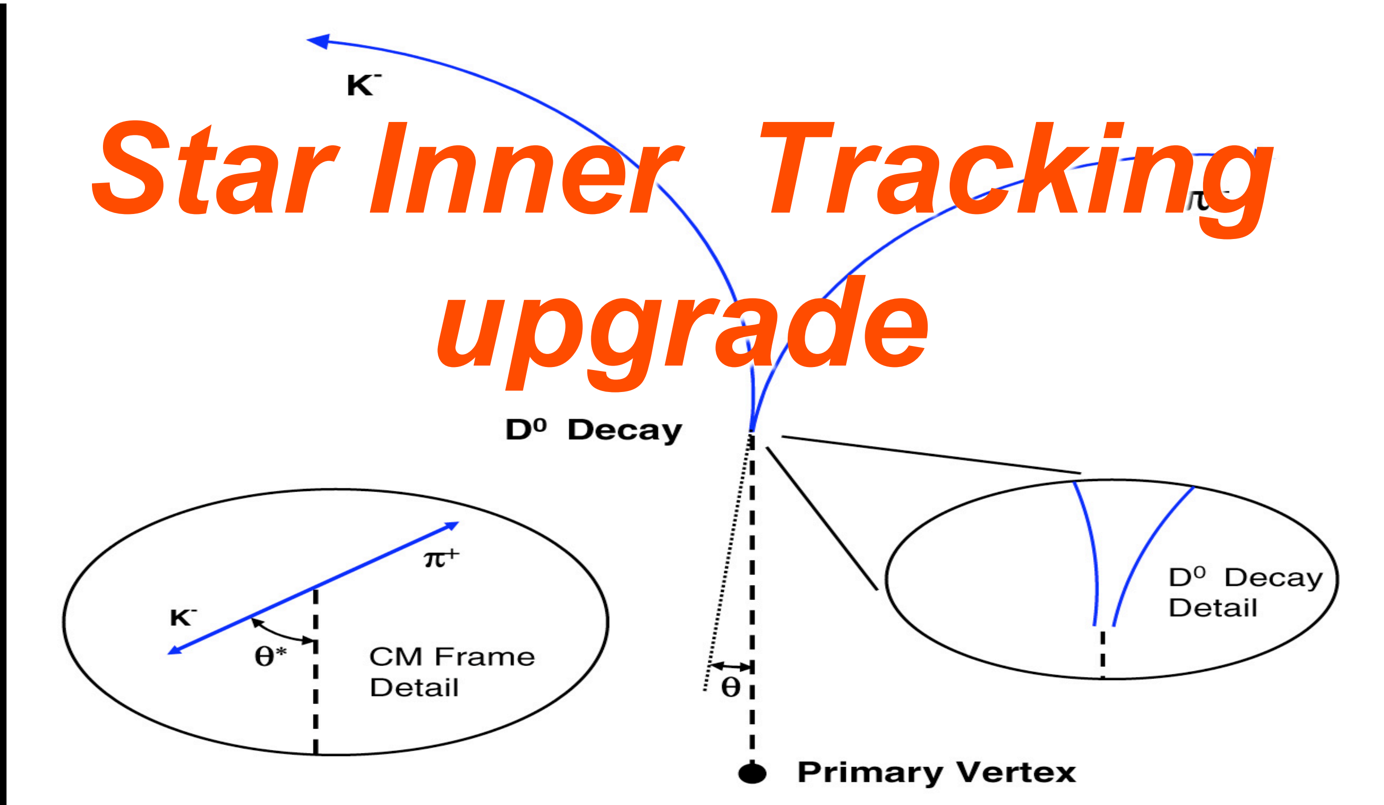
Star Inner Tracking upgrade



F. Videbaek

STAR collaboration

for the HFT upgrade group

Overview

- Physics Goals for Heavy Flavour Tracker (HFT)
- Overview of STAR
- Expected Physics Results (Simulations)
- Detector Components for HFT
  - Pixel
  - IST
  - SSD
  - Infrastructure
- Summary

Physics Goals

New frontier - heavy quark production

- HQ collectivity: test light quark thermalization
- HQ energy loss: explore pQCD in hot/dense medium

Base line reference spectra for the HI program

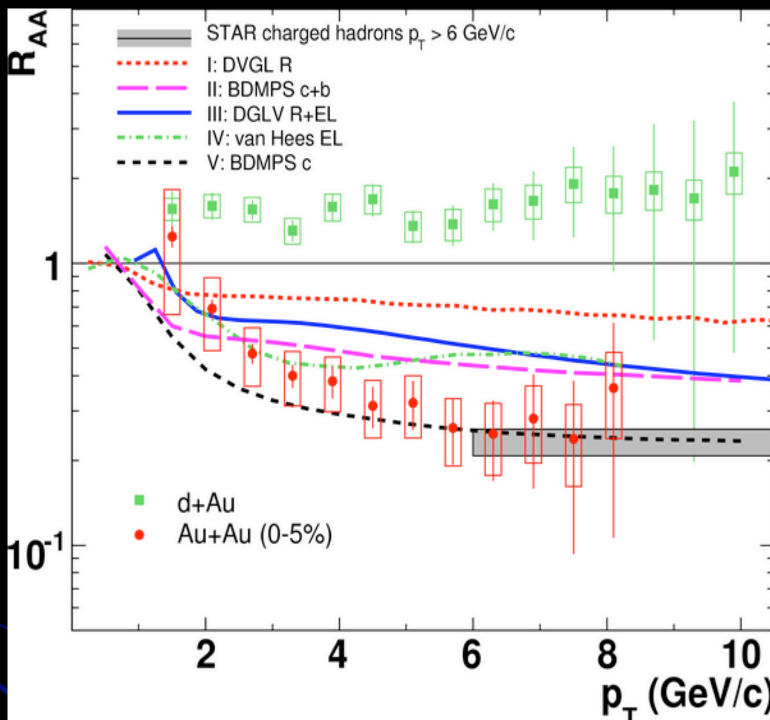
c and b cross section in pp at 200 and 500 GeV

Method : Topological identification of D's, Λ_c to low p_T.

STAR

Heavy Flavor Energy Loss

STAR PRL, 98, 192301 (2007)



1) Non-photonic electrons decayed from - charm and beauty hadrons

2) At $p_T \geq 6$ GeV/c,

$R_{AA}(n.e.) \sim R_{AA}(h^{\pm})$

contradicts naïve pQCD predictions

Surprising results -
- challenge our understanding of the energy loss mechanism
- force us to RE-think about the collisional energy loss
- **Requires direct measurements of C- and B-hadrons.**

STAR

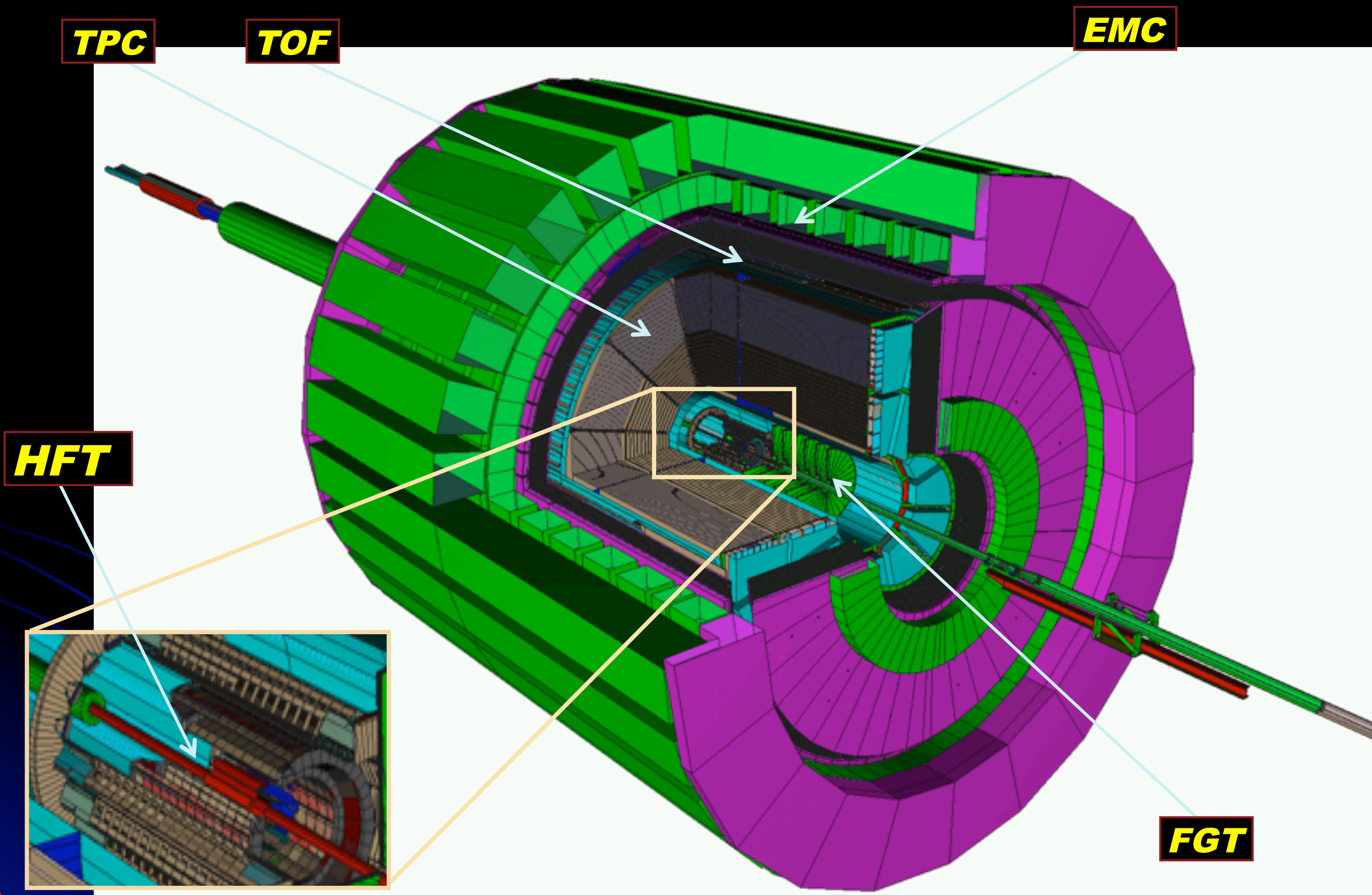
	Measurements	Requirements
Heavy Ion	heavy-quark hadron v_2 - the heavy-quark collectivity	- Low material budget and high efficiency $\varepsilon_{min} \geq 1\%$ - p_T coverage ≥ 0.5 GeV/c - mid-rapidity - High counting rate
	heavy-quark hadron R_{AA} - the heavy-quark energy loss	- High p_T coverage ~ 20 GeV/c
p+p	energy dependence of the heavy-quark production	- p_T coverage down to 0.5 GeV/c
	gluon distribution with heavy quarks	- wide rapidity and p_T coverage

Overview of Layout, concepts

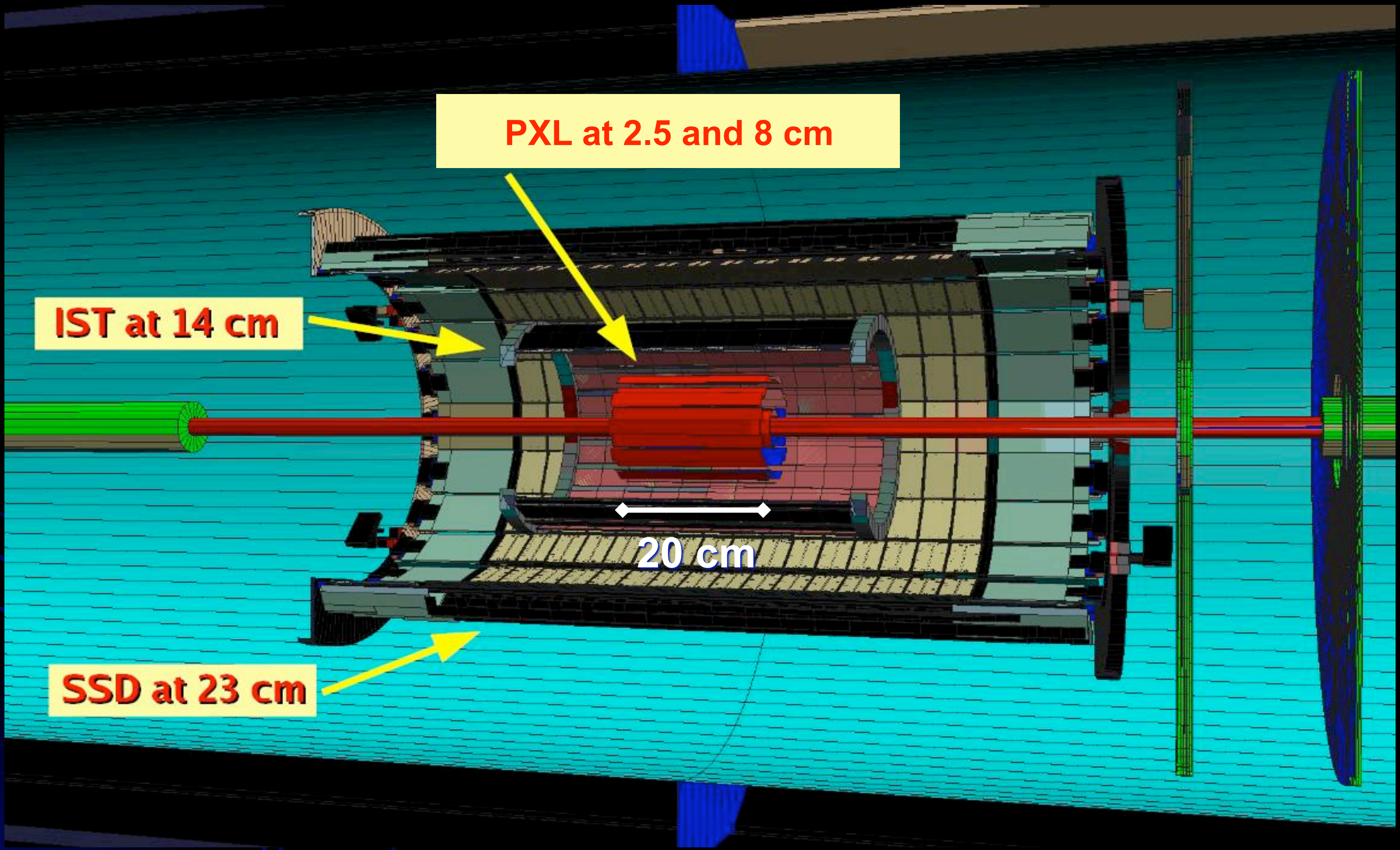
- Inner high resolution pixels are crucial for physics goal of direct D0 topological identification
- Relies on TPC-SSD-IST-PIXEL tracking for graded point matching and resolution.

STAR

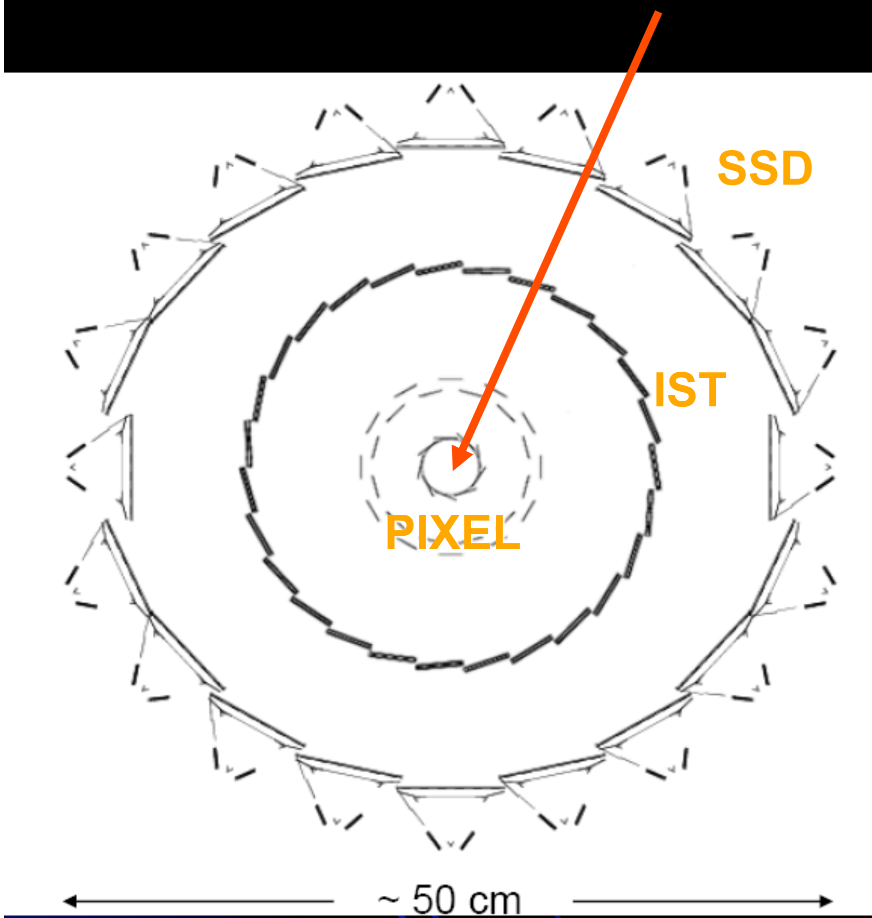
STAR Detectors: 2π Particle Identification



STAR Heavy Flavor Tracker



Concept of HFT Layers



Purpose of intermediate layers to get increasing resolution power with increasing hit-densities, so the high resolution hits in the inner pixel's can be found, assigned and displaced vertices determined.

Graded Resolution from the Outside – In	Resolution(σ)
TPC pointing at the SSD (23 cm radius)	~ 1 mm
SSD pointing at IST (14 cm radius)	~ 400 μm
IST pointing at Pixel-2 (8 cm radius)	~ 400 μm
Pixel-2 pointing at Pixel-1 (2.5 cm radius)	~ 70 μm
pixel-1 pointing at the vertex	~ 40 μm

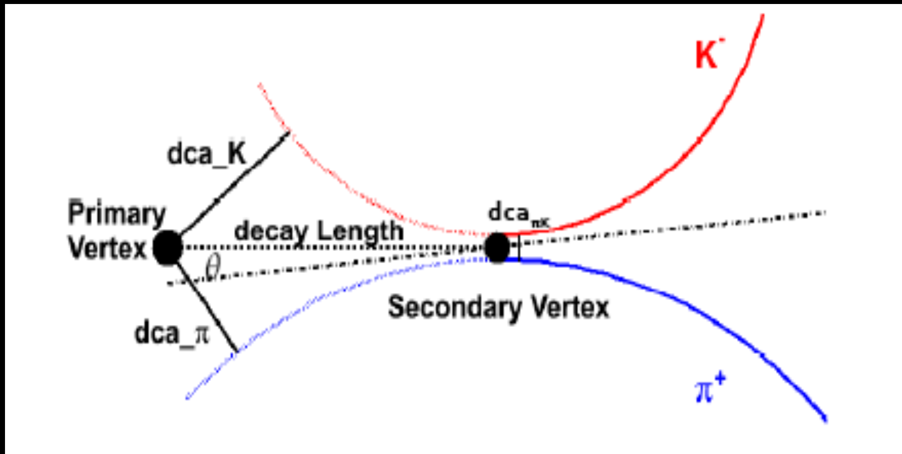
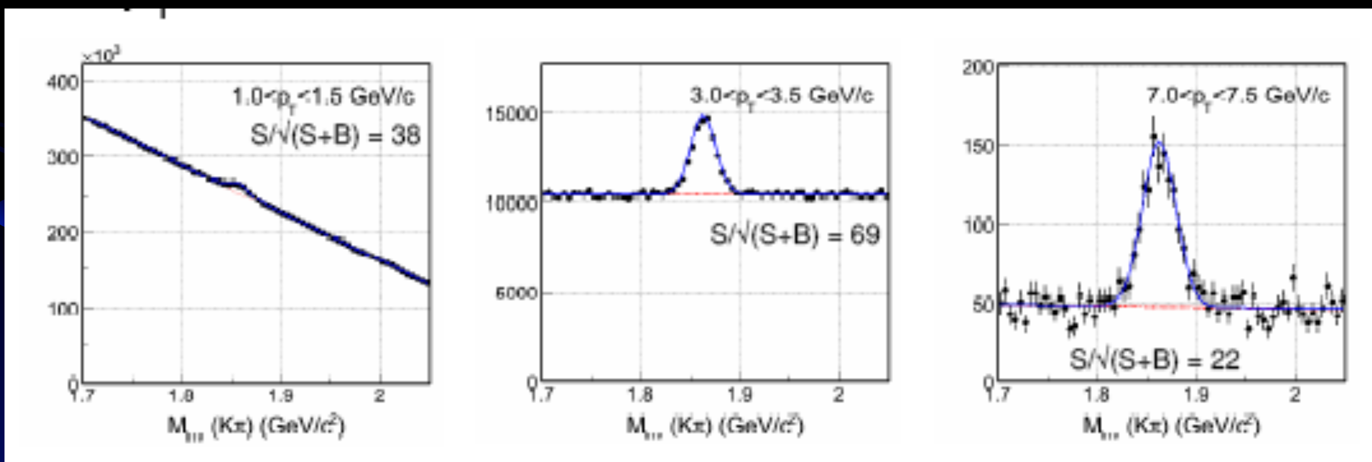


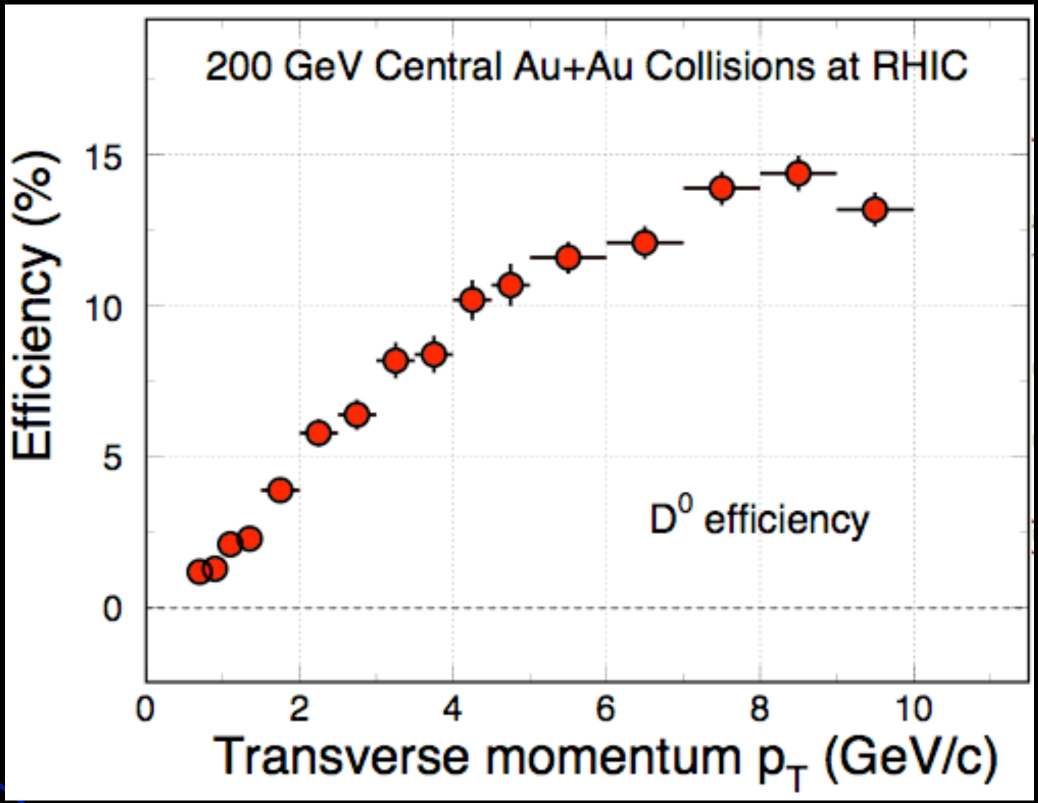
Figure 14: $D^0 \to K^- \pi^+$ decay topology.

DCA Cuts
Uses PID from TOF.

Estimated mass spectra from 100M central events

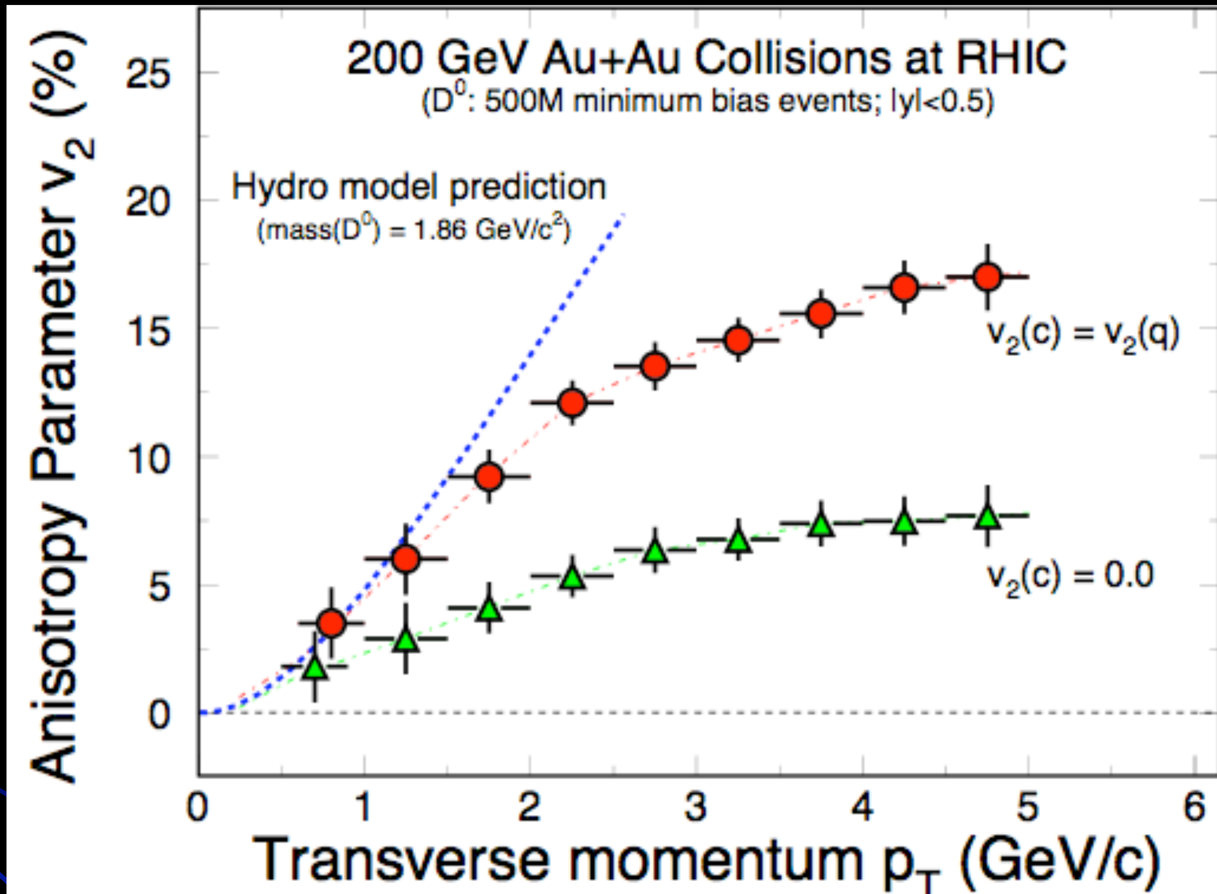


D^0 Reconstruction Efficiency



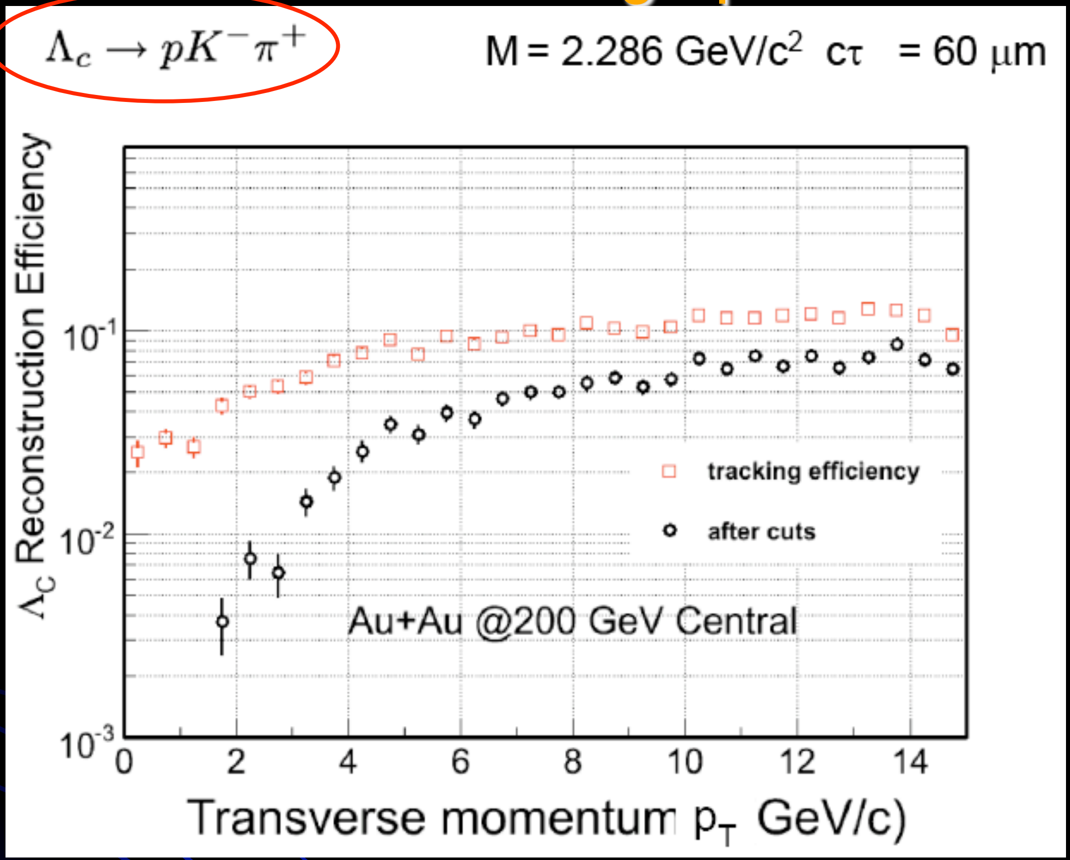
- Central Au+Au collisions: top 10%events.
- The thin detector allows measurements down to p_T ~ 0.5 GeV/c.
- Essential and unique!

Charm Hadron v_2



- 200 GeV Au+Au minimum biased collisions (500M events).
- Charm collectivity ⇨ drag/diffusion constants ⇨ ***medium properties!***

Work is continuing to refine details of the detector design/performance



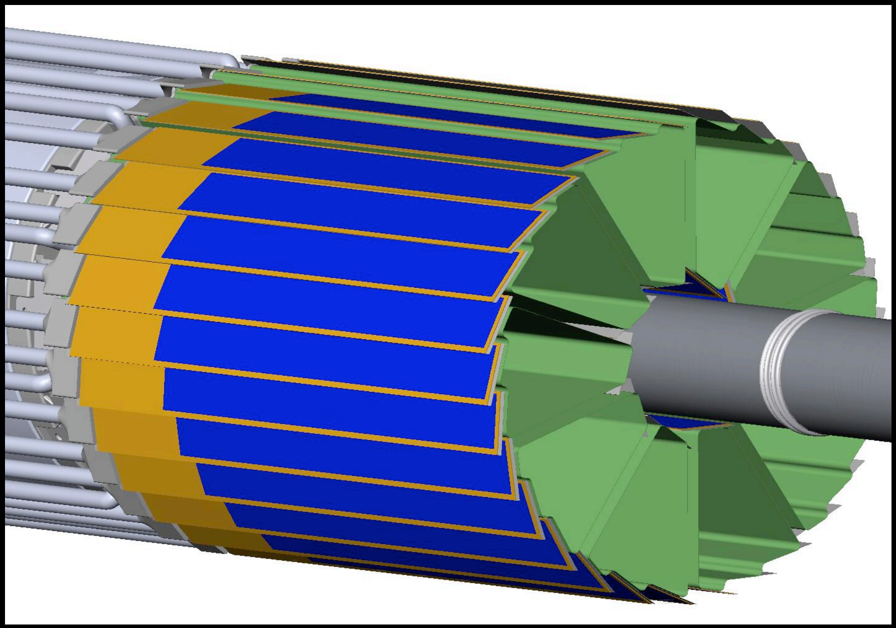
Simulations of the most challenging 3-body decays are encouraging so far

This capability, which will be provided uniquely at RHIC by the HFT, is crucial for determining whether the baryon/meson anomaly extends to heavy quark hadrons

Detector Realization

- Briefly discuss
  - PIXEL
  - IST (intermediate Silicon Tracker)
  - SDD (Silicon Strip Detector) - existing
  - Infrastructure

PIXEL

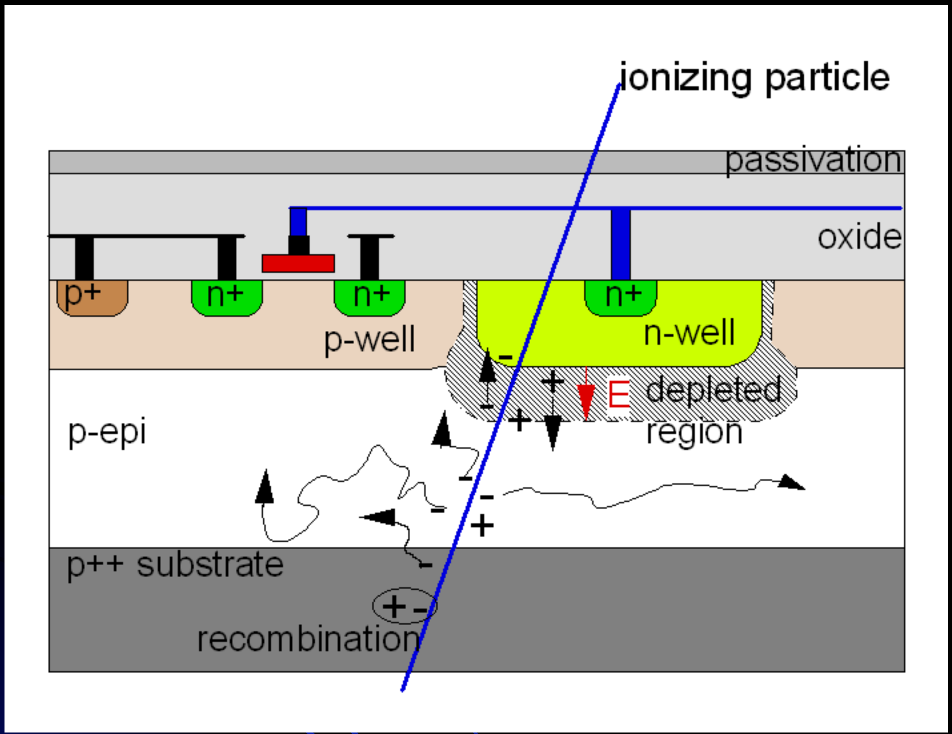


2 layers of 18x18 μm pixels at 2.5 and 8 cm radius, 20 cm long
Very low material budget to limit multiple scattering
Data reduction and formatting on chip
Rapid insertion and removal
Precision positioning
Air cooling
Ongoing APS technology R&D with Strasbourg
For RHIC luminosities needs ‘fast’ detector with better than 200 μsec integration time.
Efficiencies degrade with ‘pile-up’ within sample time

Active Pixel Sensors

pixel chips (MAPS) produced by

IReS/LEPSI → IPHC (Strasburg)



Properties:

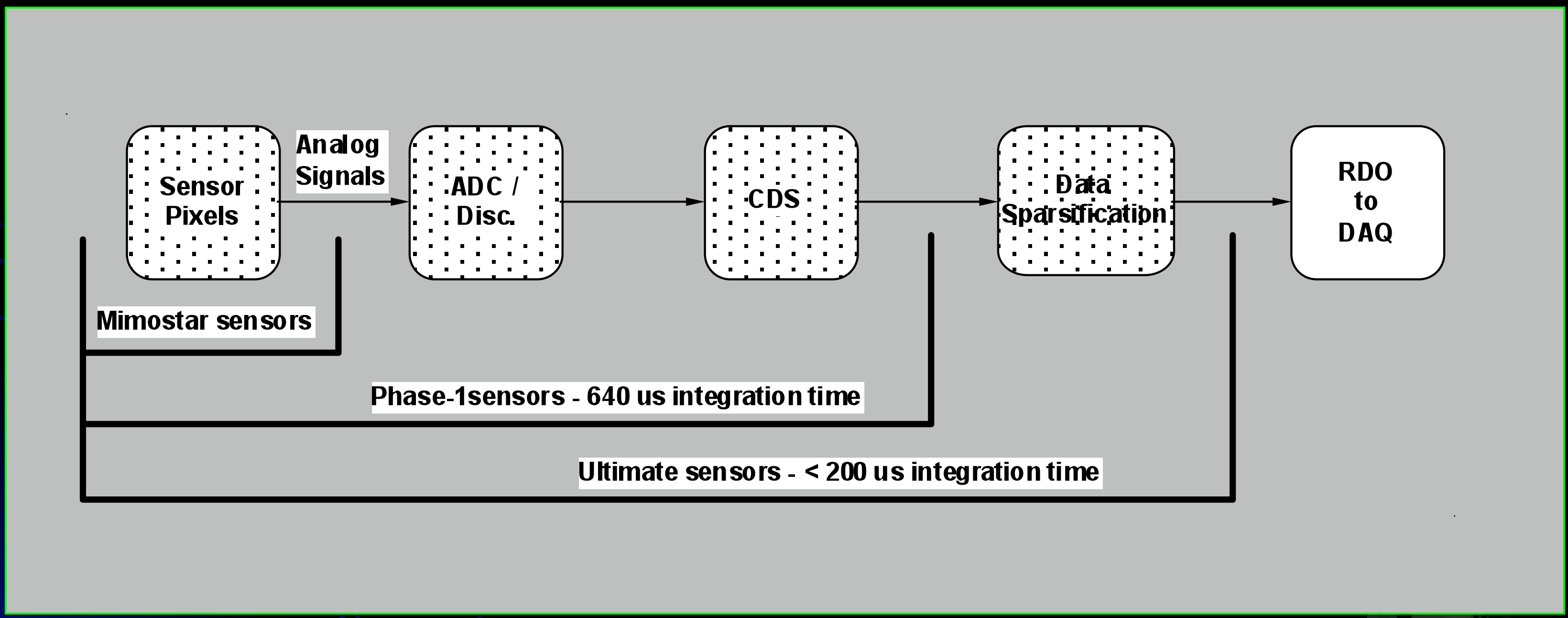
- Signal created in low-doped epitaxial layer (typically ~10-15 μm)
- Sensor and signal processing integrated in the same silicon wafer
- Standard commercial CMOS technology

IPHC Functional Sensor Development

All sensor families:
- •30 x 30 μm pixels => 18x18 μm
- •CMOS technology
- •Full Reticule = 640 x 640 pixel array=> 1024 x 1088 array

Mimostar 2 => full functionality 1/25 reticule, 1.7 μs integration time (1 frame@50 MHz clk), analog output. *(in hand and tested)*

Phase-1 and Ultimate sensors => digital output *(in development)*



Some pixel features and specifications

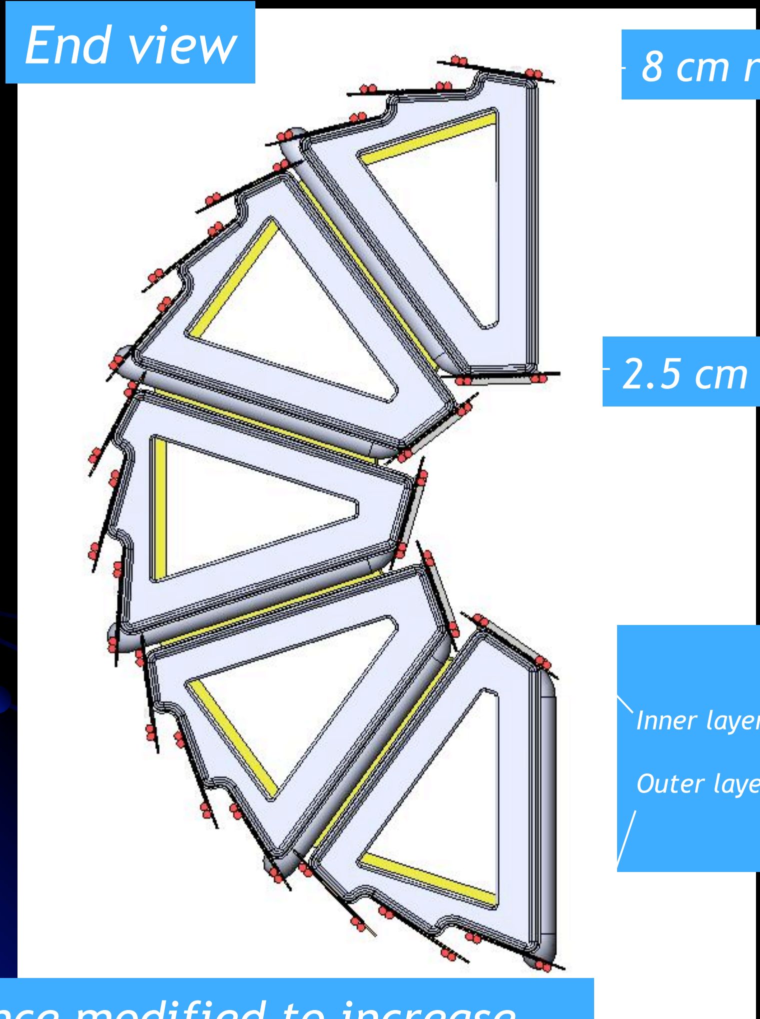
Pointing resolution	(13 ⊕ 19GeV/p·c) μm
Layers	Layer 1 at 2.5 cm radius Layer 2 at 8 cm radius
Pixel size	18.4 μm X 18.4 μm
Hit resolution	10 μm rms
Position stability	6 μm (20 μm envelope)
Radiation thickness per layer	X/X0 = 0.28%
Number of pixels	436 M
Integration time (affects pileup)	0.2 ms
Radiation tolerance	300 kRad
Rapid installation and replacement to cover rad damage and other detector failure	Installation and reproducible positioning in a shift

critical
and
difficult

(ATLAS Pixels 1.2%)

STAR

Pixel support structure

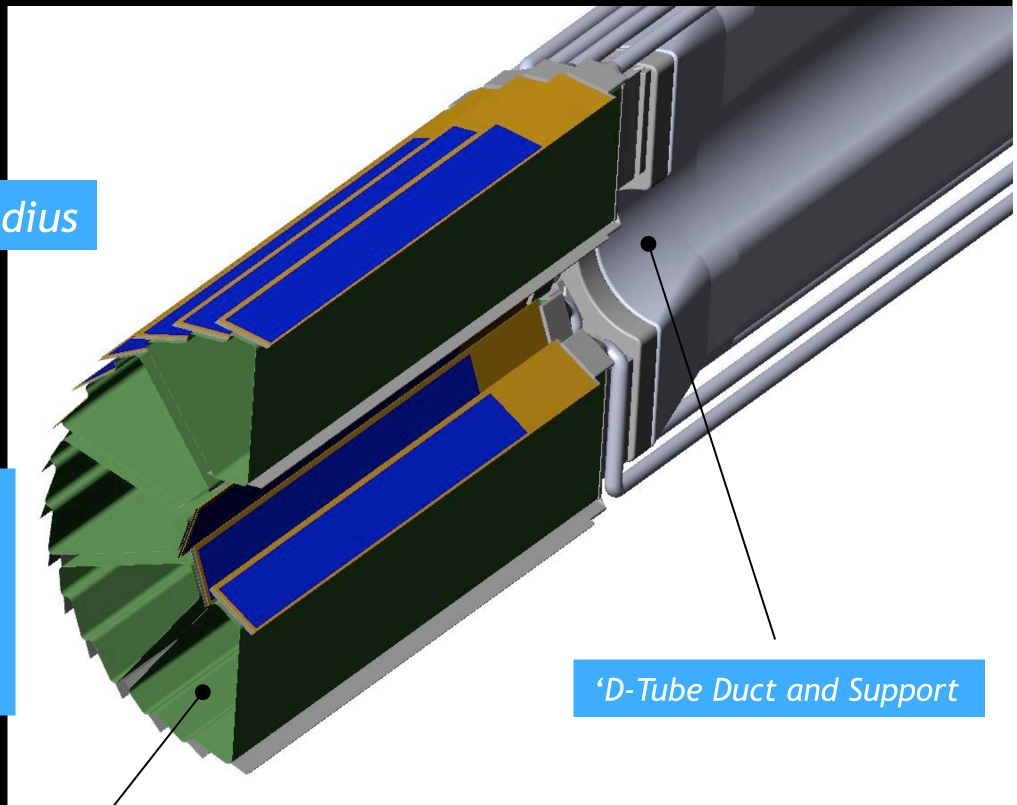


8 cm radius

2.5 cm radius

Inner layer

Outer layer



'D-Tube Duct and Support

Since modified to increase Sensor Clearances

ALICE style carbon support beams (green)

Sensor Development Status

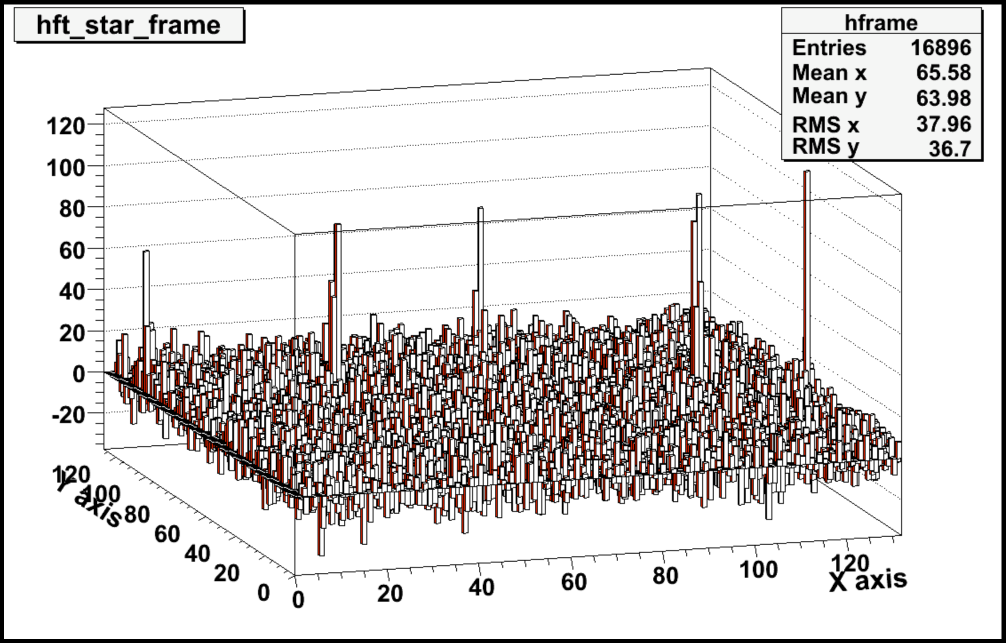
Mimostar-2

Testing complete – MS-2 Sensor telescope used at STAR for telescope test in previous run.

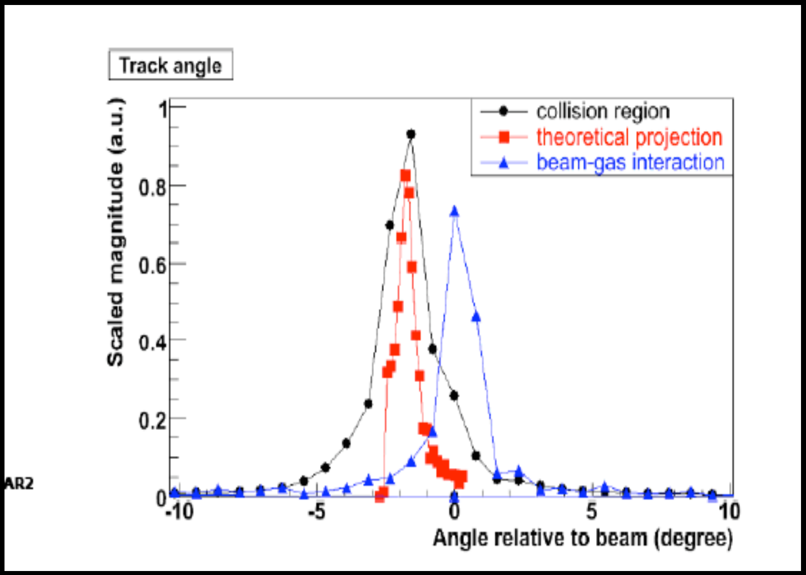
Description and results are published in:

Nuclear Instruments and Methods in Physics Research A 589 (2008) 167–172

Pixel proto in STAR, measured track density at r = 5cm, z = 145cm



4*4 mm

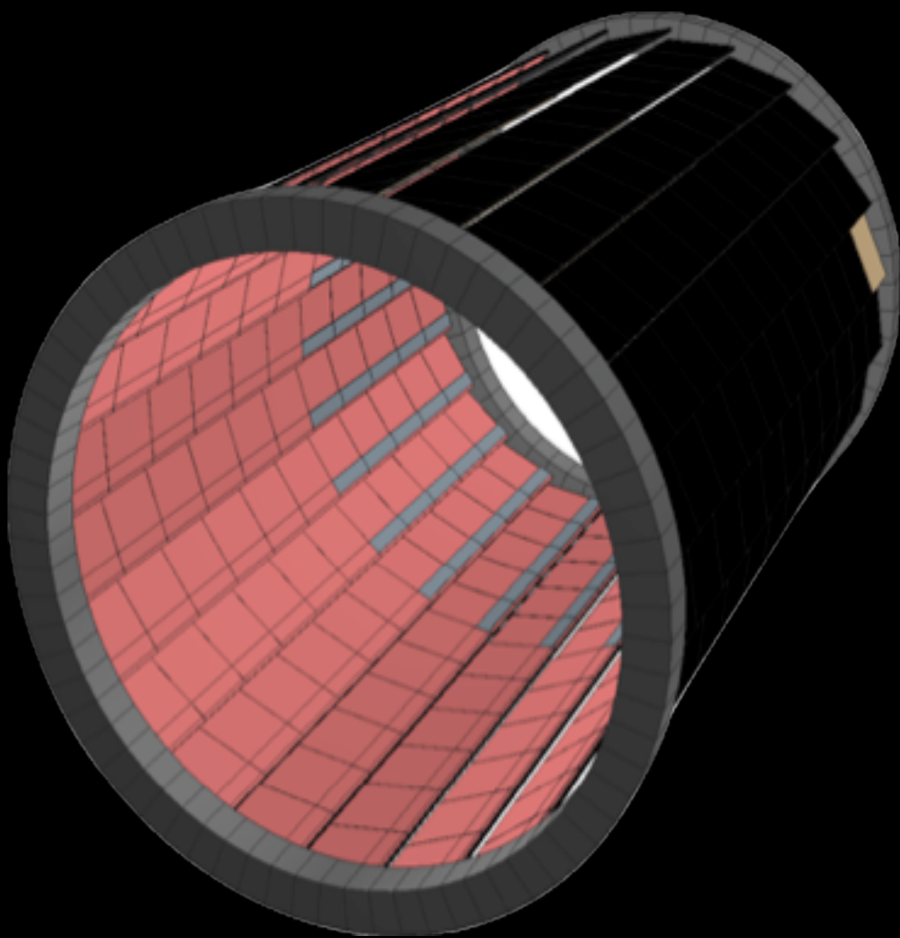


Placed inside STAR during Run-7
Located 150cm (z) 8 cm below beam
Track density low.
Resolves tracks from collision vs. background

IST Layout

- IST - 3D view

IST
1 sensor layer: Silicon-pad type



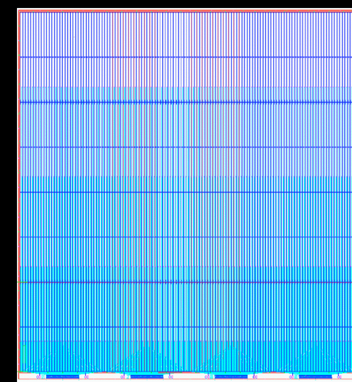
Layout:

- r = 14 cm
- ~24 ladders
- 12 units (Modules) per ladder (44cm)

Technical realization

- IST - Ladder design - Overview

Location: Silicon-pad sensor

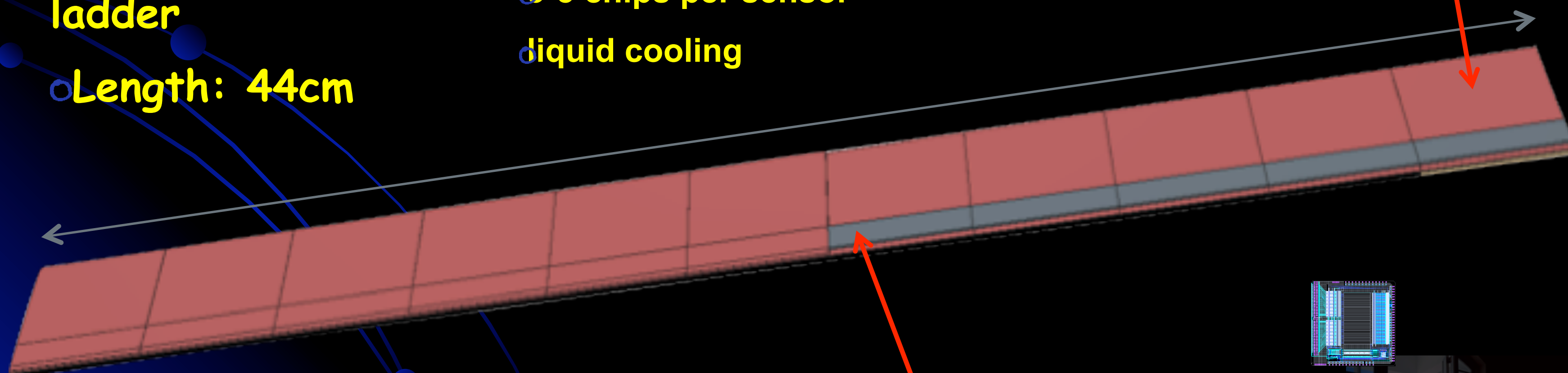


Module:

- Silicon-pad sensors: Dimensions: 4cm X 4cm
- Pad size structure still being optimized: 400µm X 1cm typically
- Readout Chip: APV25-S1
- 3-5 chips per sensor
- liquid cooling

Ladder:

- Carbon fiber base material
- 12 modules per ladder
- Length: 44cm

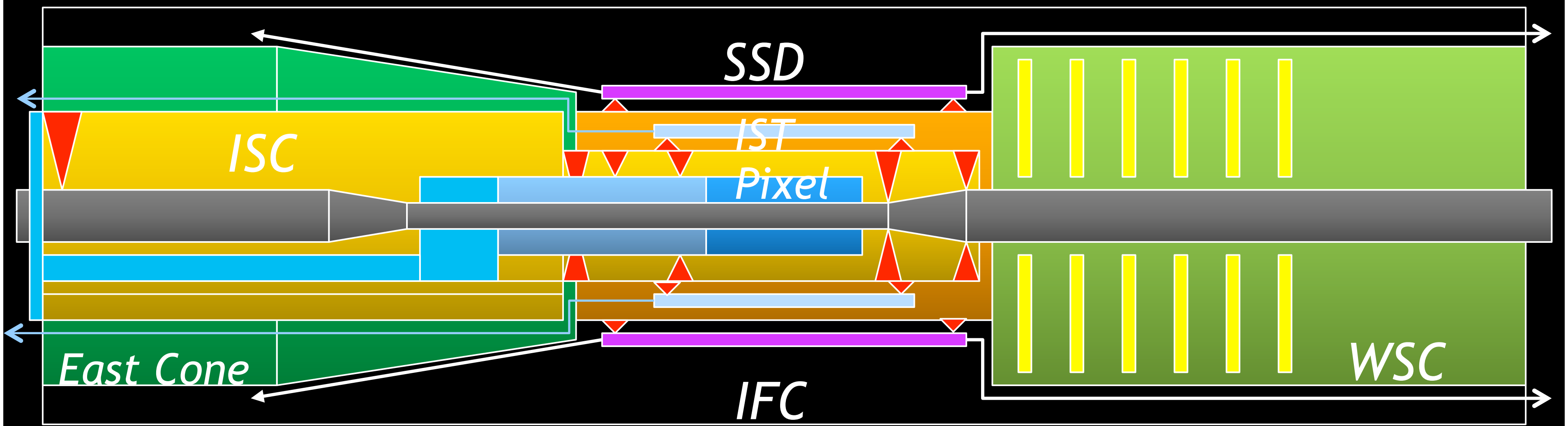


Location: APV25-S1 Readout Chips

Infrastructure

- Integration of Mechanical structures is a critical issue for the project.
- Replacement of existing beam pipe -> r ~2cm.
- Support of thin and light weight structures. Recall the total radiation length is aimed at <=3%.
- Ease in replacement of pixel ladders in case of failures, and effect of radiation.
- Support for PIXEL, IST, SSD and FGT

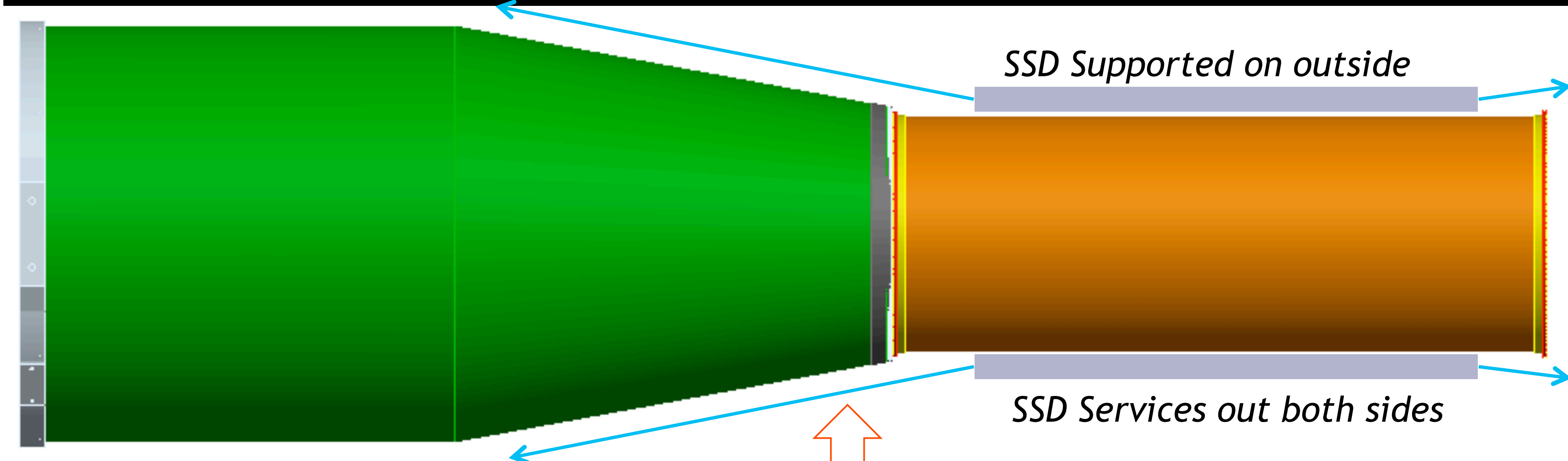
Conceptual Inner Part of STAR



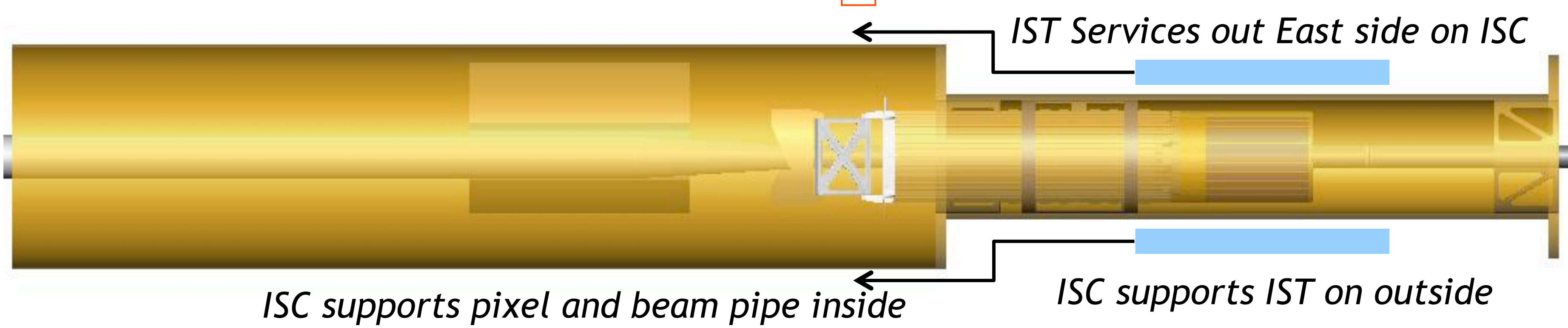
New Cone Structures inside of Inner Field Cage

- Intricate layout for 3 HFT trackers + beam pipe + FGT.

Inner Support Cylinder (ISC)

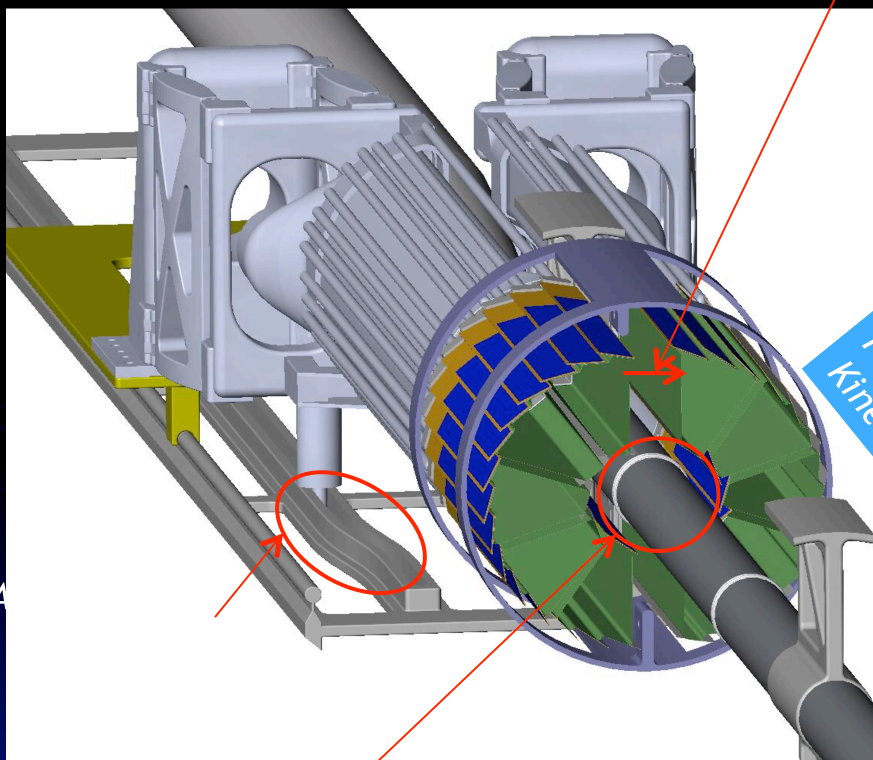


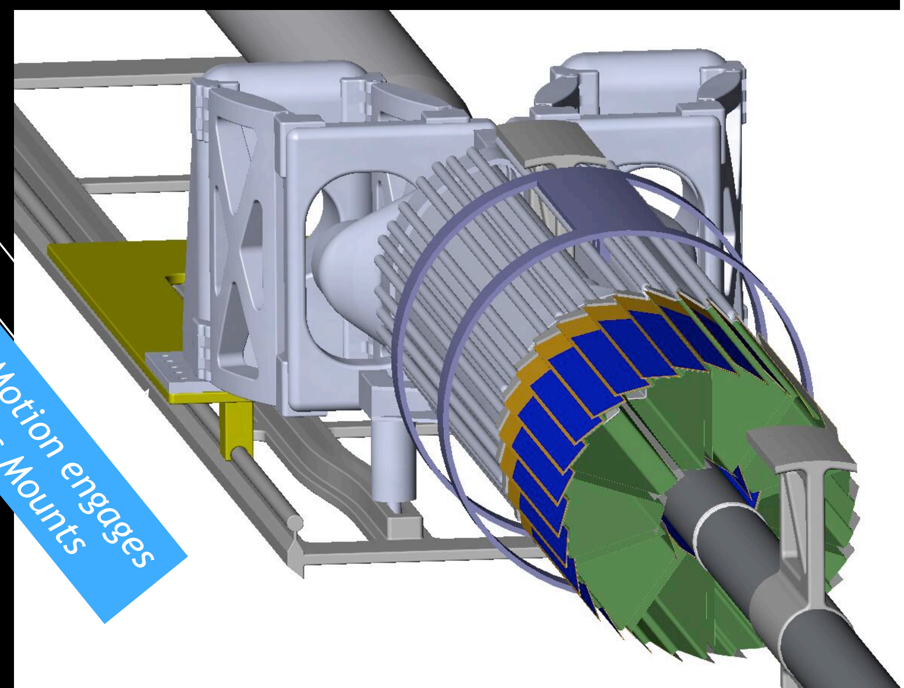
ISC fits inside and is supported by the cone



Follower guided insertion operation

Clearance for
Beam Pipe Supports and
Kinematic Mounts





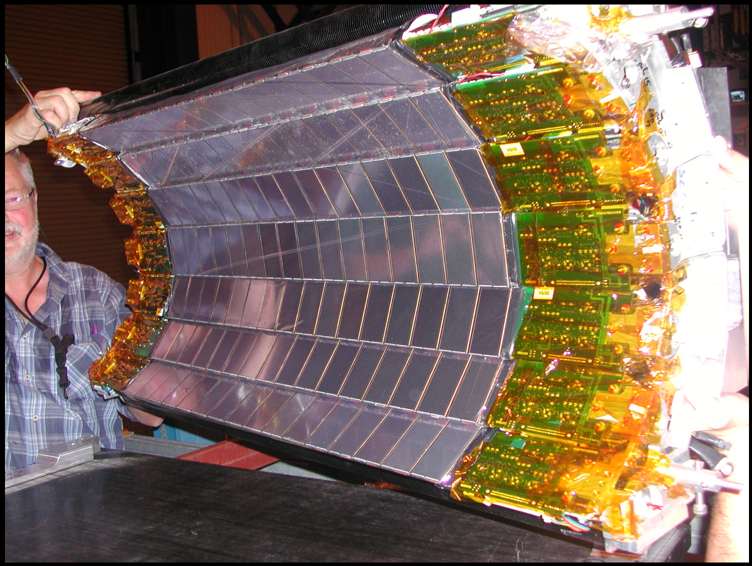
Clears Beam Pipe over
Large Diameter

Open

Closed

SSD

- The SSD is an integral part of the upgrade. It is an existing detector. It will be upgraded to be compatible with DAQ1000. Redundancy is built with the outer strip layer.



Summary

Physics of the Heavy Flavor Tracker at STAR

1) Au+Au collisions

(1) Measure heavy-quark hadron v_2, heavy-quark collectivity, to study the medium properties *e.g.* light-quark thermalization
(2) Measure heavy-quark energy loss to study pQCD in hot/dense medium *e.g. energy loss mechanism*
(3) Measure di-leptions to study the direct radiation from the hot/dense medium
(4) Analyze hadro-chemistry including heavy flavors

2) p+p collisions

(1) energy dependence of the heavy-quark production
(2) reference spectra for AuAu

3 year Run Plan when installed

1) First run with HFT: 200 GeV Au+Au
   ⇨ v_2 and R_{CP} with 500M M.B. collisions
2) Second run with HFT: 200 GeV p+p
   ⇨ R_{AA}
3) Third run with HFT: 200 GeV Au+Au
   ⇨ centrality dependence of v_2 and R_{AA}
   ⇨ Charm background and first attempt for electron pair measurements
   ⇨ Sufficient Statistics for Λ_c

A technical driven schedule would allow complete detector for Run-12. The real world with budget constraints ??

An engineering run with a few pixel ladders is planned.

Final word

- An HFT upgrade to STAR than will utilize all the strengths of STAR (2π coverage, TOF,..) and will provide crucial charm and bottom measurements.

See also Jan Kapitan's poster at this meeting

The End