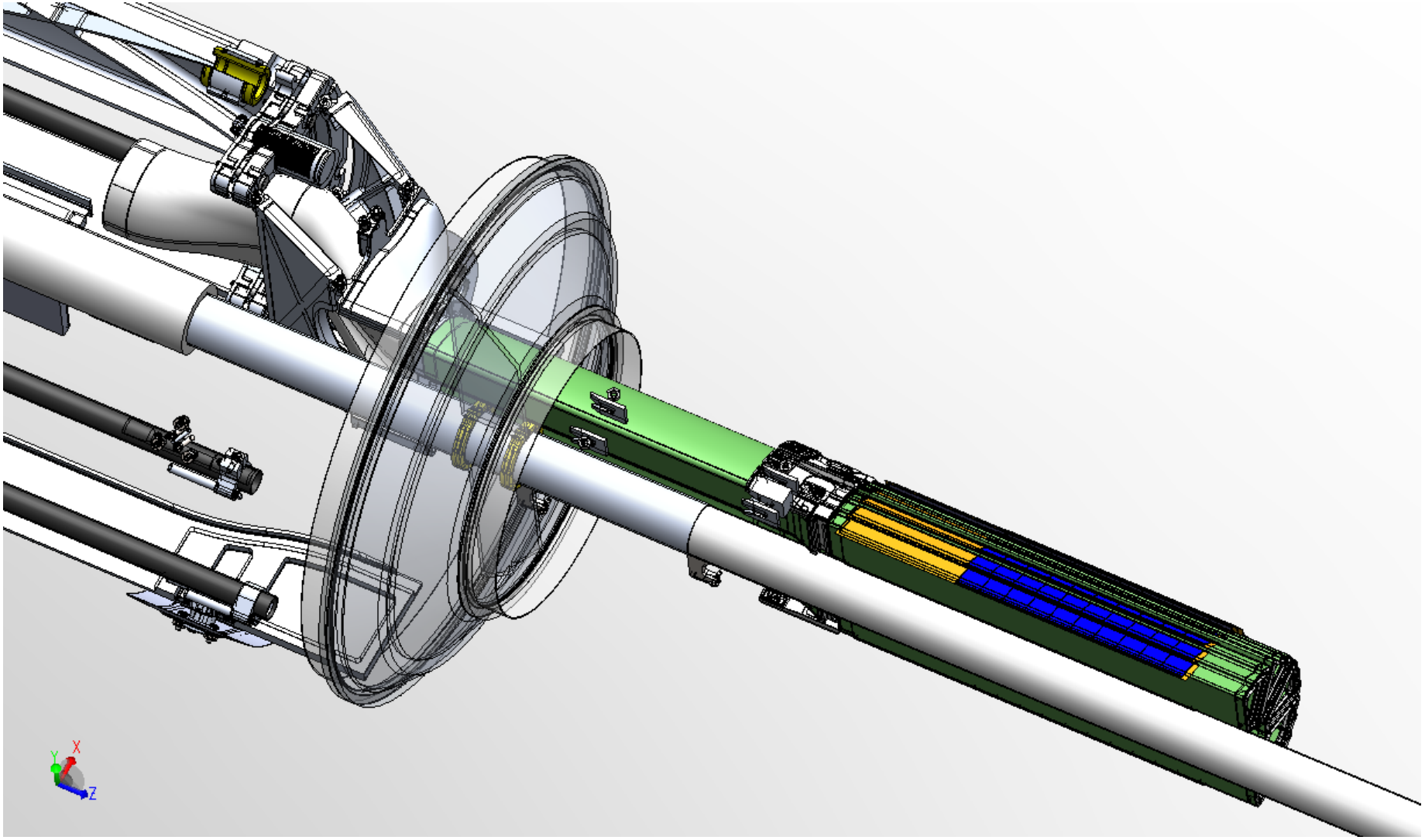






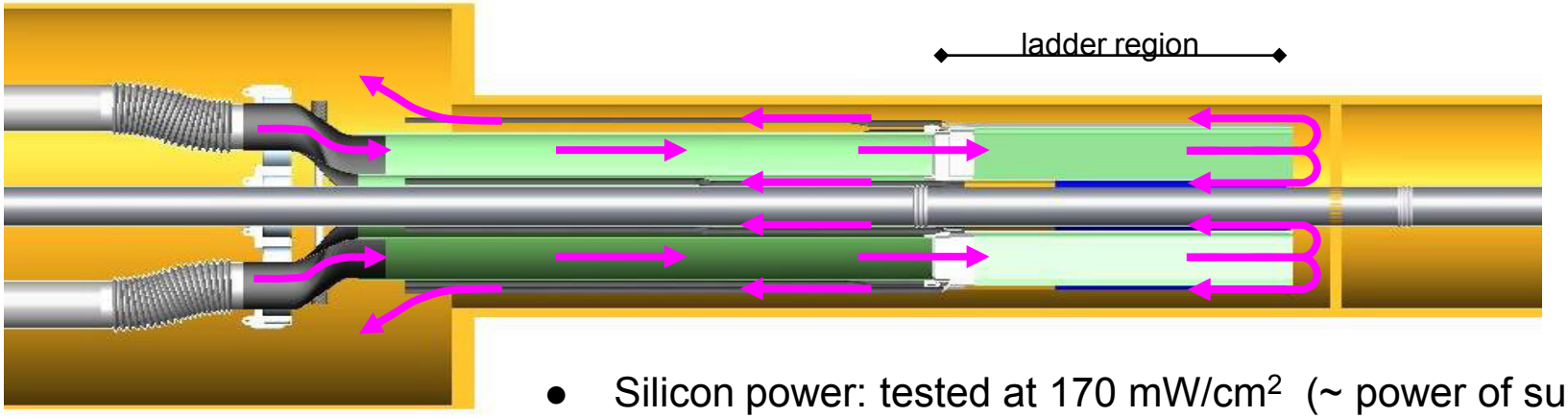


Hinge and Cooling Duct detail

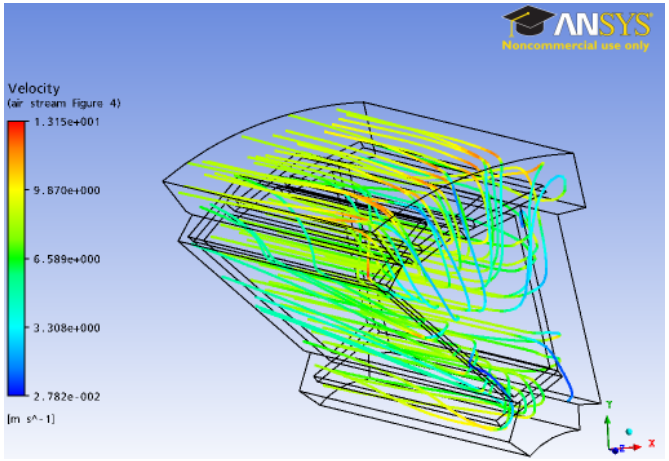


Air Cooling

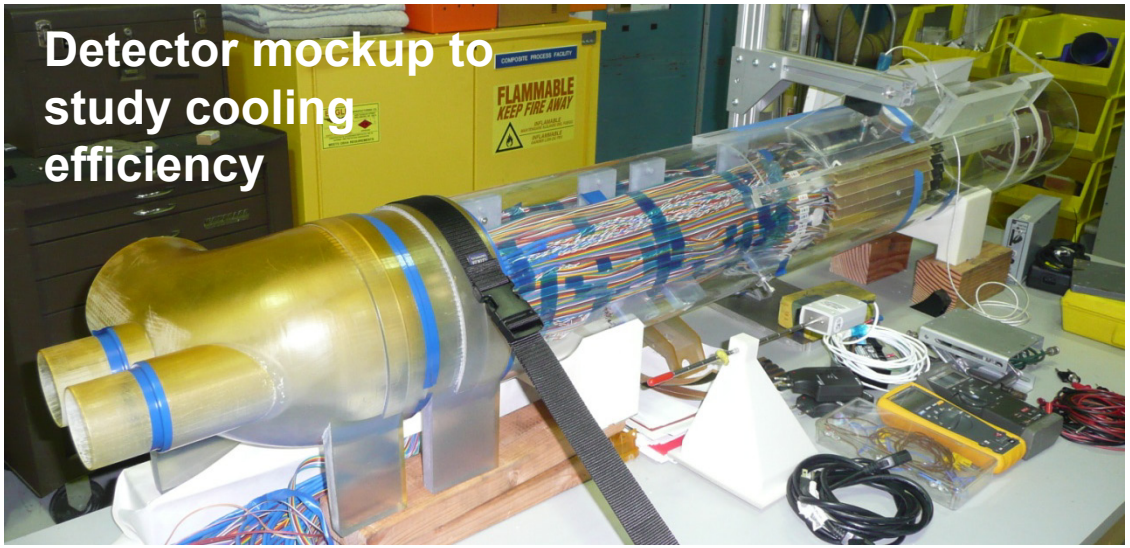
Air-flow based cooling system for PXL to minimize material budget.



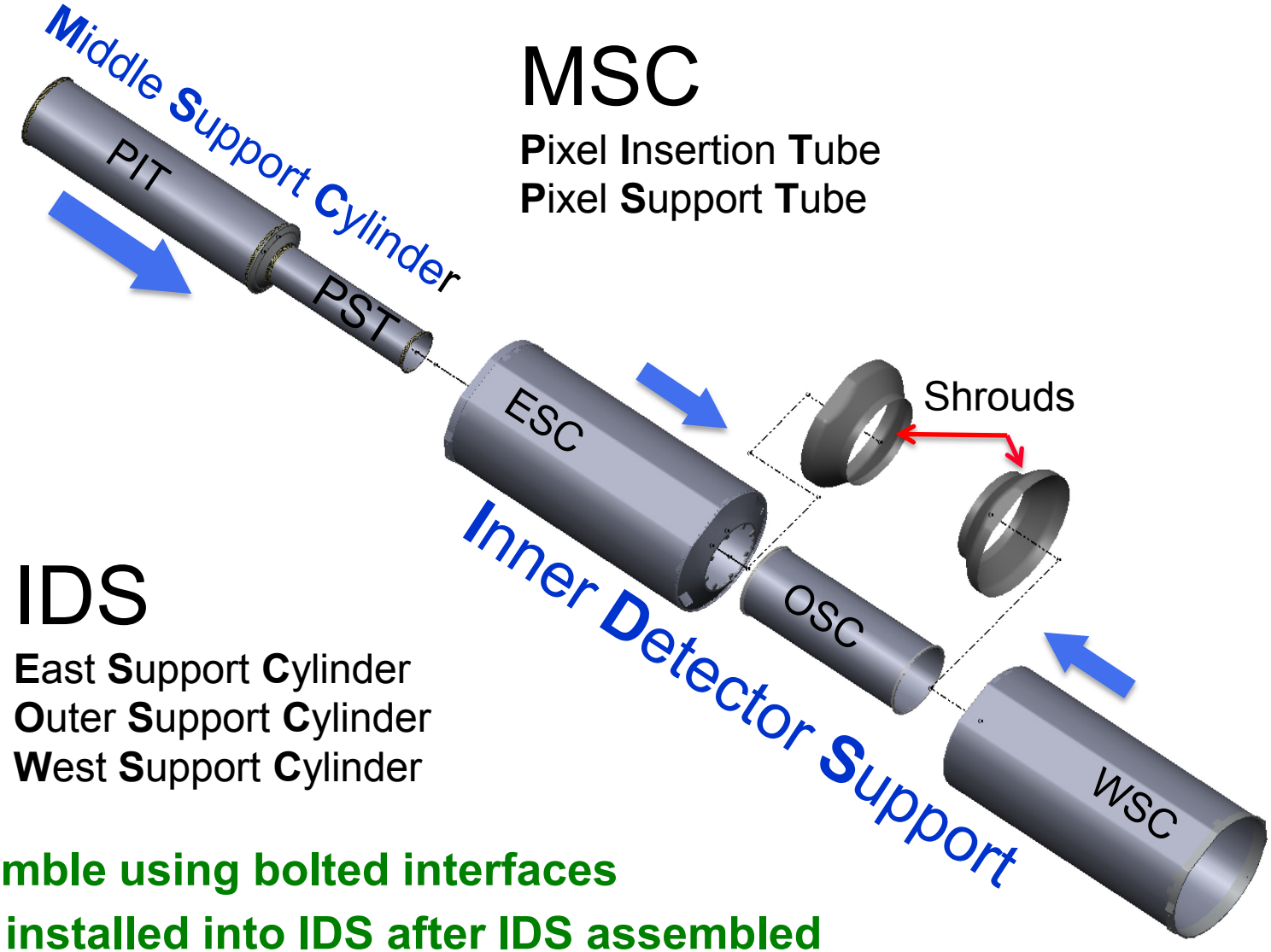
- Silicon power: tested at 170 mW/cm^2 (~ power of sunlight)
- 350 W total in the ladder region (Si + drivers)



computational fluid dynamics



Structures: Exploded Detail



MSC

Pixel **I**nsertion **T**ube
Pixel **S**upport **T**ube

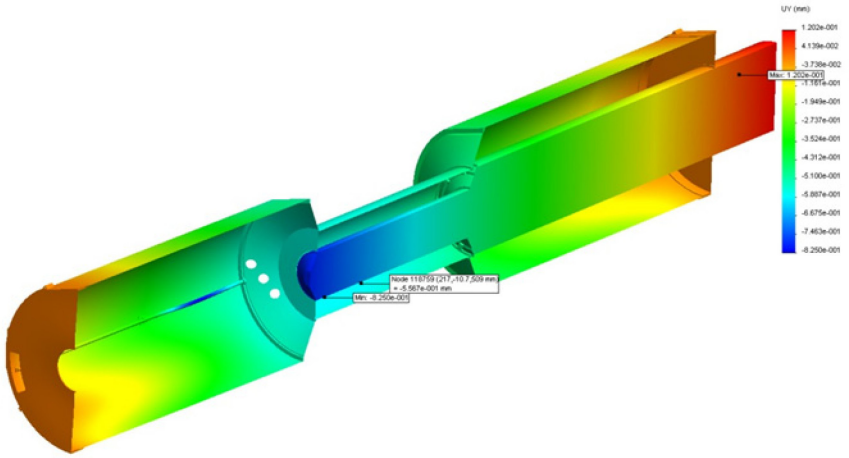
IDS

East **S**upport **C**ylinder
Outer **S**upport **C**ylinder
West **S**upport **C**ylinder

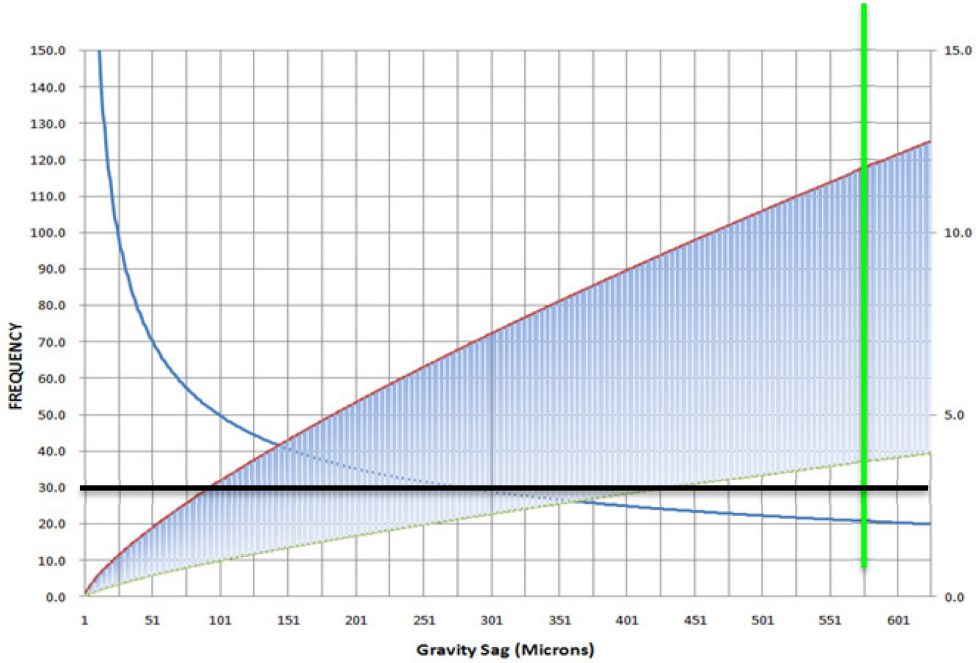
Assemble using bolted interfaces

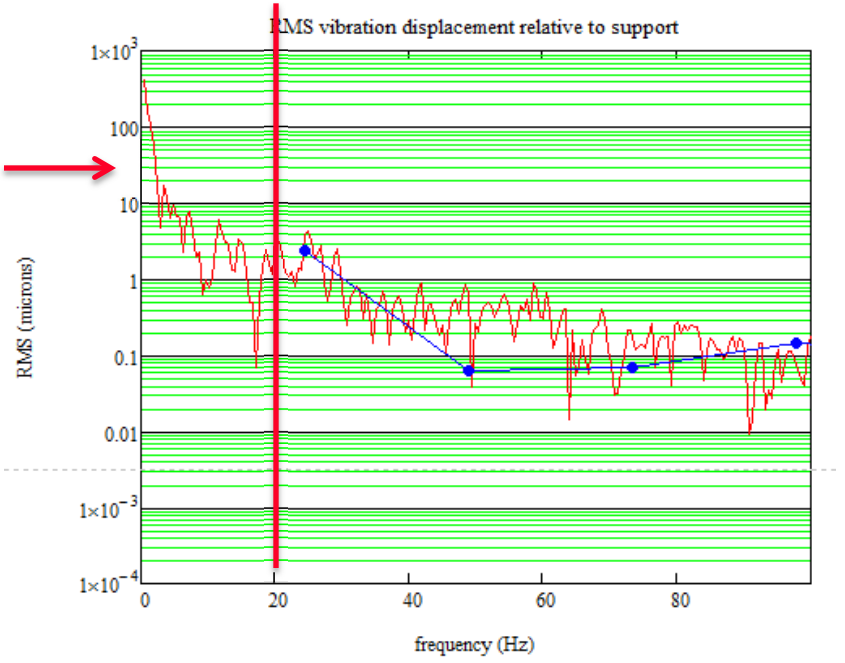
MSC installed into IDS after IDS assembled
(detectors not shown)

Stability Performance



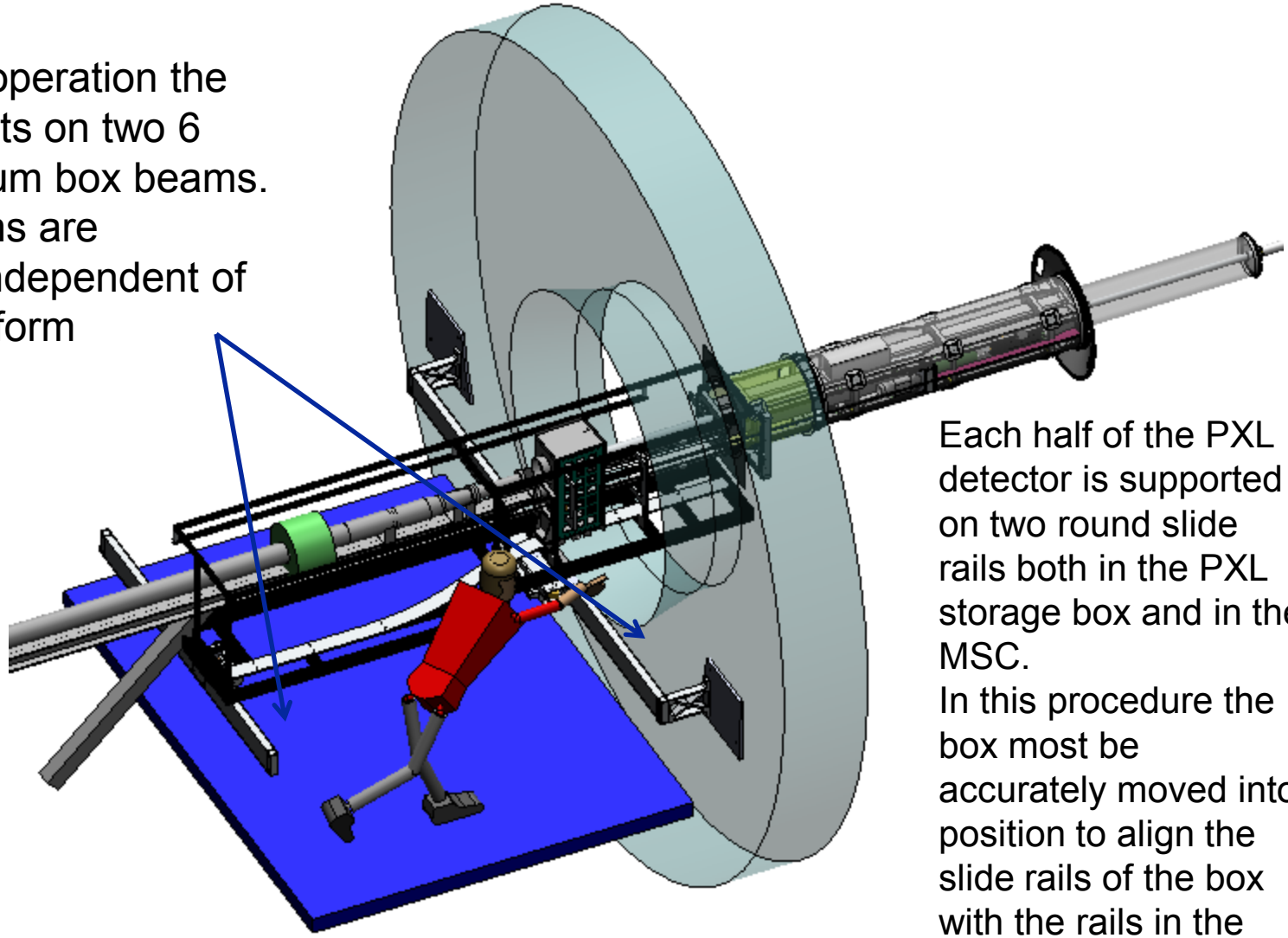
- IDS analyzed for deflection
- Anticipated response convolved with measured STAR vibration environment
- RMS Stability under 10 μm





Rapid Insertion

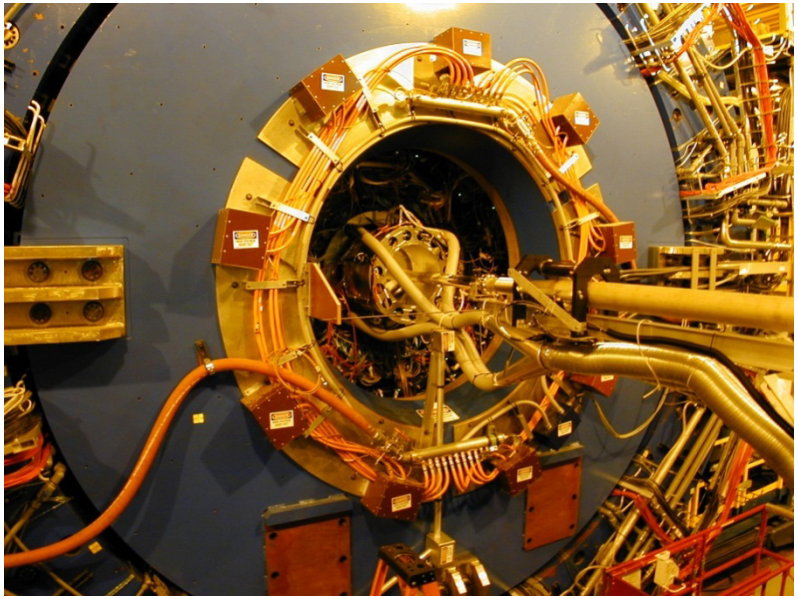
During this operation the PXL box rests on two 6 inch aluminum box beams. These beams are supported independent of walking platform



Up dated, includes measurement tool for checking alignment of two rail systems and instructions

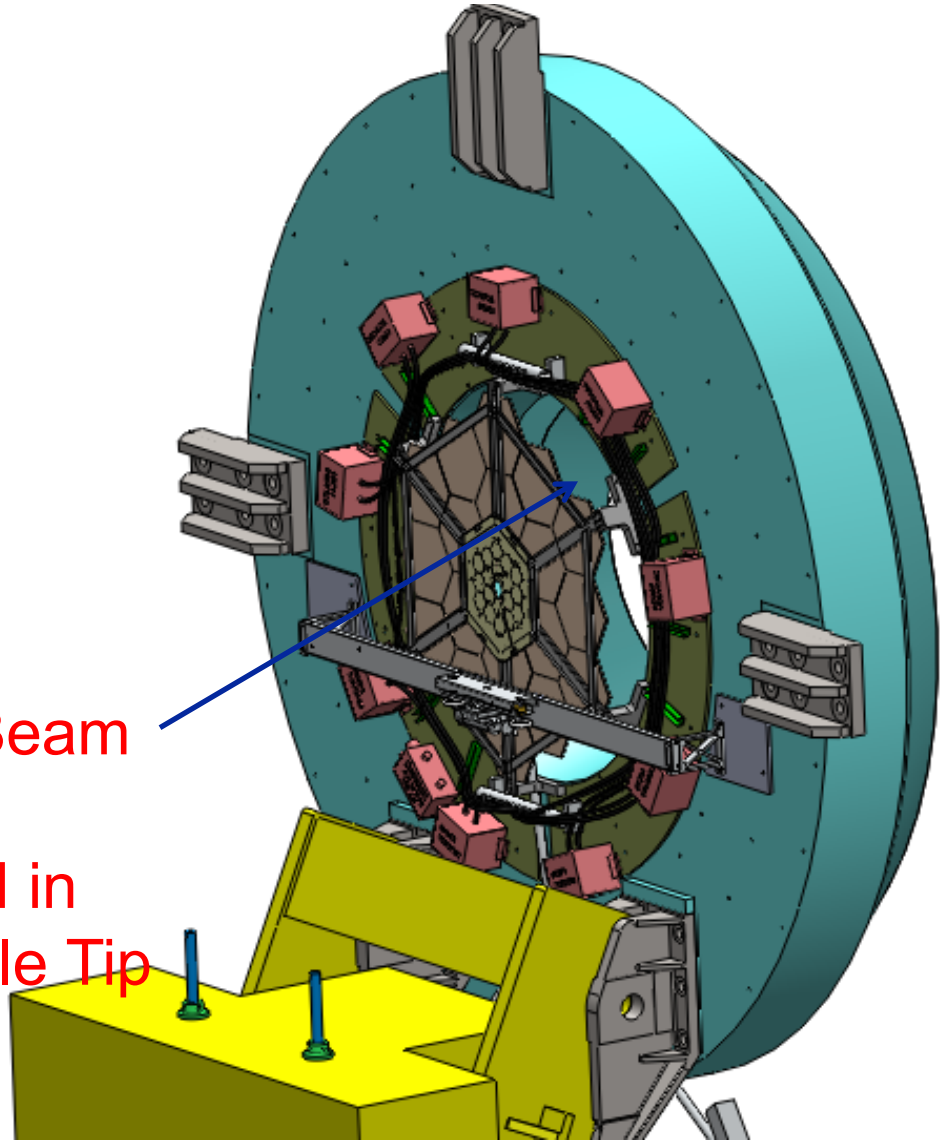
Each half of the PXL detector is supported on two round slide rails both in the PXL storage box and in the MSC.
In this procedure the box most be accurately moved into position to align the slide rails of the box with the rails in the MSC

View of Existing East Pole Tip Area



East Pole Tip as seen during a summer shutdown

Beam-Beam counter installed in East Pole Tip



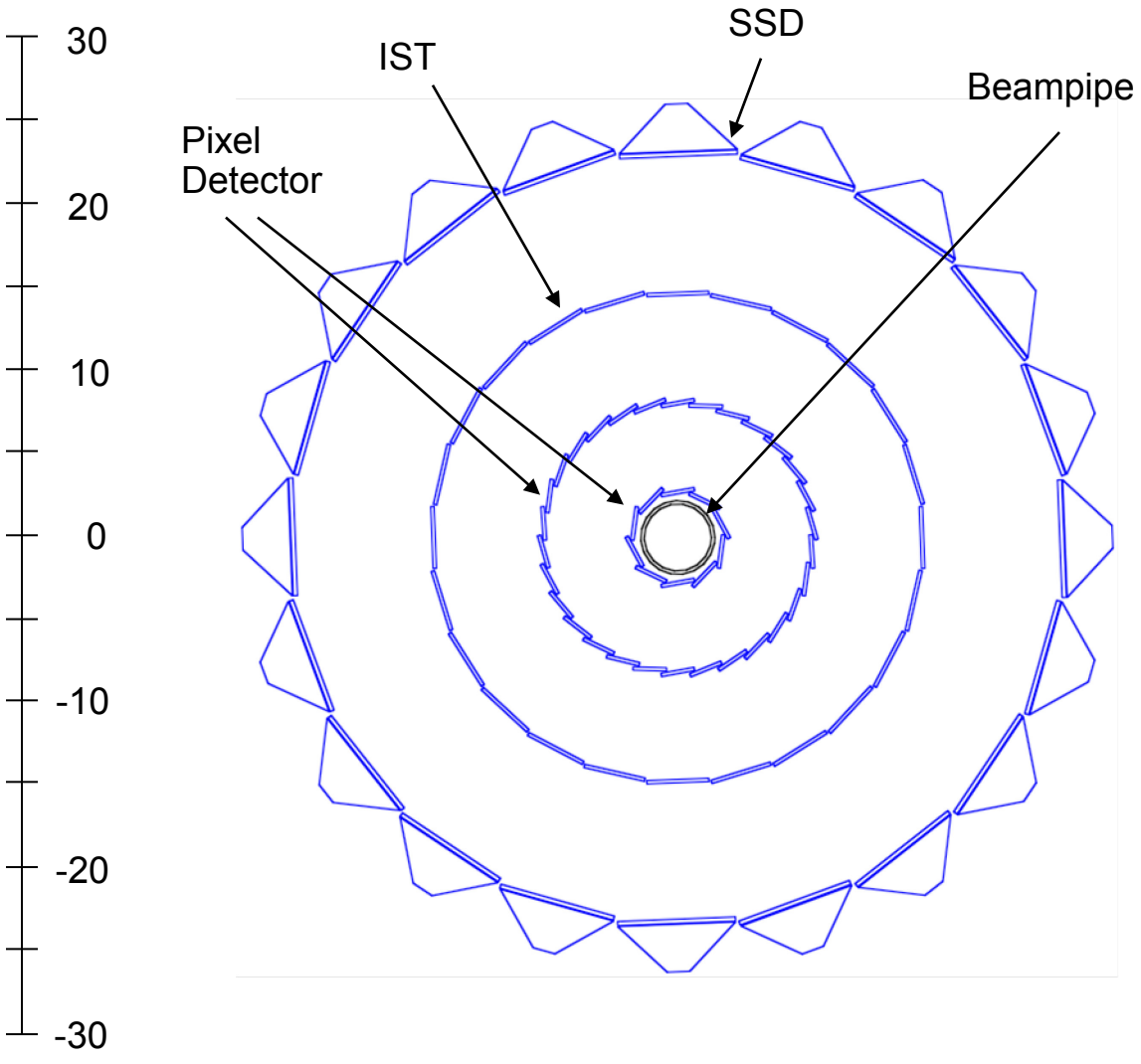
Summary: PXL Detector Characteristics

Pointing resolution	(12 ⊕ 19 GeV/p·c) μm
Layers	Layer 1 at 2.5 cm radius Layer 2 at 8 cm radius
Pixel size	20.7 μm X 20.7 μm
Hit resolution	6 μm
Position stability	6 μm rms (20 μm envelope)
Radiation length per layer	X/X_0 = 0.37%
Number of pixels	356 M
Integration time (affects pileup)	185.6 μs
Radiation environment	20 to 90 kRad $2*10^{11}$ to 10^{12} 1MeV n eq/cm^2
Rapid detector replacement	~ 1 day

356 M pixels on ~0.16 m^2 of Silicon ... it will work!

Backup Slides

The HFT – The configuration



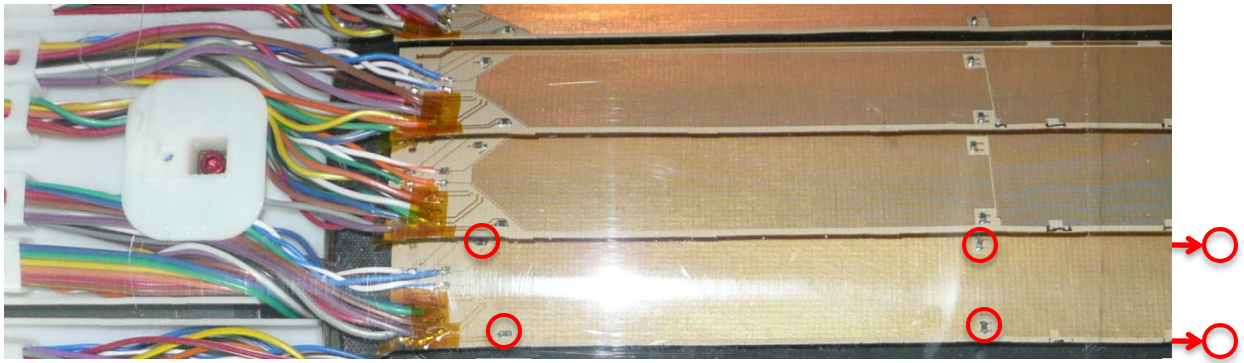
- **The HFT puts 4 layers of Silicon around the vertex**
- **Provides 8 μm space point resolution @ 2.5 cm**
- **30 μm vertex resolution @ 1 GeV, 10 μm @ 5 GeV**
- **Works at high rate (~ 800 Hz – 1K)**
- **Does topological reconstruction of open charm**
- **Will be ready for the 2014 run**

Radiation Load expected in 2014

Rad cm			2.5	2.5	14.0	22.0	2.5	2.5	14	22
		# of wks	**Phys krad**	**Phys + UPC krad**	**Phys krad**	**Phys krad**	**Ramp and Total krad**	**Ramp and Total n/cm²**	**Ramp and Total krad**	**Ramp and Total krad**
200 GeV	Au + Au Max	12	28.3	59.8	0.9	0.4	88.0	1.1E+12	1.8	0.7
	Au + Au Min	12	5.3	11.3	0.2	0.1	16.6	0.2E+12	0.3	0.1
500 GeV	p + p Max	12	133.3	133.3	4.3	1.7	266.7	5.3E+12	8.5	3.4
	p + p Min	12	28.9	28.9	0.9	0.4	57.8	1.1E+12	1.8	0.7

Thermal Studies

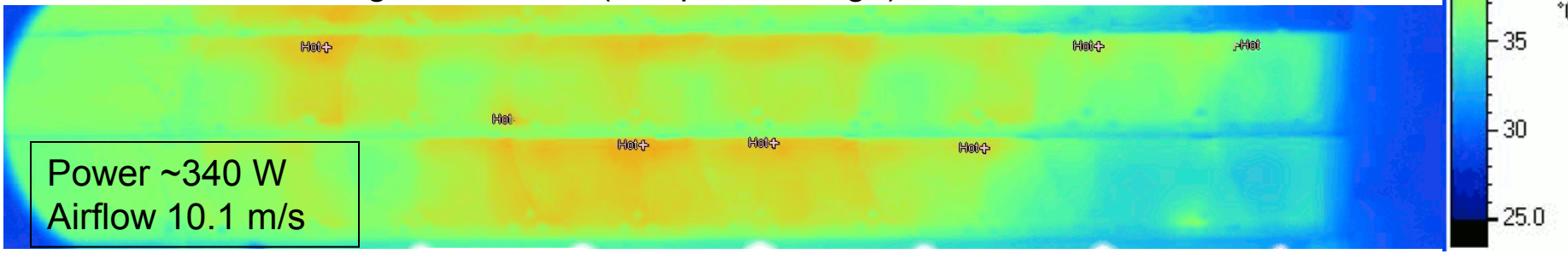
- Kapton cables with copper traces forming heaters allow us to dissipate the expected amount of power in the detector



- 6 NTC thermistors on each ladder

- Sector 1 was equipped with 10 thinned dummy silicon chips per ladder with Pt heaters vapor deposited on top of the silicon and wire bonded to heater power.

Thermal camera image of sector 1 (composite image):

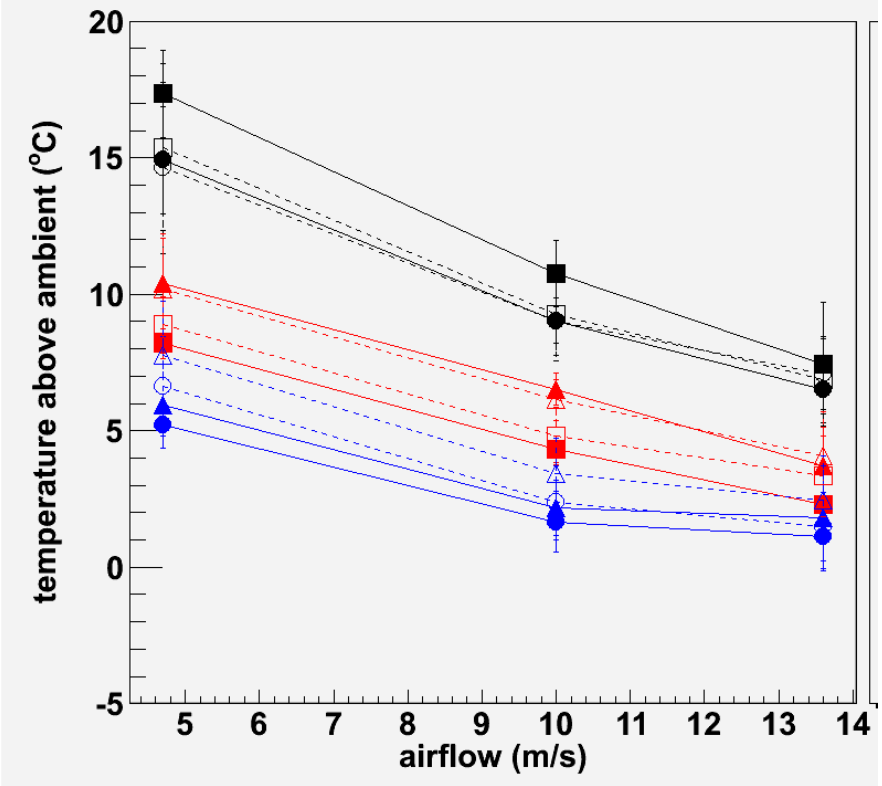


Thermal Results

unsuported end
mid-section
fixed end
Solid – inner layer
Open – outer layer

NTC thermistors (averaged at same "Z" position)

340 W with ambient air = 26.8 C



- Measurement results agree with simulations and meets calculated stability envelope tolerance.
- Air flow-induced vibrations (≤ 10 m/s) are within required stability window.