Bonner Prize

- Howard Wieman is a recipient of the Bonner Prize in Nuclear Physics for 2015
- "For developing foundational experimental and theoretical tools to enable and guide generations of experiments in relativistic heavy ion physics. The combination of experiment and theory led to the initial discoveries at RHIC, ongoing precision studies of the properties of hot nuclear matter, and to exploration of the nuclear matter phase diagram."
- Howard was the physicist in charge of designing and building the **TPC** portion of the STAR experiment facility which was installed at the RHIC collider. Leadership of this project was shared with mechanical engineer, Russell Wells. The TPC provides tracking for the high energy, heavy ion collisions at STAR. At the time of installation, this was the largest TPC built. He initiated and guided the design and construction of a vertex detector (**HFT PXL**) which was installed and began operation in the STAR experiment in 2014. This vertex detector is the first to use monolithic CMOS pixel technology in a collider experiment. It is a significant advance in vertex detector performance and was developed to identify D meson decays in the high track density environment of heavy ion collisions."

- Fortunate to have Howard here, and we have two talks one on HFT and one on TPC

A Brief History and Status of HFT
and
some of Howard's contributions

Flemming Videbæk

Overview

- Want to highlight a few of Howard’s contribution to the HFT, and at the same give some details on the project that many of you may not appreciate, and at the end give a status update
- What was HFT?
- What did it become?
- Performance

Disclaimer: I know very little of STAR details before 2007

RHIC mid-term plan

- STAR presented to RHIC two separate upgrades in early 2006 to the RHIC upgrade committee

1. Pixel Vertex detector
2. Integrated tracking aka outer si layers and forward tracking

This lead to full proposal later that year.

HFT Proposal 2006

Howard started thinking about pixel systems in 1997.
This developed into an R&D program with IPHC and LBNL and with STAR into a first proposal in June of 2006.
Title page is shown:

Proposal is quite detailed:

- Silicon development detailed
- Early Electronics plan
- Mechanics ideas developed
  - Precision positioning
  - Rapid insertion

A Heavy Flavor Tracker for STAR

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University of California, Irvine, California

H. Huang, A. Tai
University of California, Los Angeles, California 90095

V. Kushpil, M. Sumbera
Nuclear Physics Institute AS CR, 250 68 Rez/Prague, Czech Republic

C. Colledani, W. Dulinski, A. Himmi, C. Hu, A. Shabetai, M. Szelezniak, I. Valin, M. Winter
Institut de Recherches Subatomique, Strasbourg, France

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L. Greiner, Y. Lu, H.S. Matis, M. Oldenburg, H.G. Ritter, F. Retiere, A. Rose, L. Ruan, K. Schweda, E. Sichtermann, J.H. Thomas, H. Wieman, N. Xu, Y. Zhang
Lawrence Berkeley National Laboratory, Berkeley, California 94720

I. Kotov
Ohio State University, Columbus, Ohio 43210

Early Mechanics

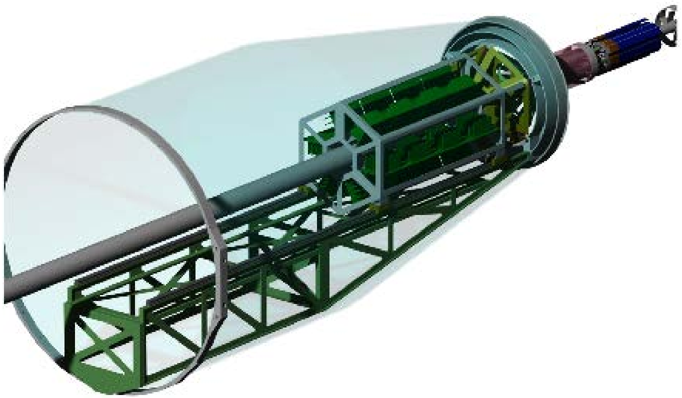


Figure 49: The HFT is shown integrated with the STAR inner detectors cone assembly.

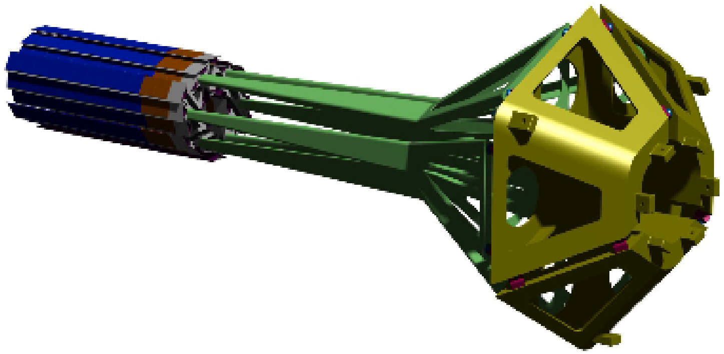


Figure 51: Detector support structure with kinematic mounts to insure repeatable detector positioning.

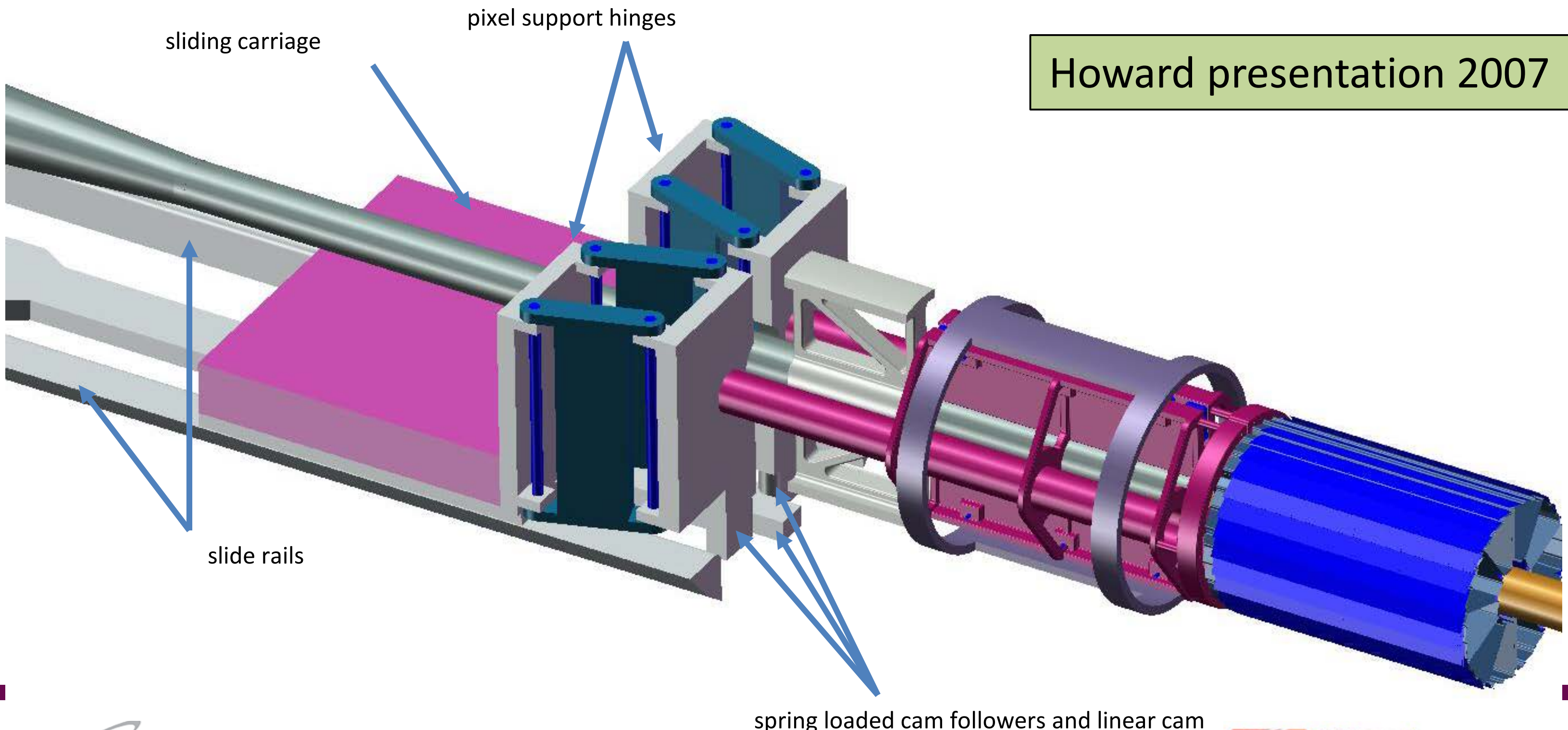
Does anyone recognize this ? Probably not – But
It has all the critical elements:

- Precision mounting
- Rapid insertions
    - At that time the expectation was to change detector 2 times per year

Pixel placement concept

- Detector assembly slides in on rails
- 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

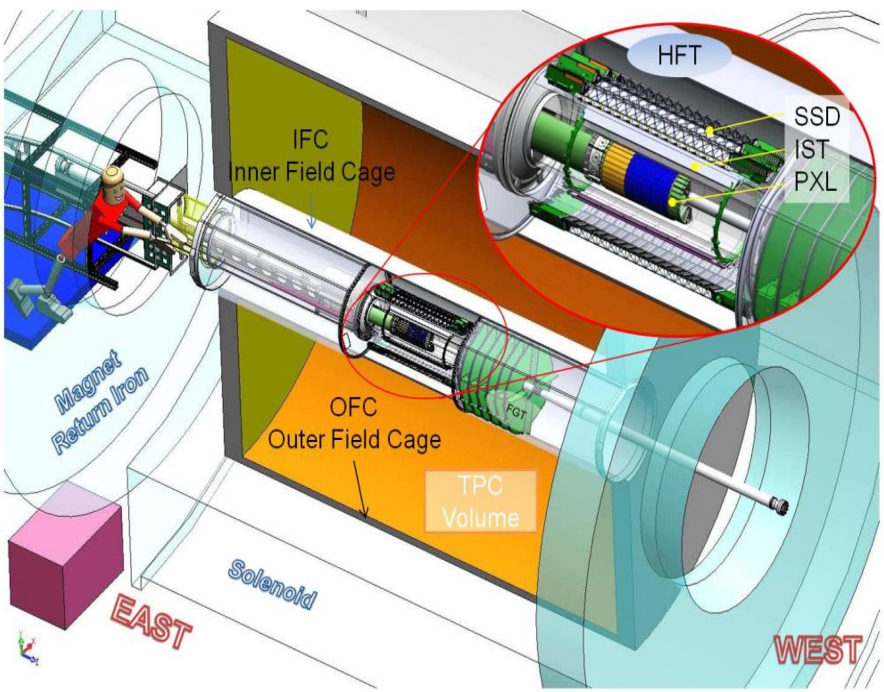
Howard presentation 2007



Proposals

- 2008-2009 CD0 – 2010 CD1
- At this time the concepts were still in development
  - PXL mechanics
  - PXL electronics
  - Integration with IST and SSD, though SSD was not part of proposal
- 2011 CD2/3
- 2014 Completed and taking data

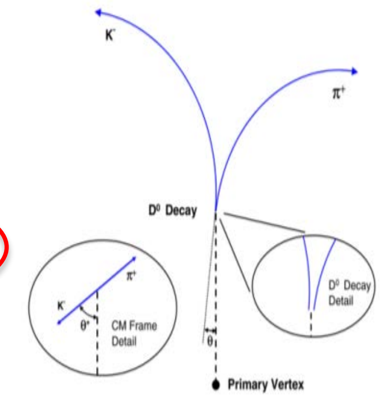
HFT PXL in STAR Inner Detector Upgrades



TPC – Time Projection Chamber
(main tracking detector in STAR)

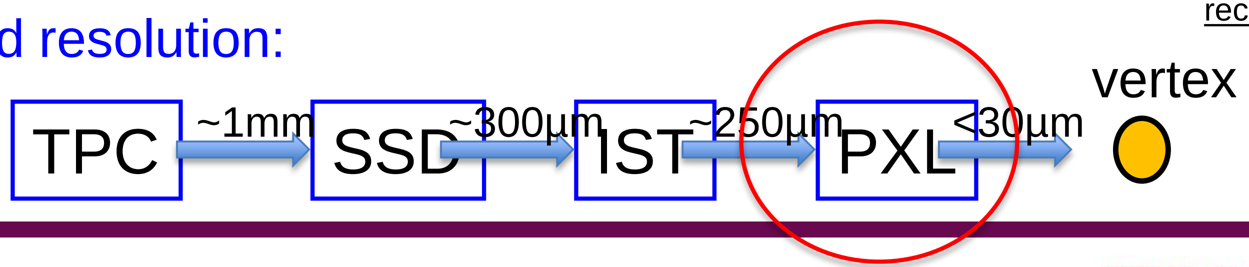
HFT – Heavy Flavor Tracker

- SSD – Silicon Strip Detector
  - r = 22 cm
- IST – Inner Silicon Tracker
  - r = 14 cm
- PXL – Pixel Detector
  - r = 2.8, 8 cm

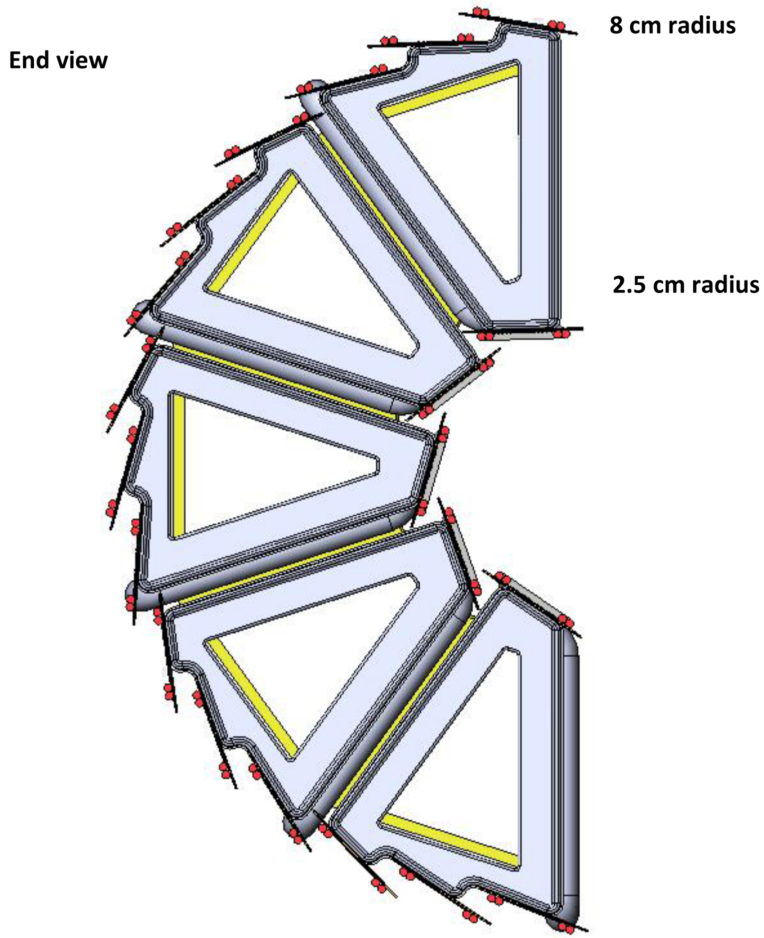


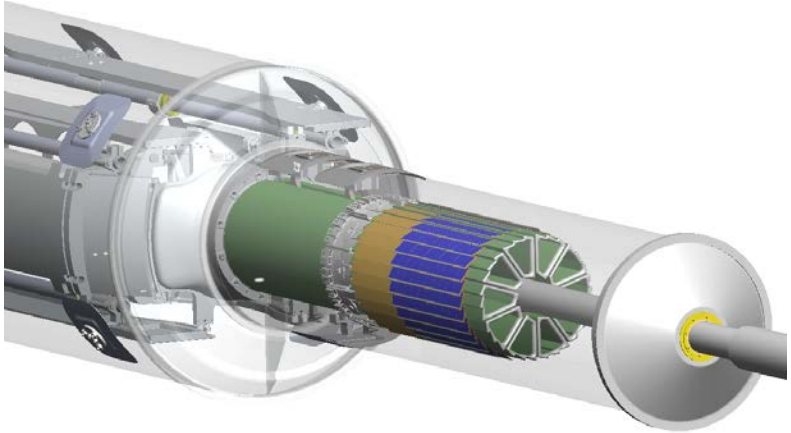
Direct topological reconstruction of Charm

We track inward from the TPC with graded resolution:



Pixel Detector (PXL)





Mechanical support with kinematic mounts (insertion side)

carbon fiber sector tubes (~ 200μm thick)

Insertion from one side

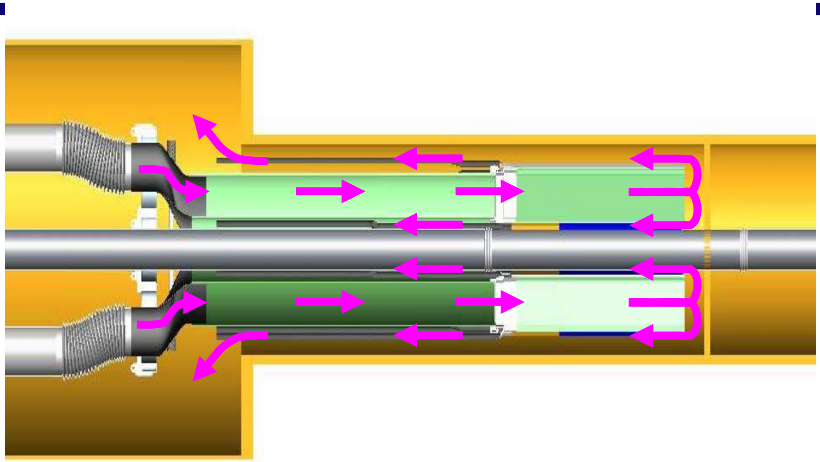
- 2 layers at 2.5 and 8 cm
- 5 sectors / half
- 4 ladders/sector

Significant Contributions

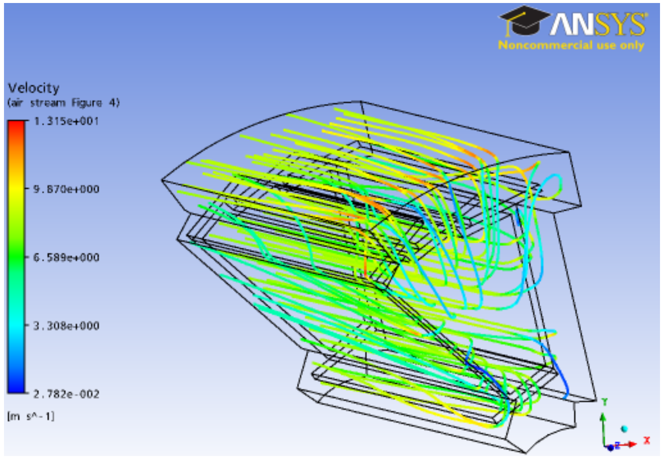
- Airflow/vibrations
- Metrology
- Insertion mechanism
- 3D modeling
- Assembly tooling
- Electrostatics

Much of this material is from a talk by Howard at DESY July 2014

PXL Air Cooling

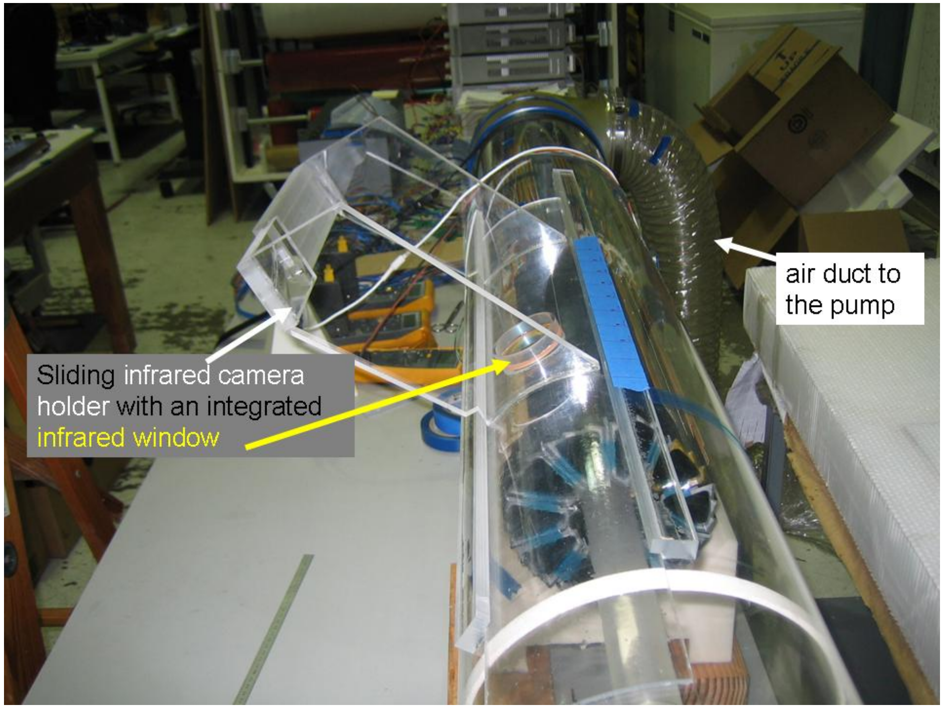


- Silicon power: 100 mW/cm^2
- 240 W total Si + drivers



- air flow velocity 9-10 m/s
- maximum temperature rise above ambient: 12 deg C
- sector beam surface – important component to cooling
- dynamic pressure force 1.7 times gravity

Full scale mockup to verify cooling capability



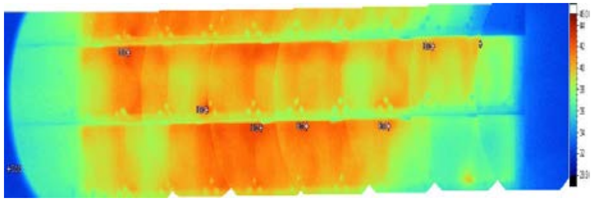
Platinum on thinned silicon to simulate detector chip heat load

Additional heaters to reproduce driver heat sources

Input and output thermocouple monitoring of air temperature

Thermistors distributed on mockup pixel ladders

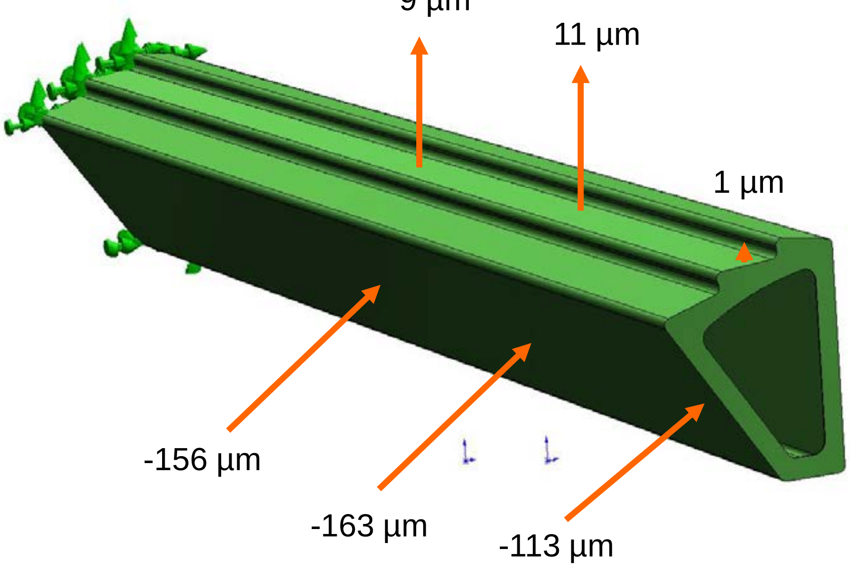
IR camera to measure surface temperatures



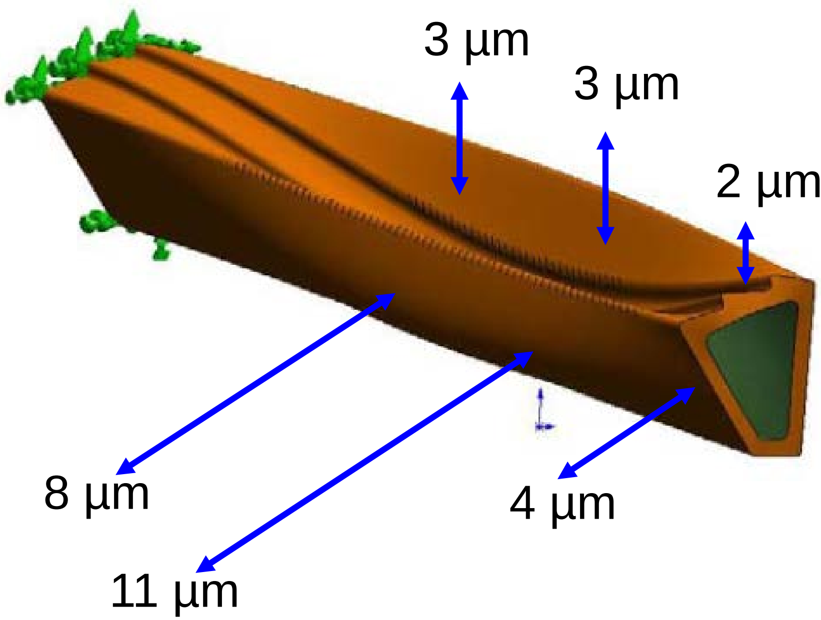
Result: $\Delta T = 11\ ^{\circ}C$ with 10.4 m/s air velocity, verifying CFD estimate

Static displacement and vibration induced by cooling air flow

- Sector vibration modes were examined with FEA
- Prototype sector vibrations measured with airflow tests. This was determined to be less time consuming than setting up transient CFD calculations.
- Measurement of completed detector



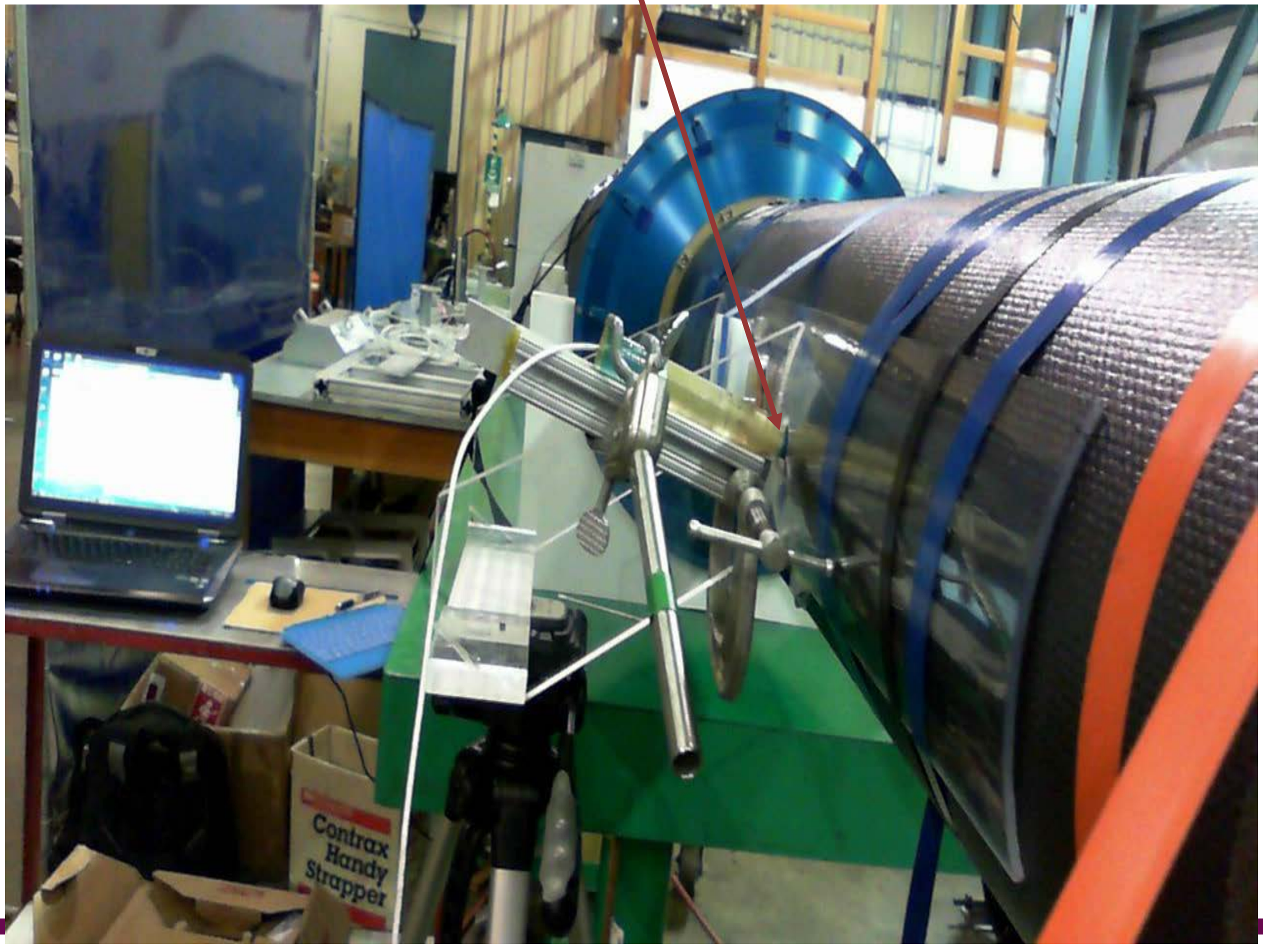
static deformation



vibration (RMS)

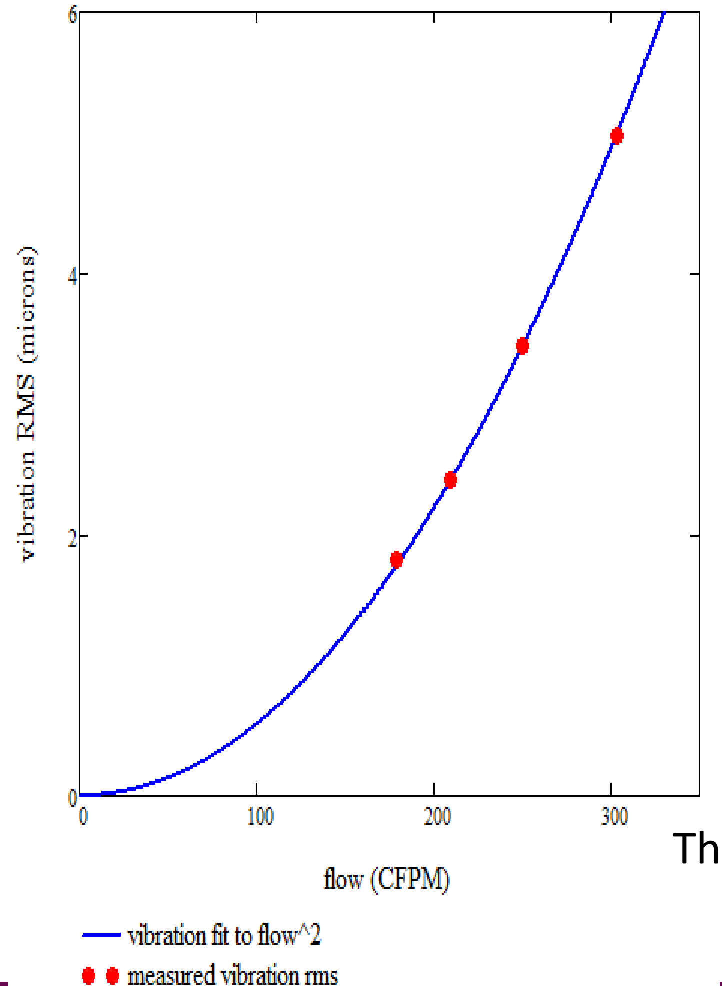
Radial sector motion measured with capacitive probe inserted through hole in PST

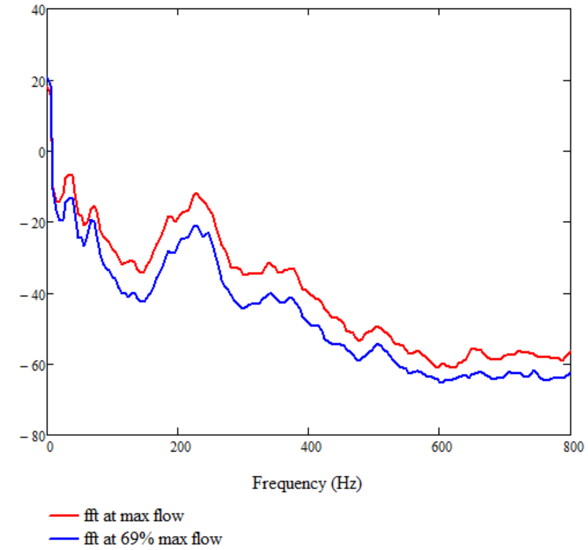
capacitive probe measurement of completed PXL detector



North half sectors populated with operating ladders. South half populated with empty sector tubes. System operated with full cooling air

Measured sector radial vibration as a function cooling air flow for edge



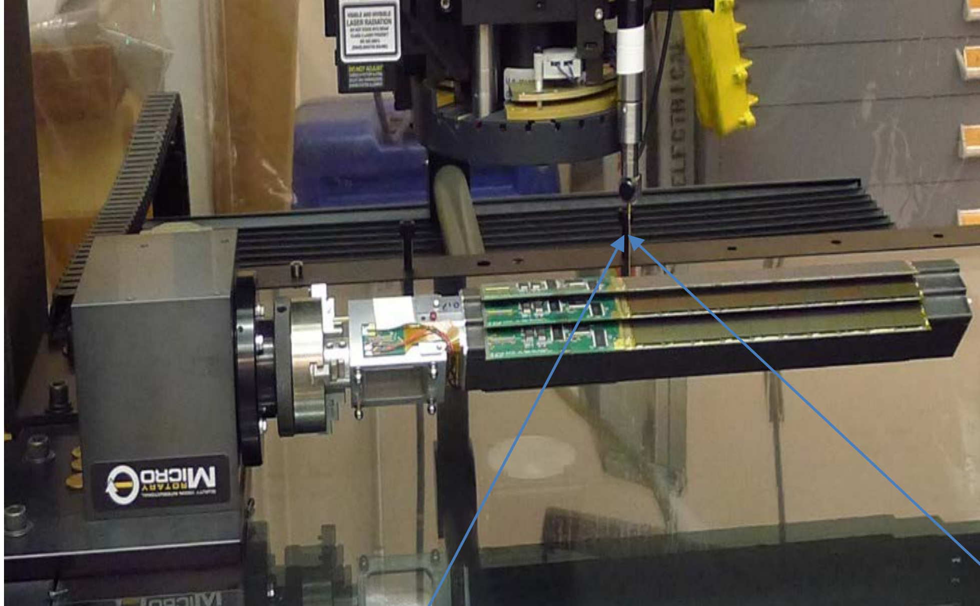


capacitive probe measurement of completed PXL detector

The measured vibration with no air flowing:

35 nm RMS

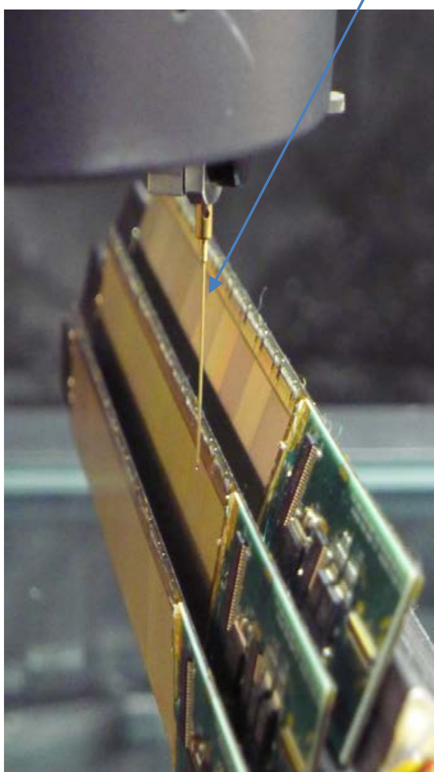
Spatial mapping of the pixels

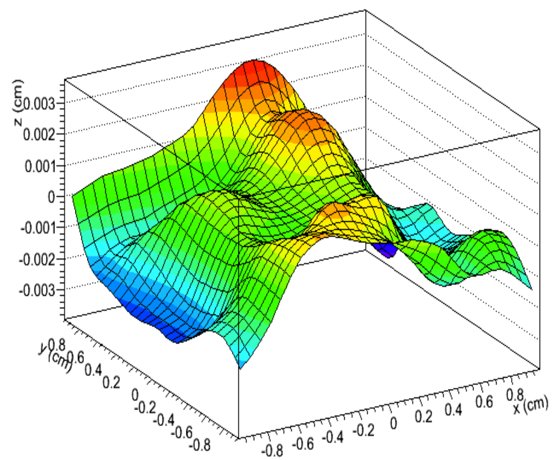


Pixel locations determined with CMM equipment to within 10 μm prior to installation in STAR

Programmed CMM Measurement method#:

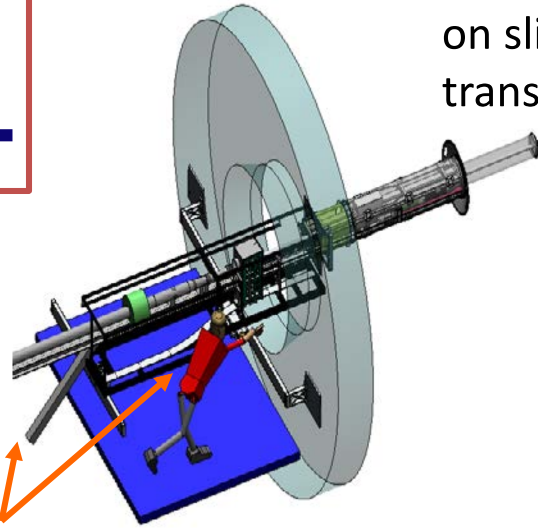
- All pixels located on a sector with respect to 3 sector tooling balls
  - 2 Lithography points on the chips measured with optical head
  - Chip surface profile measured with 11 x 11 point pattern using a Feather Probe*. Using a touch probe permits picking up over hung surfaces





PXL sensor surface profile from survey:
± 30 μm > PXL hit error,
and the chip to chip surface deviation along the ladder surface is still larger, but all of this is then corrected with the spatial map

System for rapid PXL installation (external mechanics)

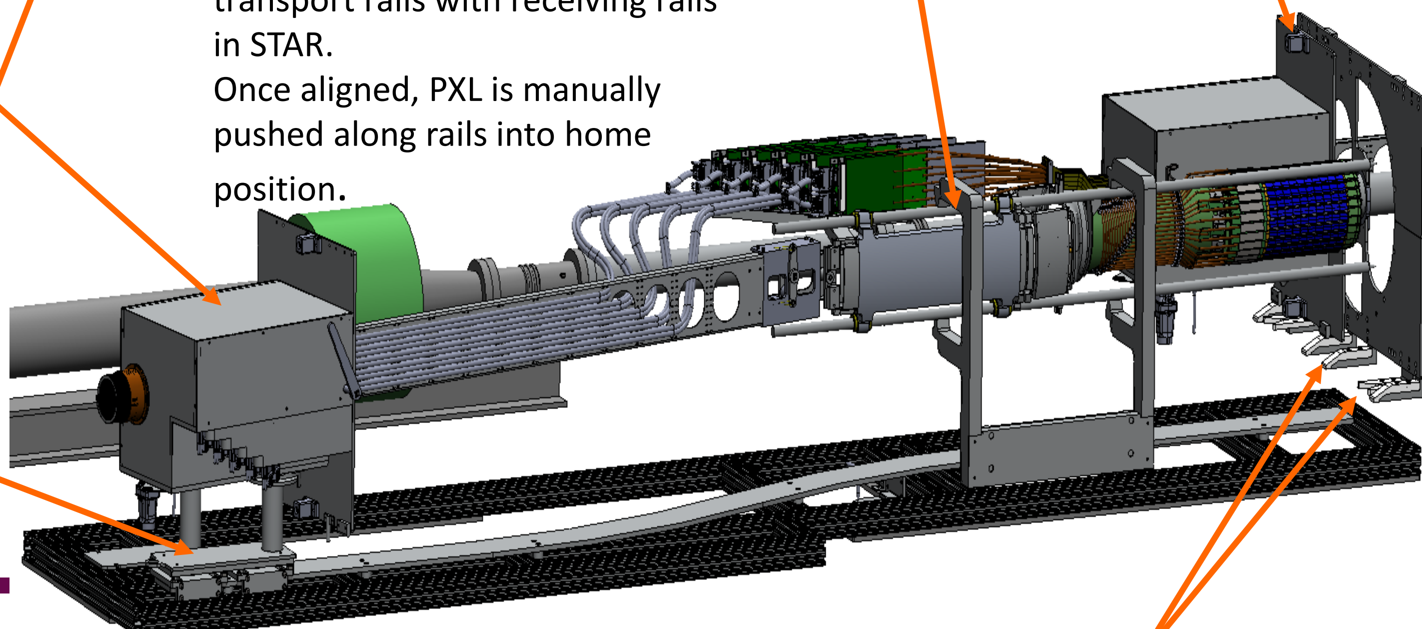


PXL carriage supported on slide rails in transport fixture

two captured screws, one top one bottom, secure and seal the bulkhead box to the detector housing

The 6 degree screw jack system, built into support, is used to align transport rails with receiving rails in STAR.
Once aligned, PXL is manually pushed along rails into home position.

Bulkhead box with all electrical and air connections



Trolley guide to steer box around beam pipe elements

positioning guides to receive the

PXL Ladder Assembly

Precision vacuum chuck fixtures to position sensors by hand.

Sensors are positioned with butted edges. Acrylic adhesive prevents CTE difference based damage.

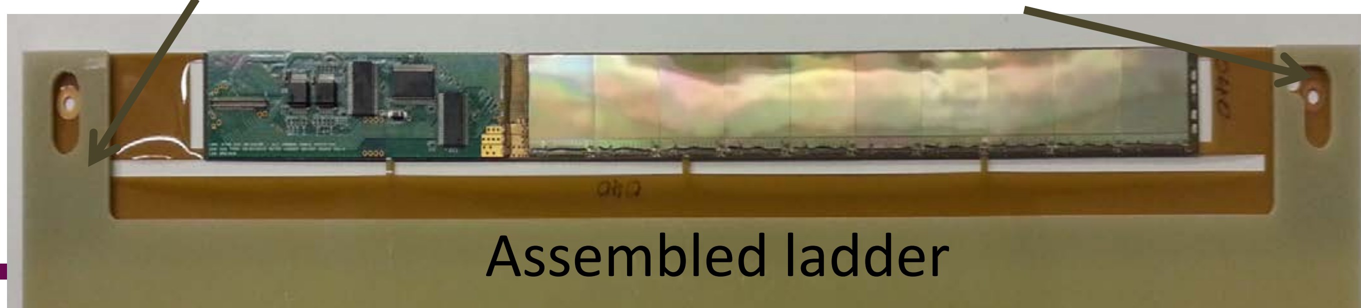
Weights taken at all assembly steps to track material and as QA.

Hybrid cable with carbon fiber stiffener plate on back in position to glue on sensors.

Sensor positioning

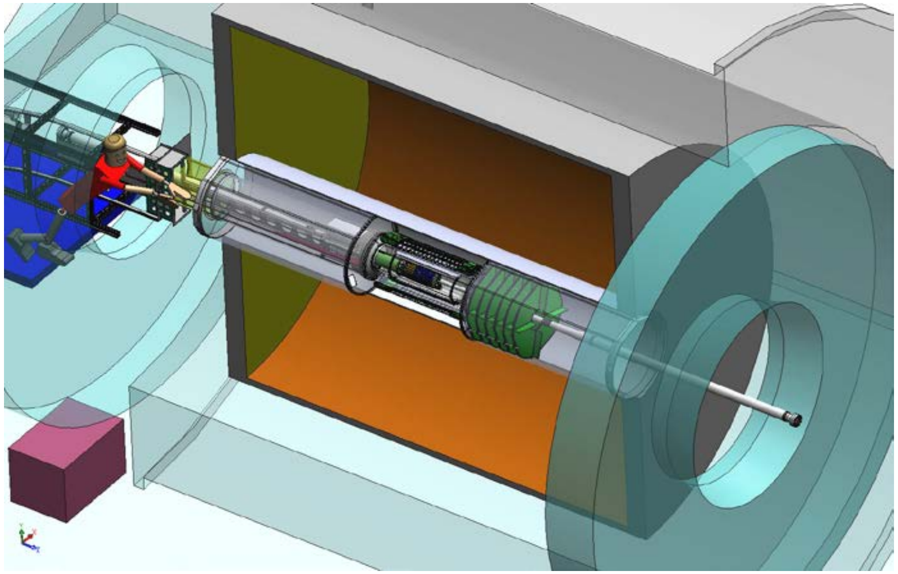
FR-4 Handler

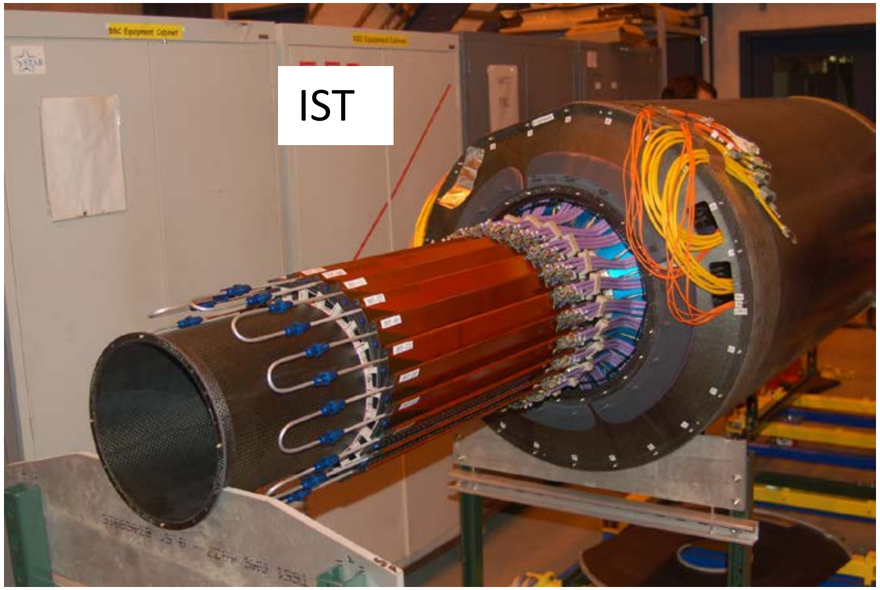
Cable reference holes for assembly

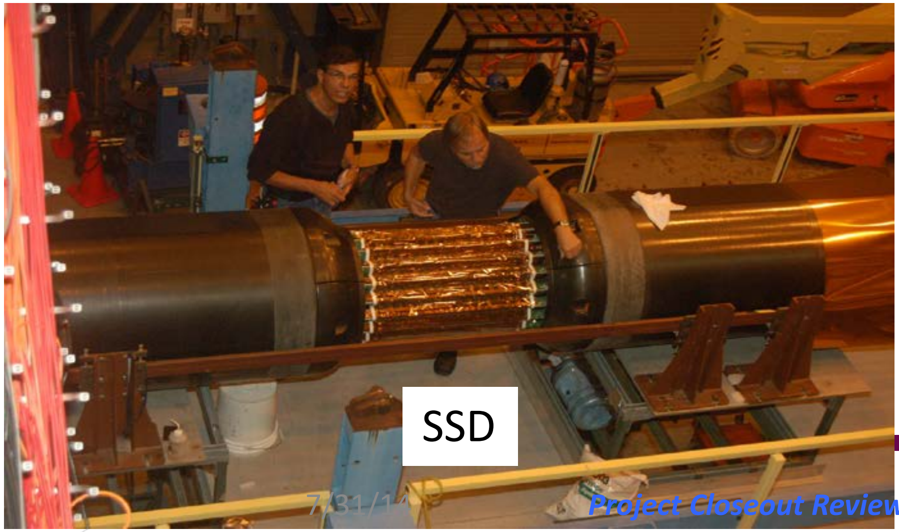


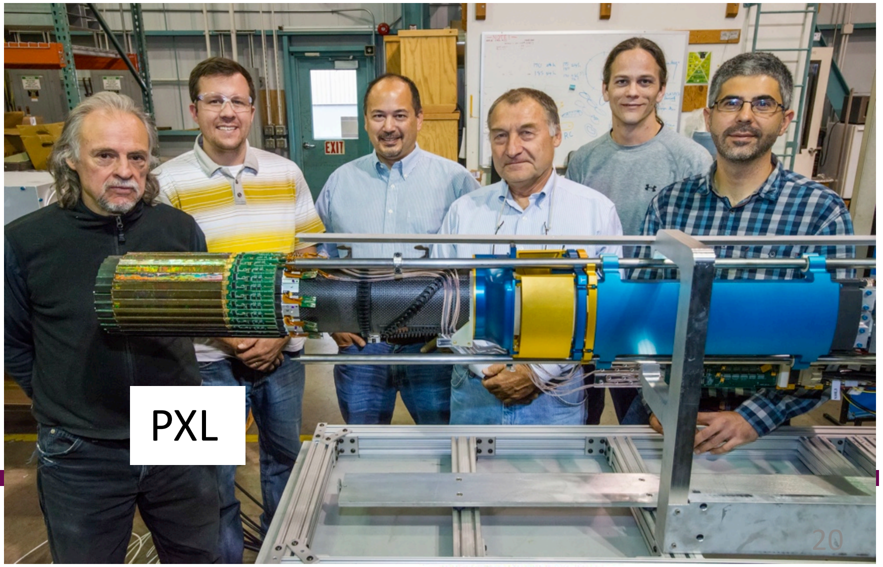
Assembled ladder

Heavy Flavor Tracker



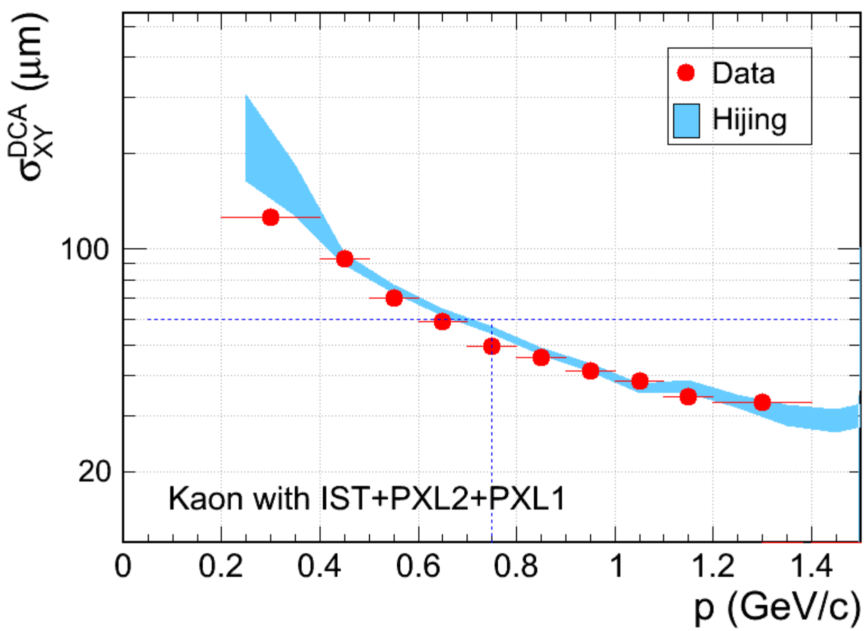




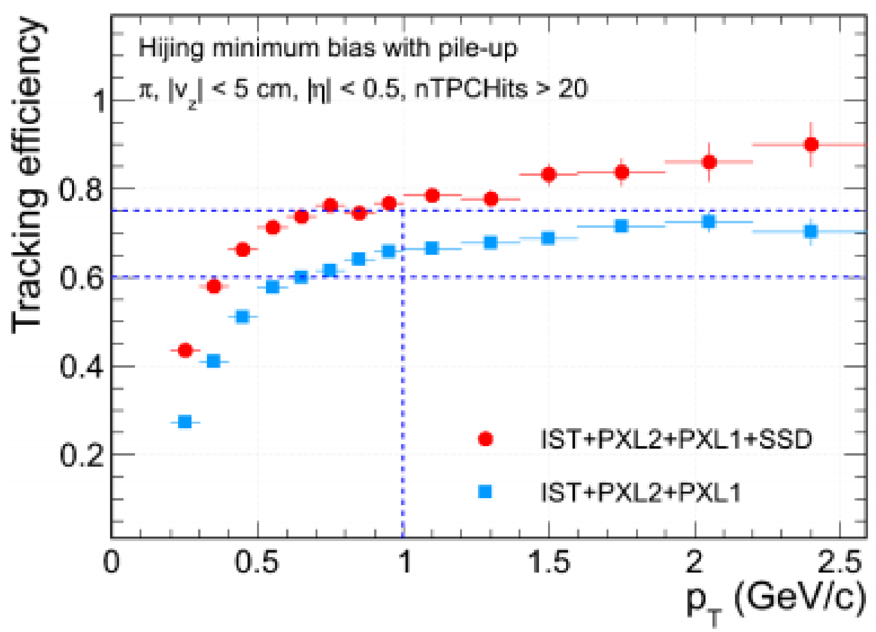


HFT Performance Status

Pointing resolution of kaons



HFT tracking efficiency of single pions



- Kaon track pointing resolution exceeds the requirement - 55 μm at 750 MeV/c
  - pointing resolution in the region with Al-cables ~ 45 μm
- Single pion HFT tracking efficiency (preliminary Sti software) ~ 65% at 1 GeV/c
  - fine-tuning tracking efficiency on-going

Challenges

- Insertion in reality
  - How to fix problems on the fly
- Response of sensors to beam
- AL cables production
- The construction and successful operation of a MAPs based micro vertex detector leads the way for future projects

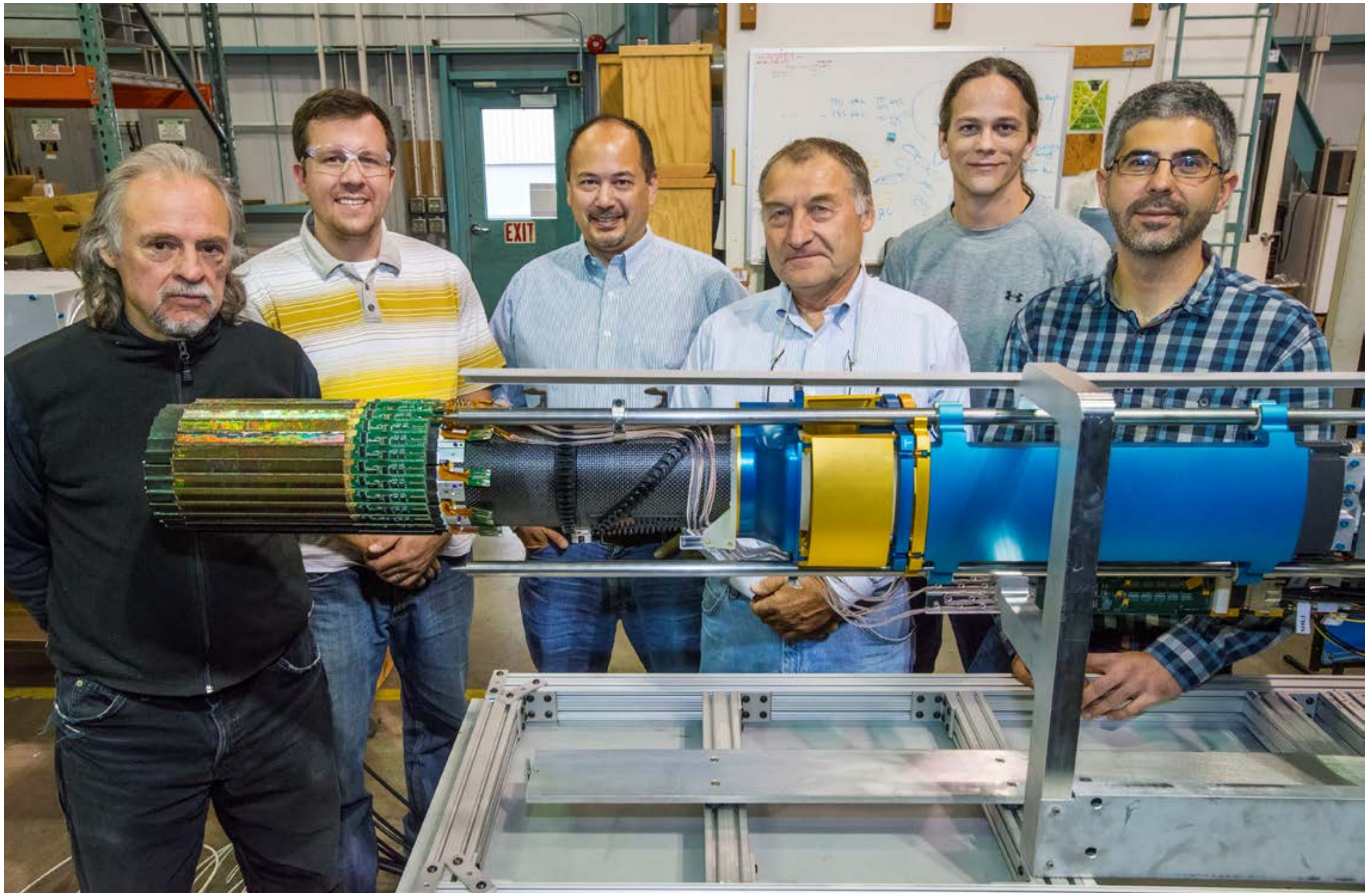
Conclusion

- It took a long time from initial ideas
  - Getting funding
  - Sensor development
  - New development High-res Epi layers
- It was worth the wait since the detector is superior to anything else build so far for a micro-vertex detector
- We should get the physics output soon.

Lessons for future

- Dedicated effort attention to details!
- Test all aspects of detector systems
- Be prepared for surprises
- Don’t give up

Thanks Howard



Thanks Howard