Heavy Flavor Tracker at the STAR Experiment

Miroslav Simko

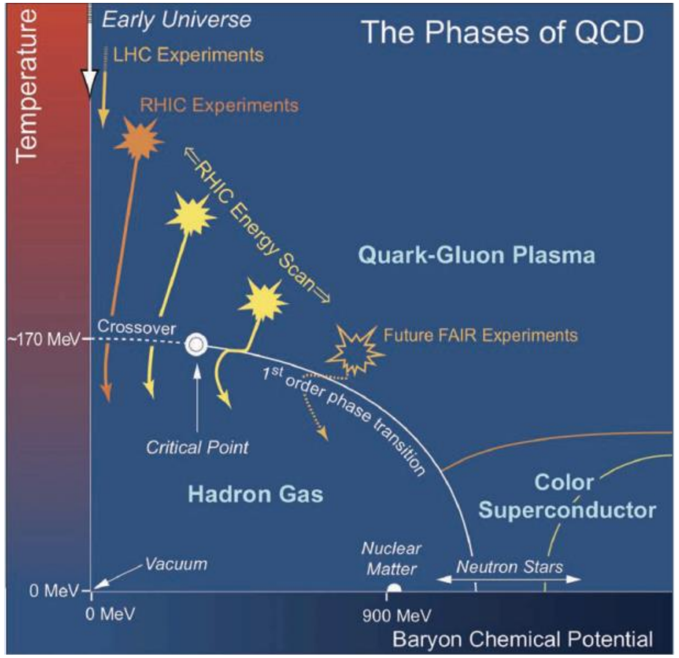
for the STAR Collaboration

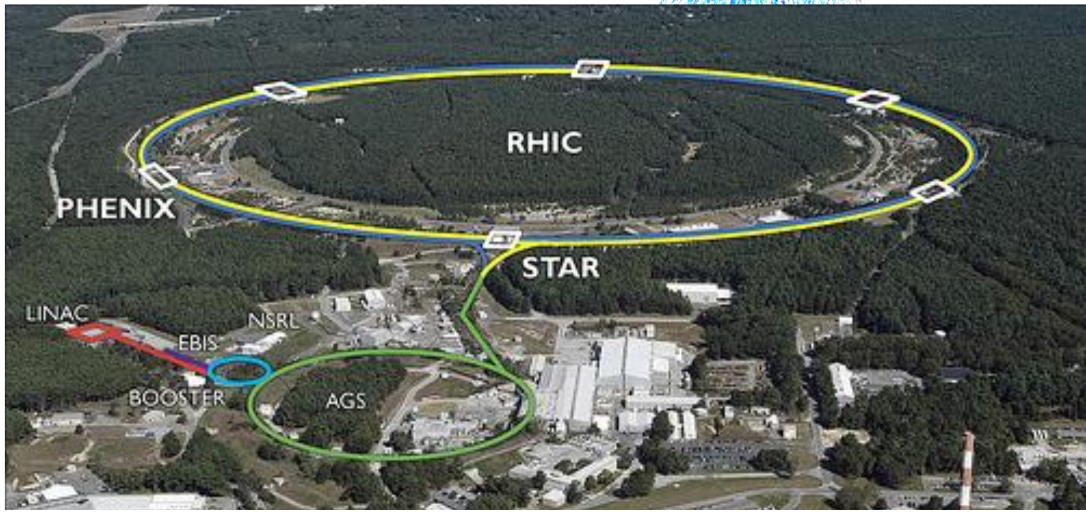
Faculty of Nuclear Sciences and Physical Engineering,

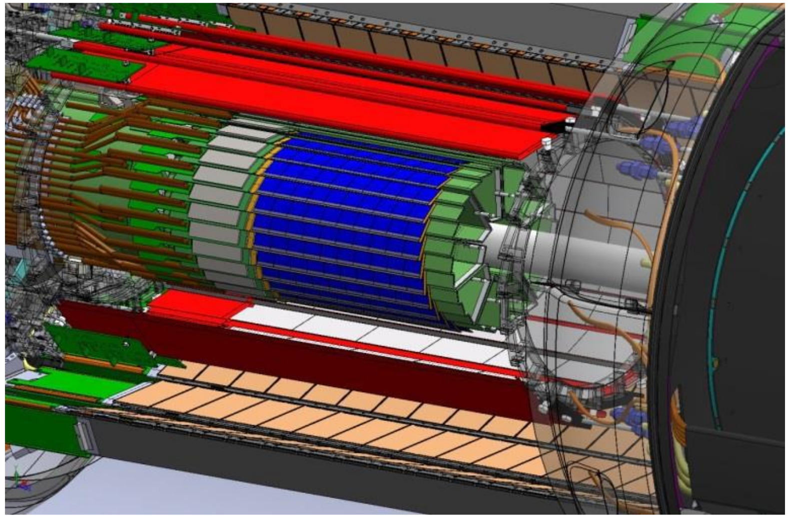
Czech Technical University in Prague

Outline

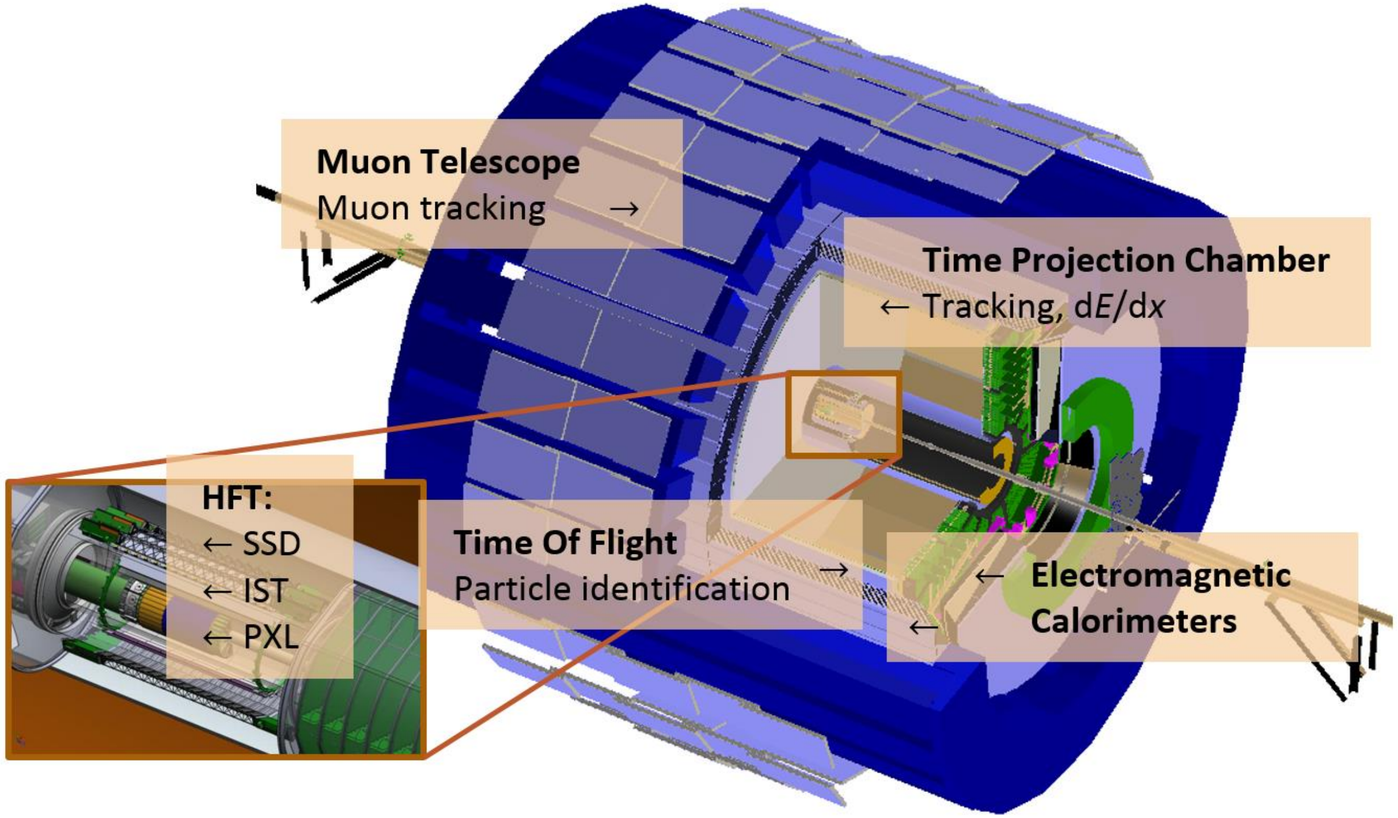
- Physics of the Heavy Flavor Tracker
- STAR HFT
  - 3 subdetectors
- Pixel Detector
  - First MAPS in a collider experiment
- HFT status and performance
- Summary

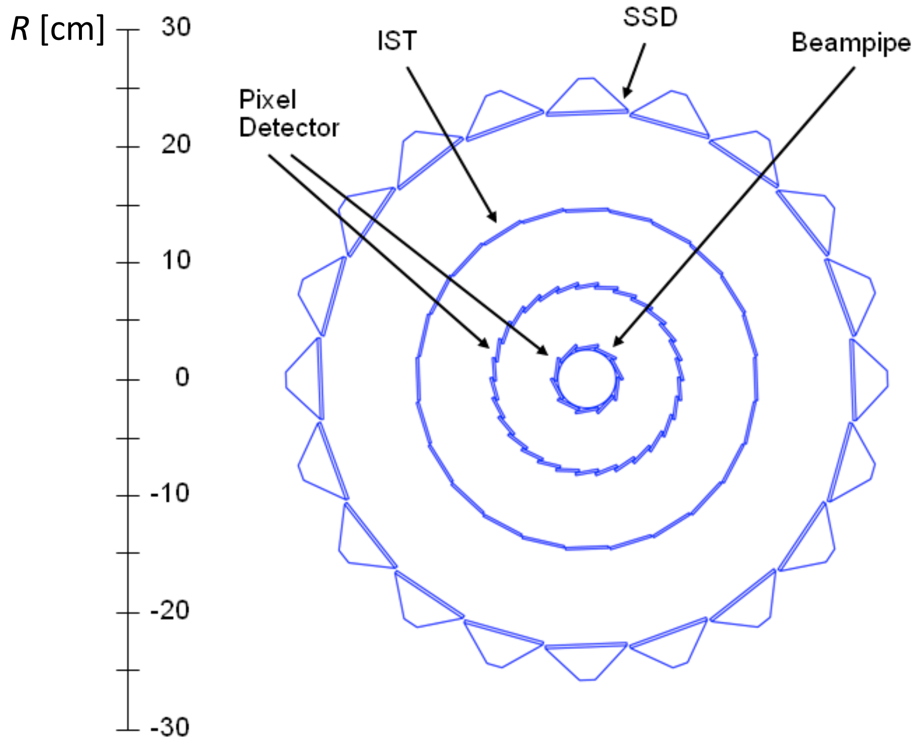






STAR detector





- STAR detector – 7.3 m diameter, approx. 1200 tons
- Heavy Flavor Tracker
  - 4 layers of silicon detectors
  - 3 subdetectors

Physics motivation

- Heavy flavor: Particles containing b and c quarks
  - $m_{b,c} \gg T_c, \Lambda_{QCD}, m_{u,d,s}$
  - Is produced in the initial hard scatterings

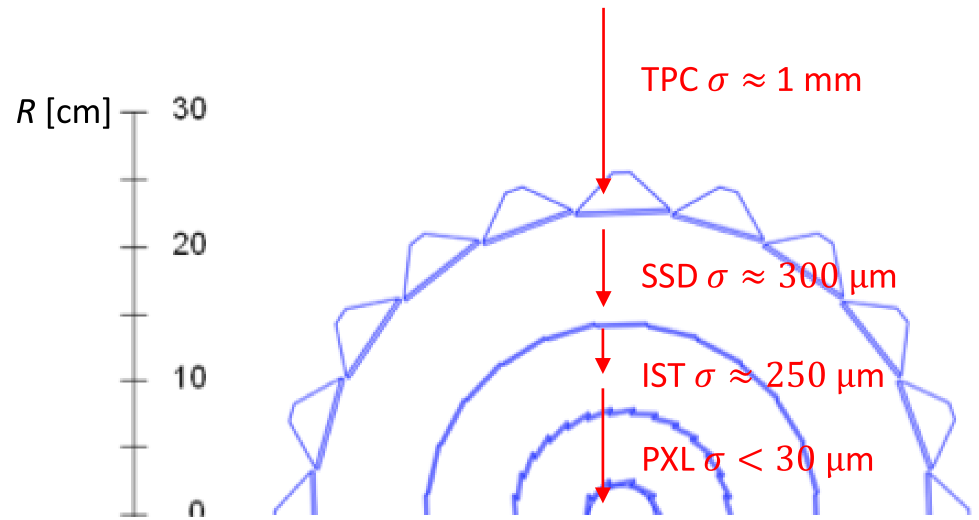
Excellent probe to QGP

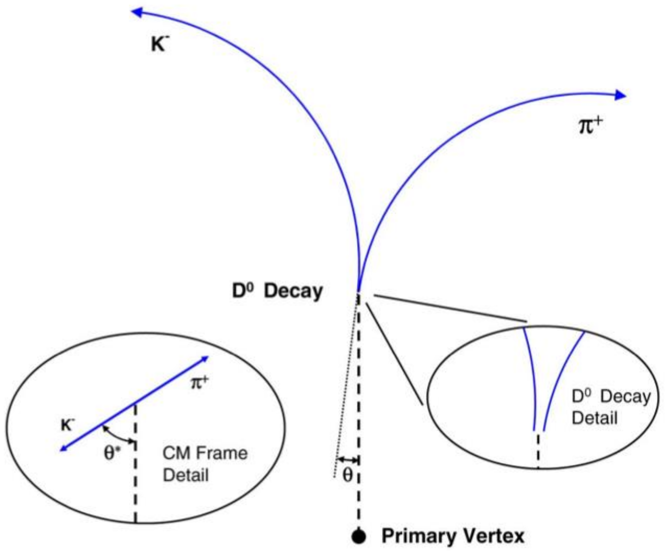
- However, hard to perform a direct reconstruction
  - Low yields compared to light flavor particles
  - Large combinatorial background

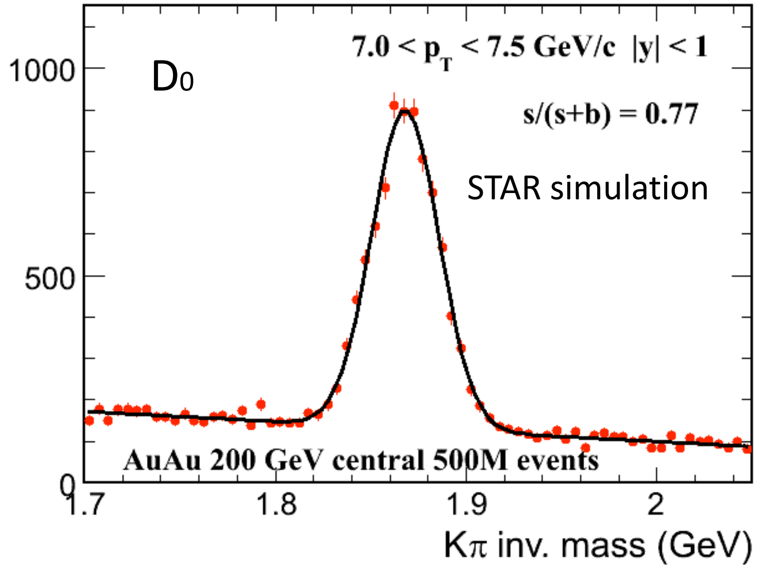
- Decay outside of the primary vertex ⇒ precision secondary vertex finder is an important tool to study open HF physics

How Heavy Flavor Tracker helps

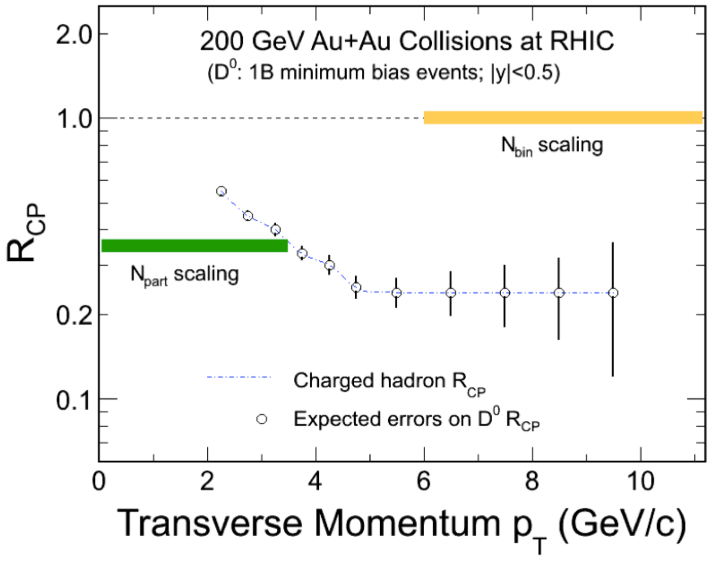
- Examples of displaced heavy flavor vertices
  - $\mathrm{D}^0 \rightarrow \mathrm{K}^-\pi^+$ BR = 3.89% $c\tau \sim 120\ \mu\mathrm{m}$
  - $\Lambda_c^+ \rightarrow \mathrm{pK}^-\pi^+$ BR = 5% $c\tau \sim 60\ \mu\mathrm{m}$
  - B mesons $\rightarrow \mathrm{J}/\psi + \mathrm{X}$ or e $+ \mathrm{X}$ $c\tau \sim 500\ \mu\mathrm{m}$





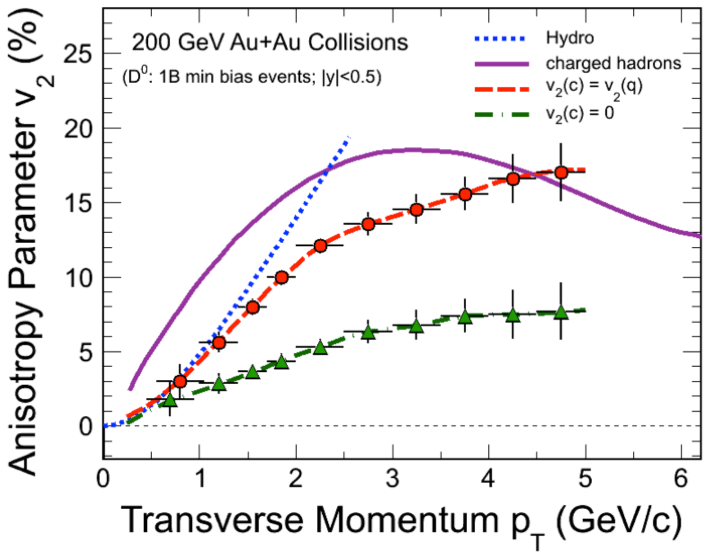


Heavy Flavor measurements with HFT

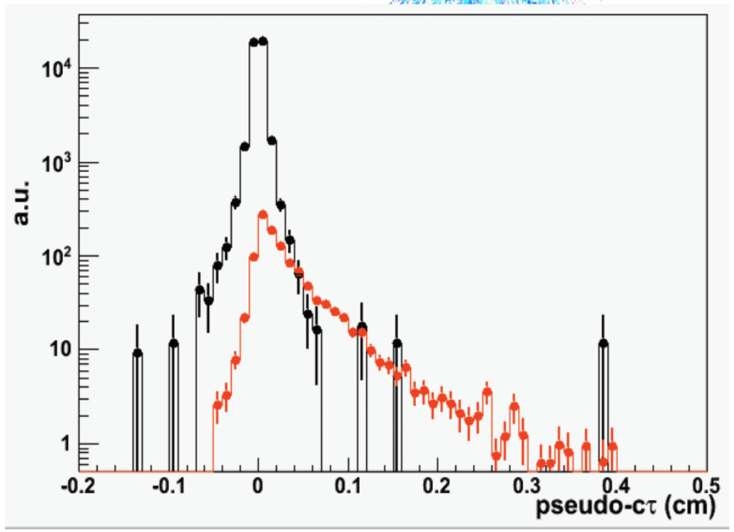


Projection of $D^0 R_{CP}$ with HFT

J. Kapitan et Al., Eur. Phys. J. C 62, 217 (2009)



Projection of $D^0 v_2$

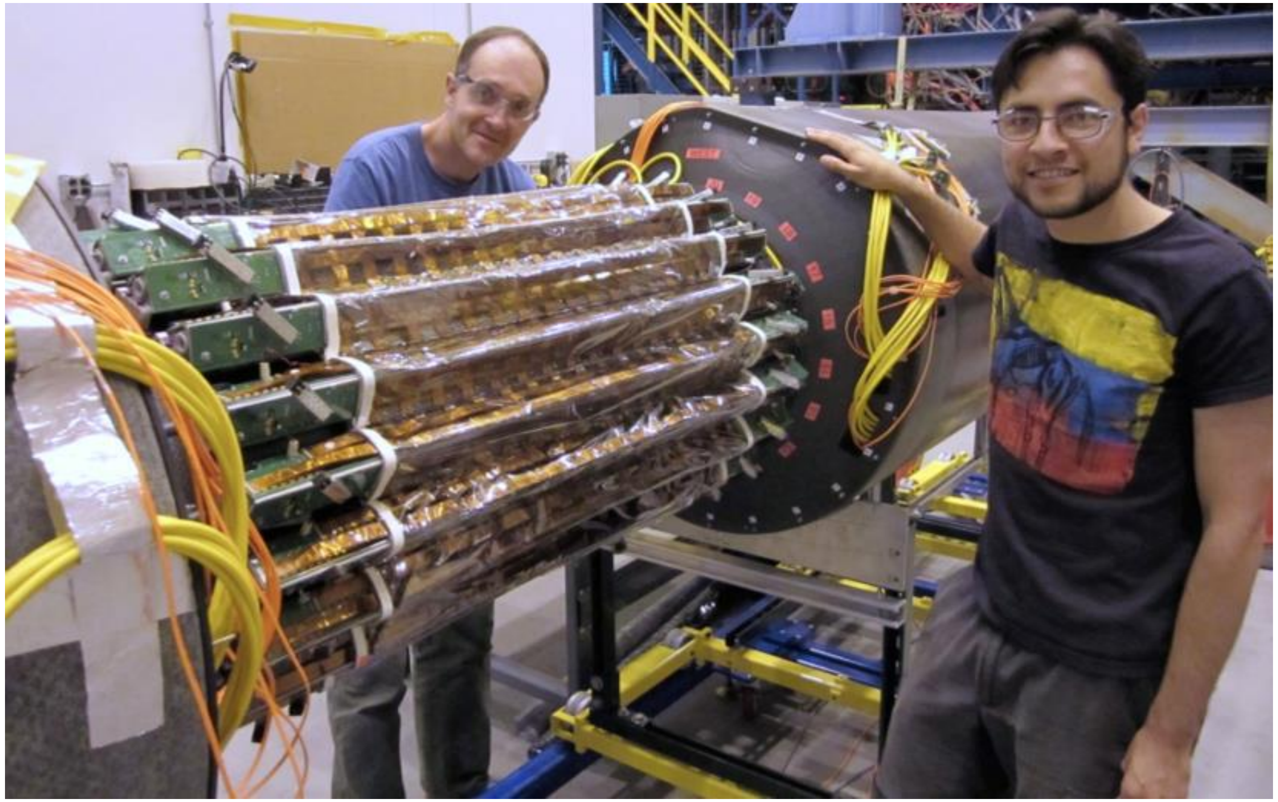


Simulation of the separation of prompt J/ψ (black) vs J/ψ from B decay (red)

- Total charm yield → charmonium suppression and coalescence
- R_{CP} and R_{AA} → energy loss of the heavy flavor
- v_2 → degree of thermalization with light flavor
- Measuring charm and beauty → probing the medium with different mass of quarks

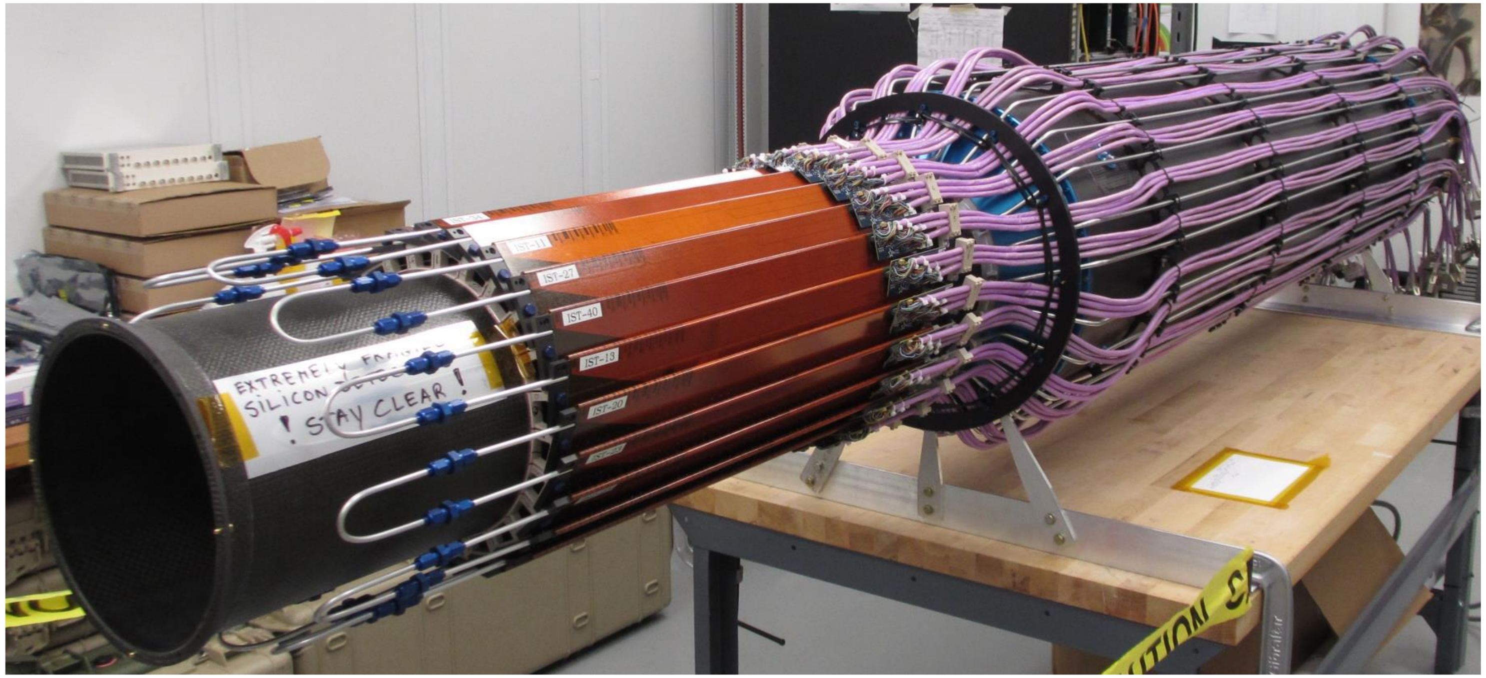
Silicon Strip Detector (SSD)

- Double sided silicon strip detector with 95 μm pitch
- Upgraded existing detector with new faster electronics
- $\sigma_{r\phi} = 20\ \mu\mathrm{m}, \sigma_z = 740\ \mu\mathrm{m}$
- Radius 22 cm
- Radiation length 1% X_0
- From 200 Hz to 1 kHz
- Upgraded cooling system – air cooled



Intermediate Silicon Tracker (IST)

- Single sided silicon pad detector
- Radius 14 cm
- Pitch 600 μm × 6 mm
- Radiation length < 1.5% X_0

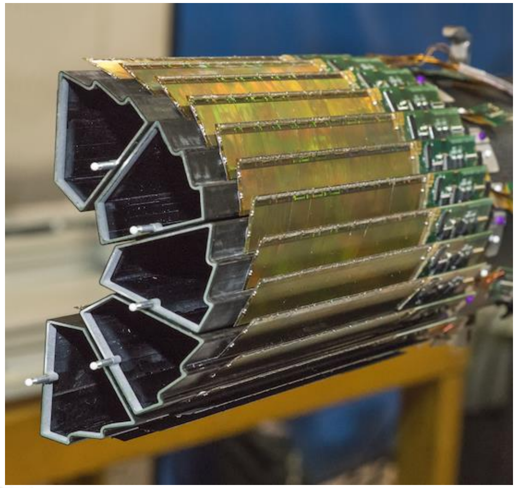


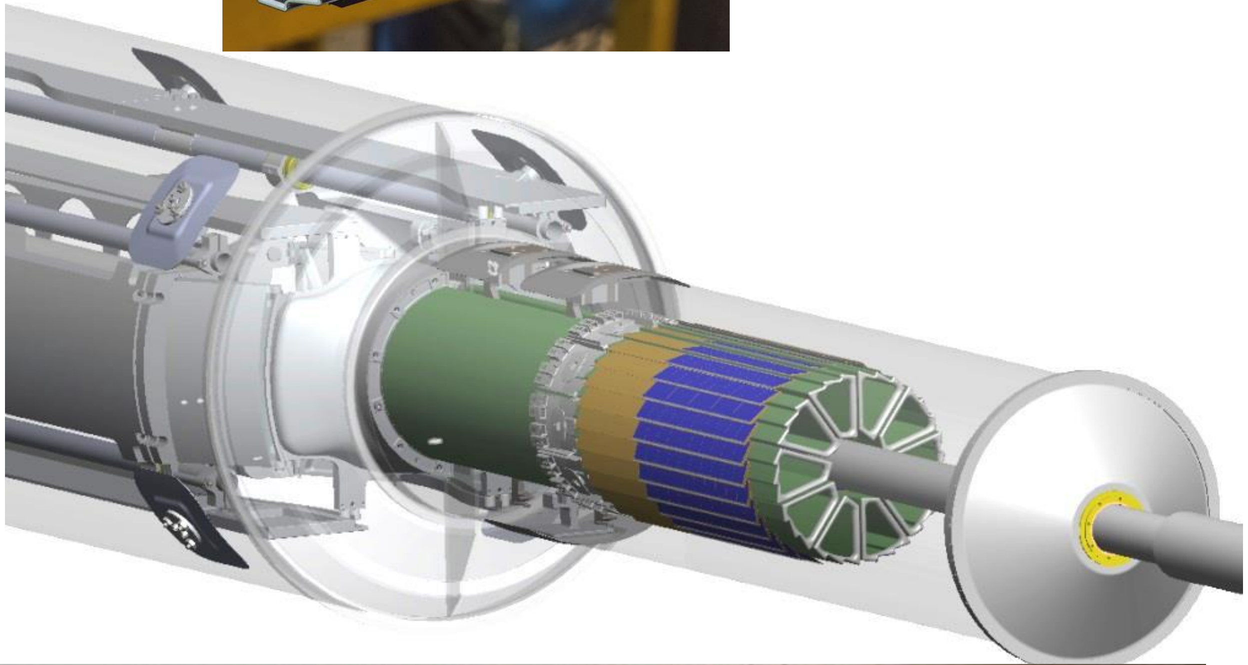
Pixel detector (PXL)

- First MAPS based detector at a collider experiment

- Sensor developed at IPHC Strasbourg
- MAPS sensors with 20.7 μm pitch
- Radii 2.8 cm and 8 cm
- Radiation length:
  - < 0.4% X_0 inner layer
  - < 0.5% X_0 outer layer
- Pointing resolution $(12 \oplus 24\ \mathrm{GeV}/p_T c)\mu\mathrm{m}$
- 356 M pixels on $\sim 0.16\ \mathrm{m}^2$ of silicon

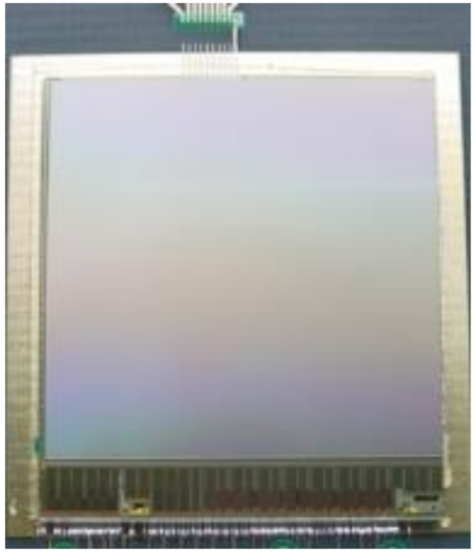
PXL architecture



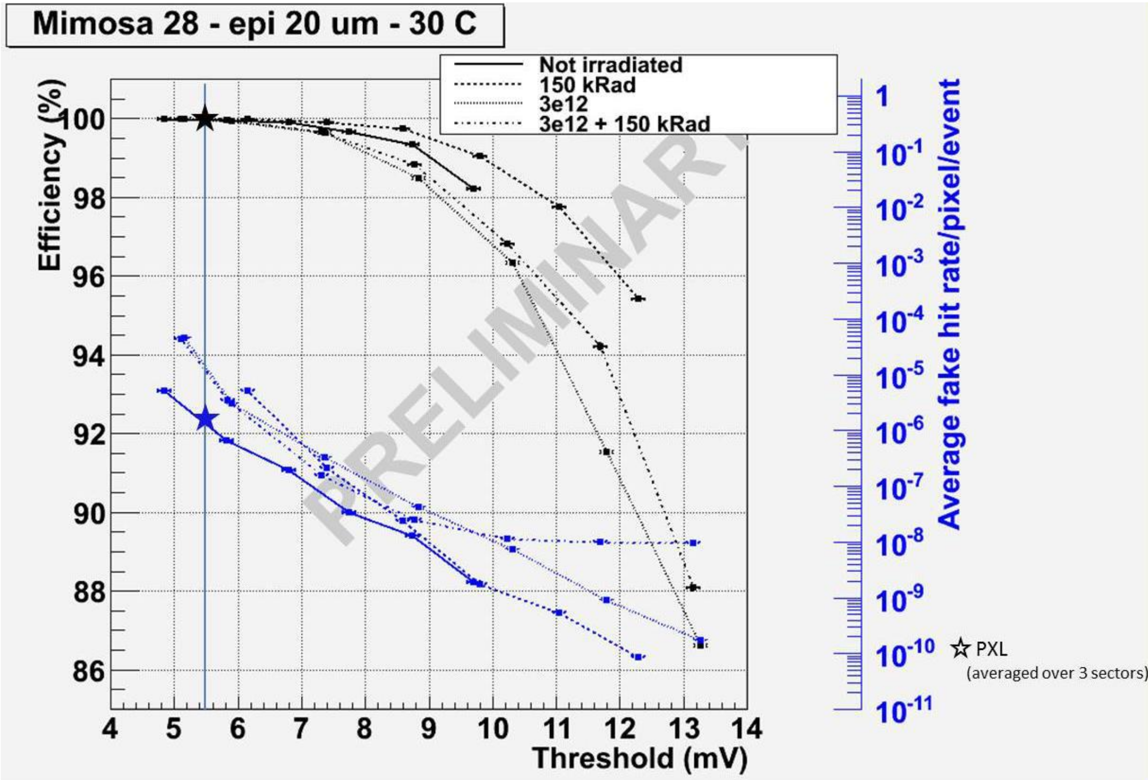


- 10 sectors with 4 ladders
- Innovative insertion mechanism allows for rapid (1 day) replacement
- Detector is inserted along rails and then locks in “kinematic mounts”
- 10 sensors/ladder 2×2 cm each

Pixel MAPS sensors



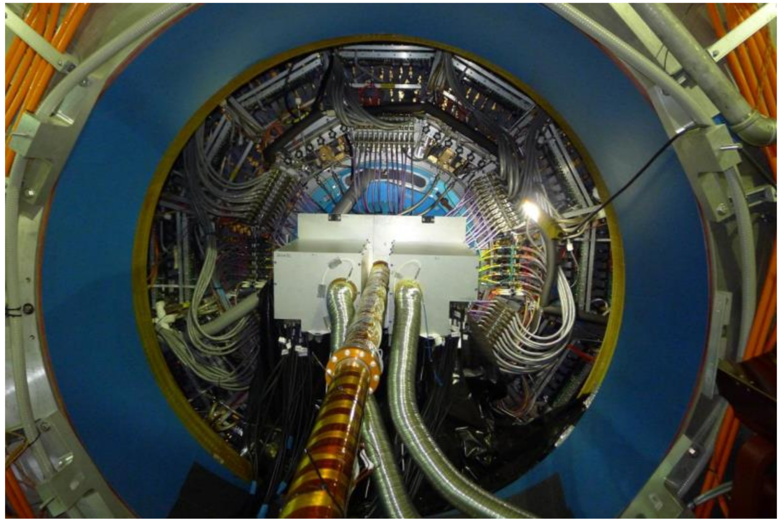
- Ultimate-2
  - 960 x 928 array
  - Pixel pitch 20.7 μm

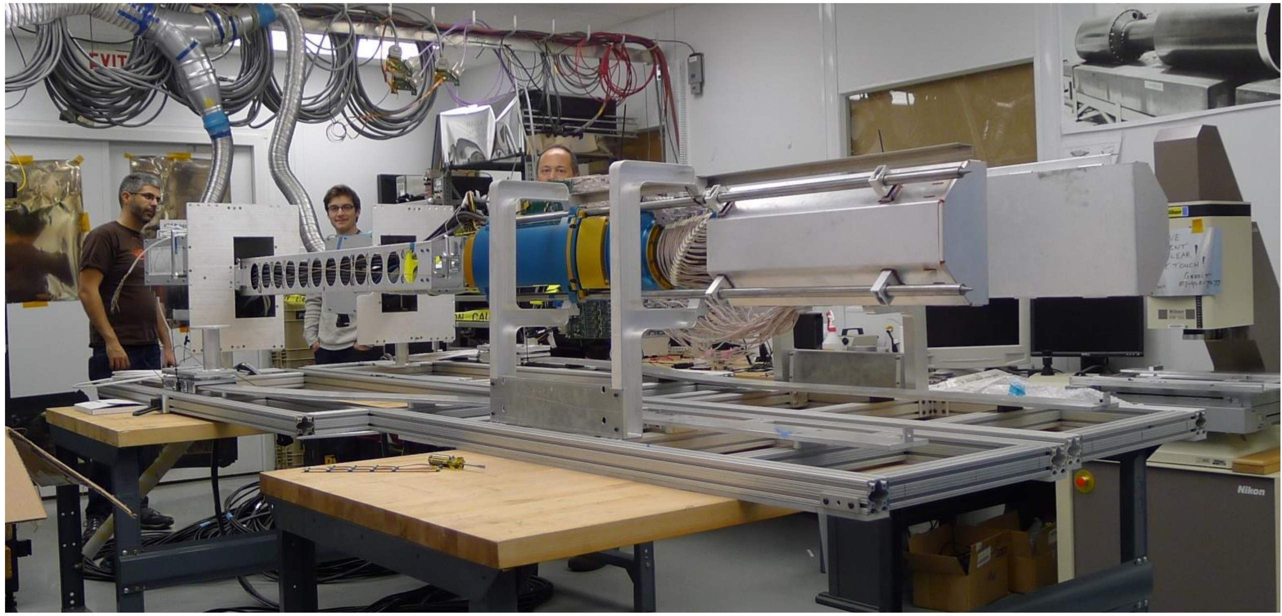


- Air cooling
- Integration time 185.6 μs
- Developed by the PICSEL group at IPHC Strasbourg

Pixel installation

- After installation:
  - All 400 sensors working
  - < 2k bad pixels
  - Noise rate tuned for $\sim 1.5 \times 10^{-6}$ per sensor (for most sensors)

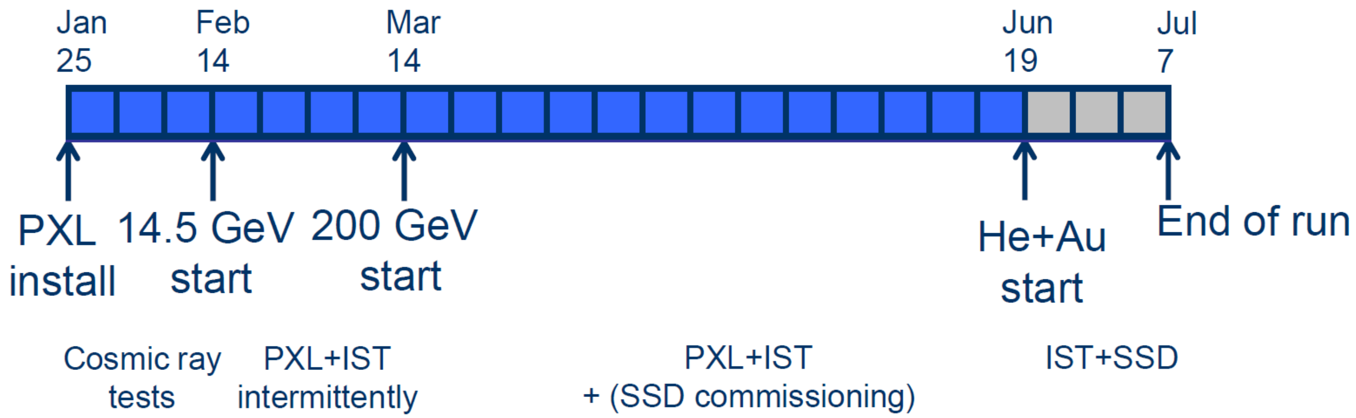




PXL assembled in the clean room at BNL

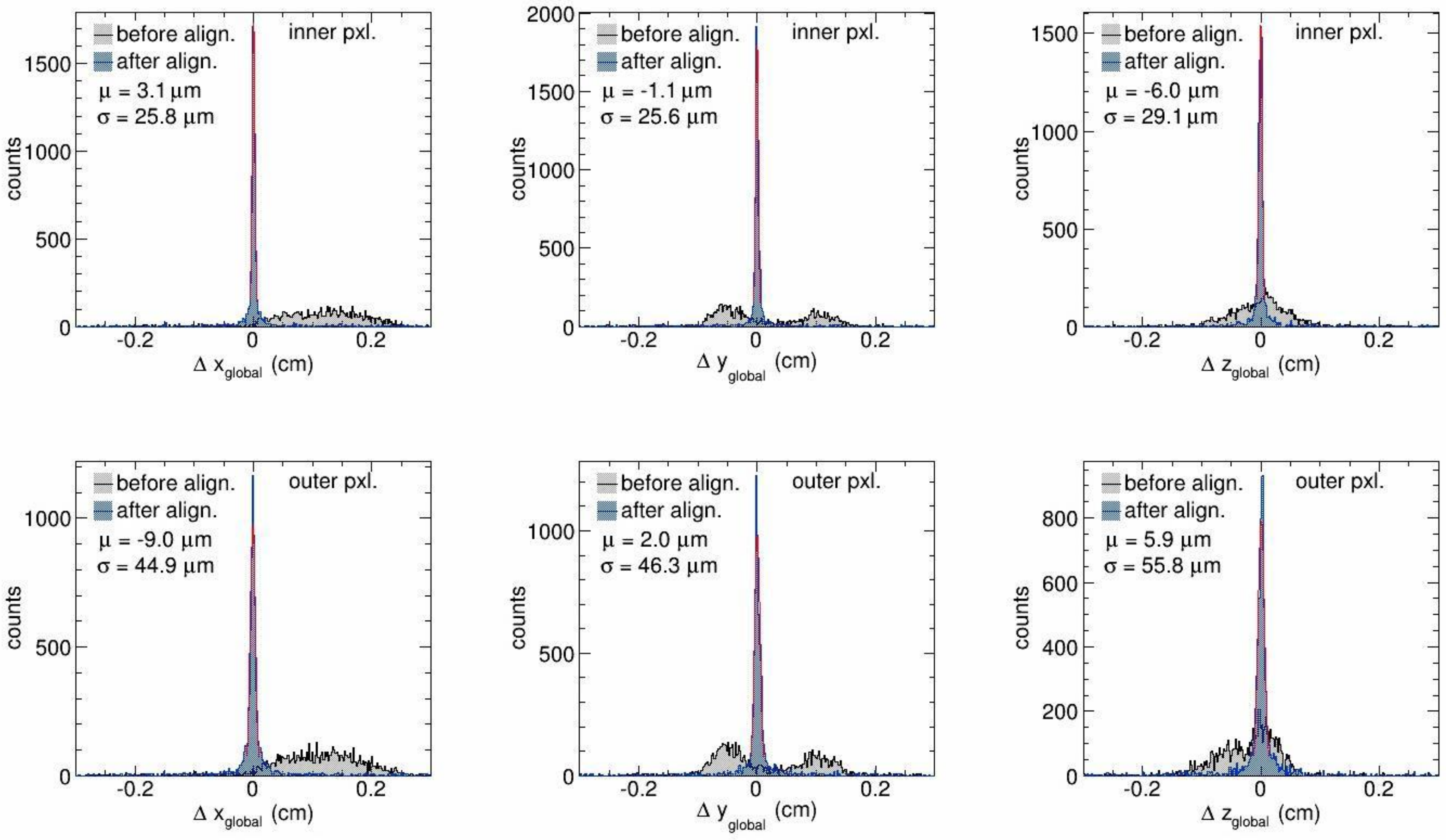
HFT Status

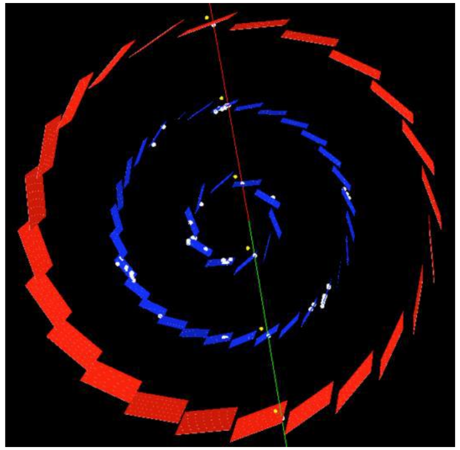
- SSD and IST installed in fall 2013
- PXL installed in January 2014
- February 2014: commissioning including cosmic data taking and low luminosity
- More than 1.2 billion events taken
- HFT ready for 2015 run and has taken cosmic data



Alignment for run 14

- Half-to-half pointing residuals
- $\sigma \sim 25\ \mu\text{m}$ inner for the inner layer and $\sigma \sim 50\ \mu\text{m}$ for the outer layer



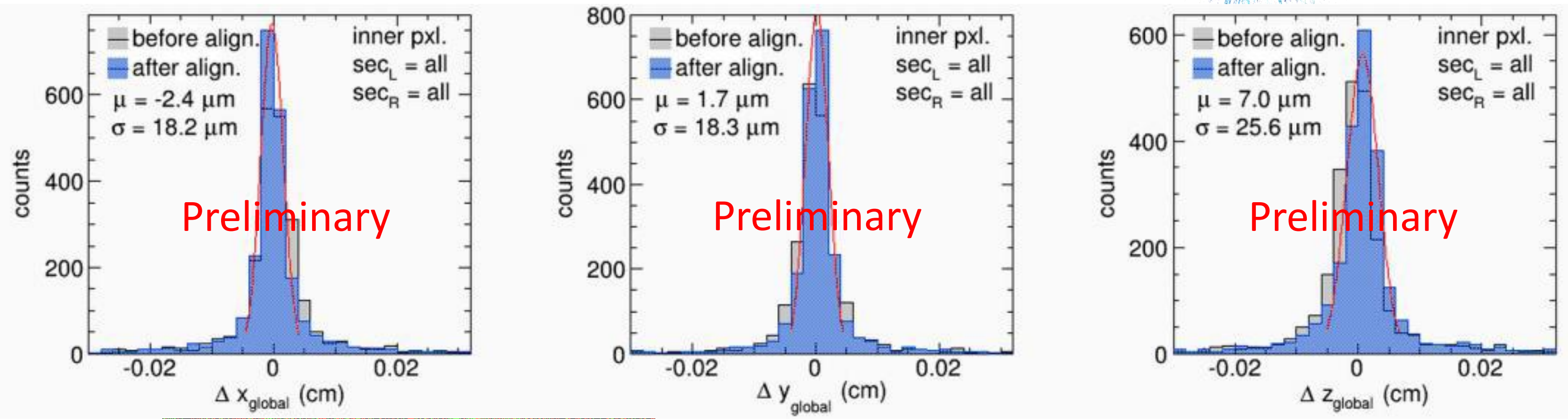


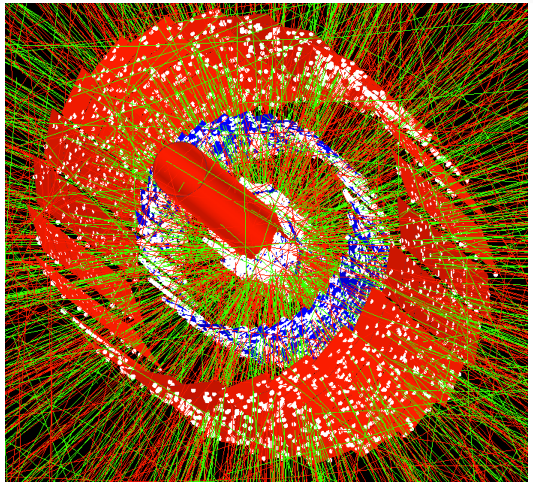
A cosmic event in PXL plus IST

Preliminary DCA pointing resolution

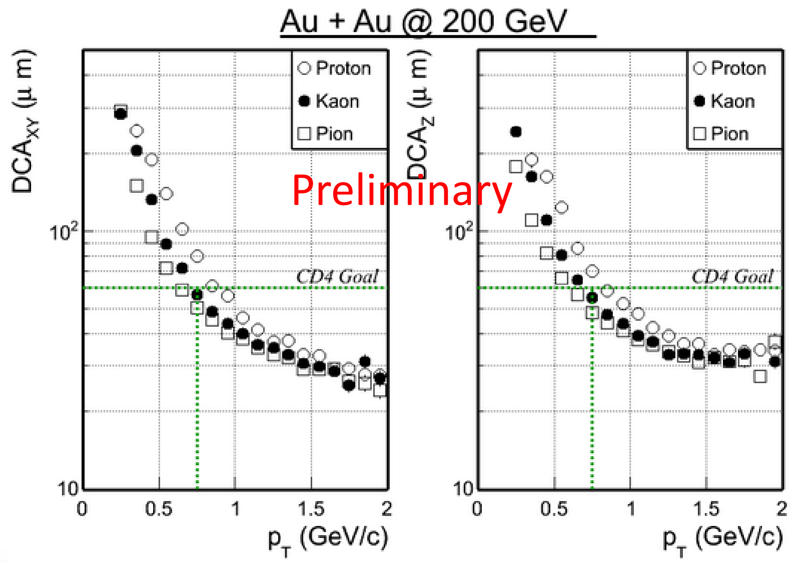
- PXL preliminary half-to-half
- $\sigma < 25\ \mu m$ inner layer

- DCA pointing resolution ~ 30 μm





200 GeV Au+Au event



Conclusion and outlook

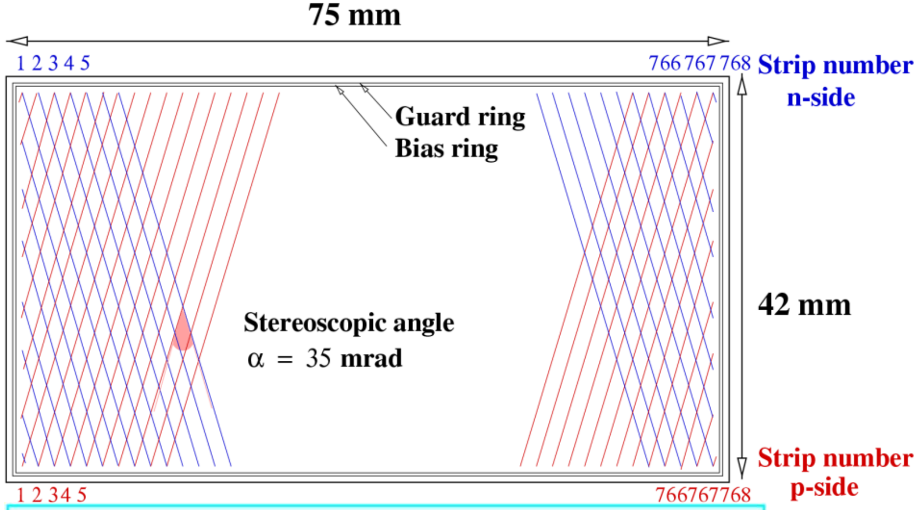
- HFT was successfully installed for the RHIC 2014 run
- The pointing resolution meets its design goals
- HFT is ready for 2015 run

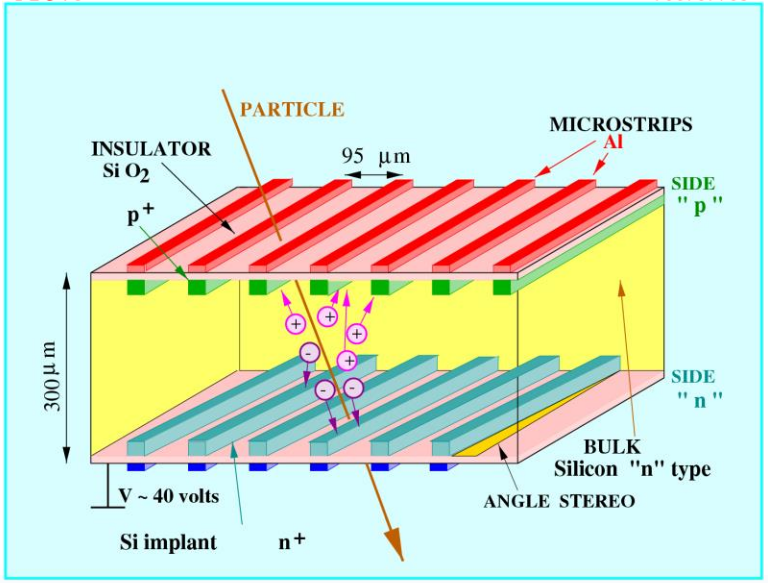
- MAPS technology seems to be working well for the VERTEX detectors
- More MAPS based vertex finders are soon to come … including the ITS upgrade at ALICE

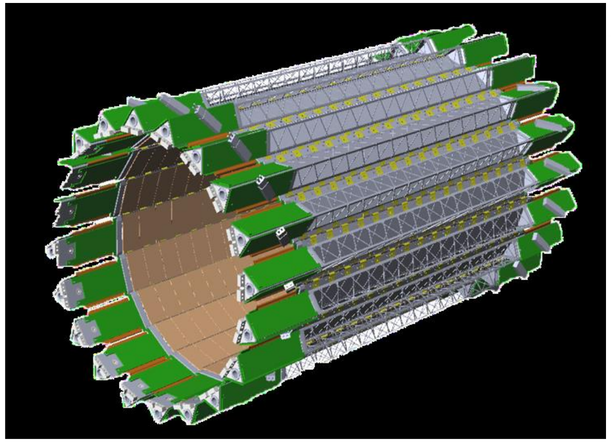
Thank you for your attention

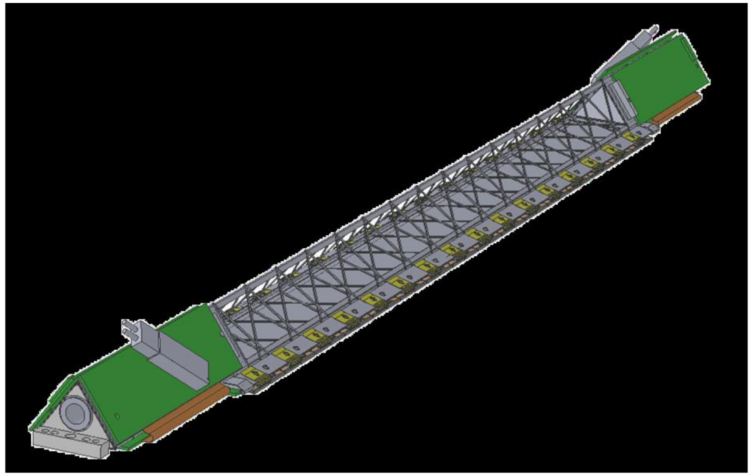
Backup

Silicon Strip Detector (SSD)





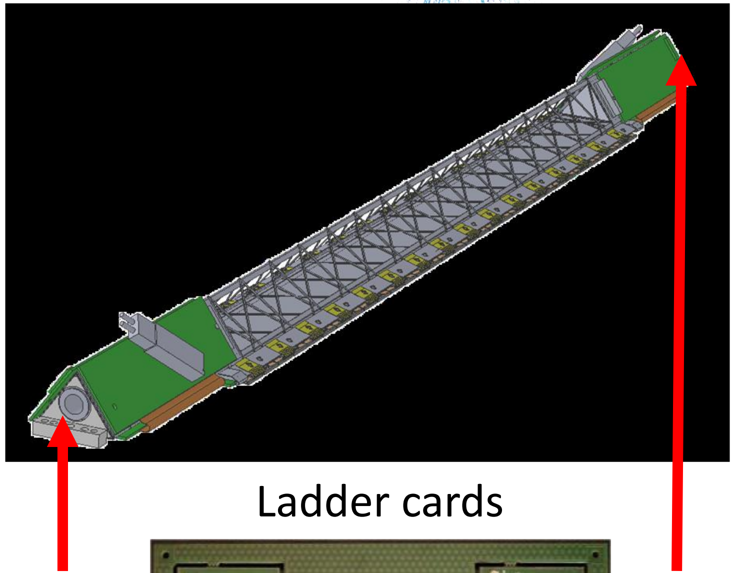




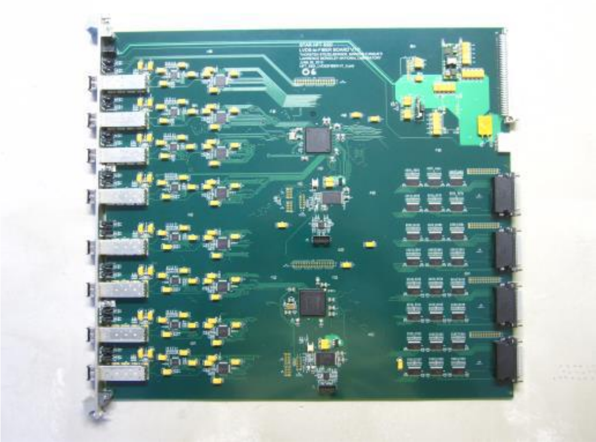
SSD radius	22 cm
SSD length	106 cm
$\lvert\eta\rvert$ coverage	< 1.2
Number of ladders	20
Number of wafers per ladder	16
Total number of wafers	320
Number of strips per wafer side	768
Number of sides per wafer	2
Total number of channels	491520
Silicon wafer size	75 × 42 mm
Silicon wafer sensitive size	73 × 40 mm
Silicon thickness	300 µm
Strip pitch	95 µm
Stereo angle	35 mrad
R-ϕ resolution	20 µm
Z resolution	740 µm

SSD readout refurbishment

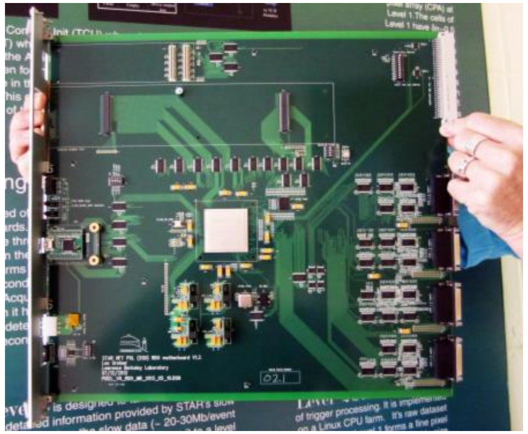
- Upgrade from 200 Hz to 1 kHz
- New
  - 40 ladder cards on detector
  - 5 RDO cards
  - 5 Fiber-to-LVDS boards



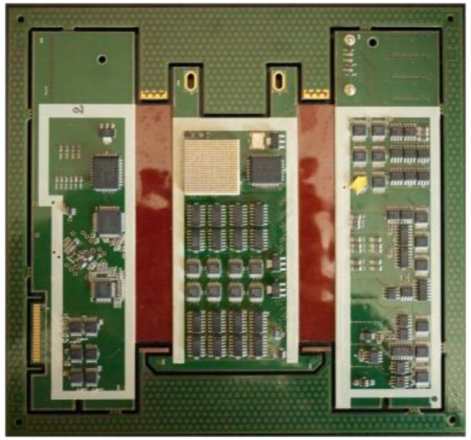
Fiber-to-LVDS



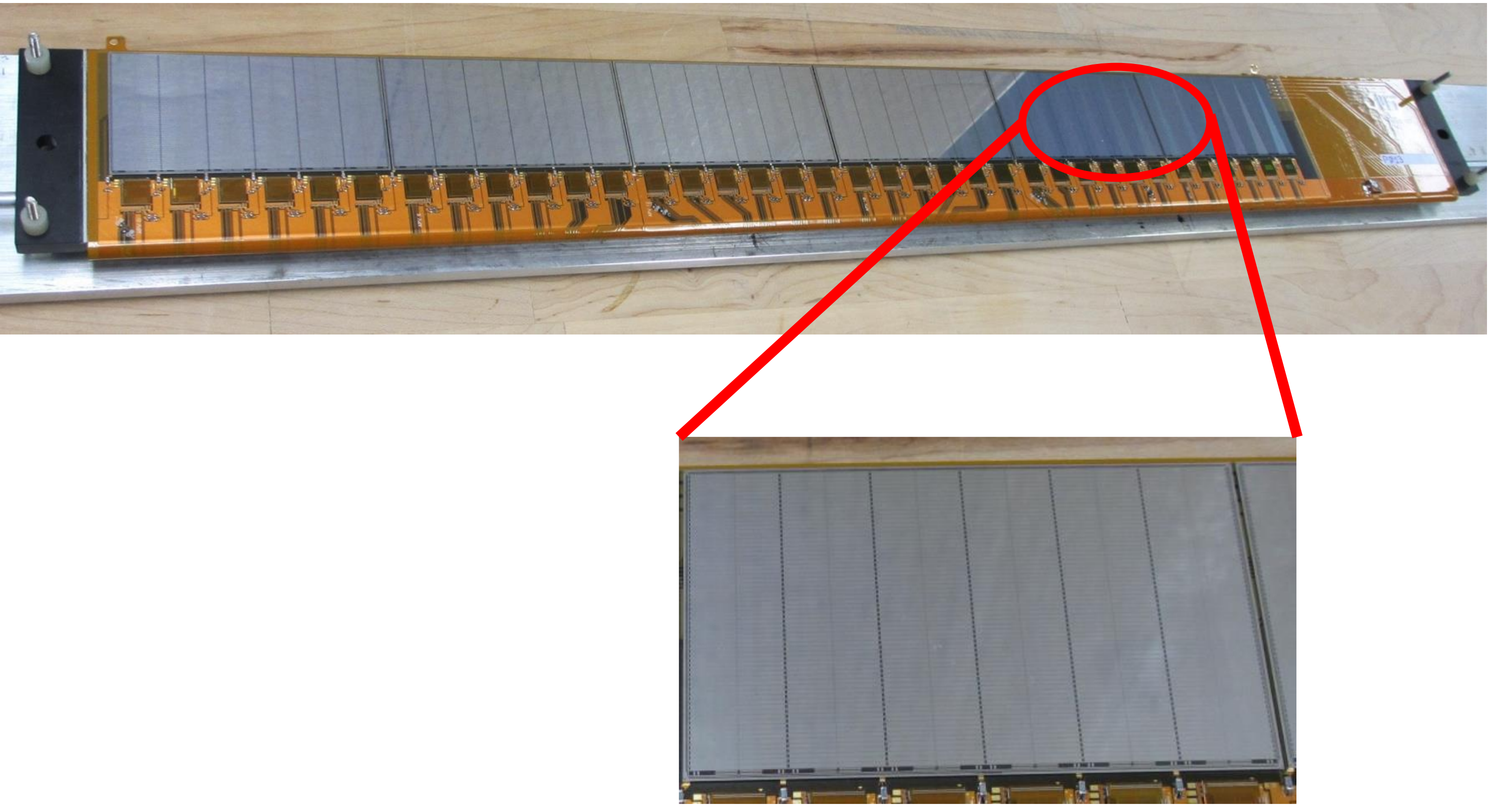
RDO board – adapted from PXL



Ladder cards



Intermediate Silicon Tracker (IST)



Radius	14 cm
Length	50 cm
ϕ-Coverage	2π
$\lvert\eta\rvert$-Coverage	≤ 1.2
Number of ladders	24
Number of hybrids	24
Number of sensors	144
Number of readout chips	864
Number of channels	110592
R-ϕ resolution	172 μm
Z resolution	1811 μm
Z pad size	6000 μm
R-ϕ pad size	600 μm

Pixel detector (PXL)

DCA pointing resolution	$(12 \oplus 24\ \mathrm{GeV}/p_T c)$
Radii	Layer 1 at 2.8 cm Layer 2 at 8 cm
Pixel size	$20.7\ \mu\mathrm{m}\ \times 20.7\ \mu\mathrm{m}$
Hit resolution	$3.7\ \mu\mathrm{m}$
Position stability	$6\ \mu\mathrm{m}$ RMS ($20\ \mu\mathrm{m}$ envelope)
Radiation length	Layer 1: $X/X_0 < 0.4\%$ Layer 2: $X/X_0 < 0.5\%$
Number of pixels	$\sim$ 356 M
Integration time (affects pileup)	185.6 ms
Radiation environment	20 – 90 kRad/year 2×10^{11} to 10^{12} 1 MeV n eq/cm^2
Installation time	$\sim$ 1 day

PXL readout chain

Mass Termination Board
- Signal buffering
- Latch-up protected power

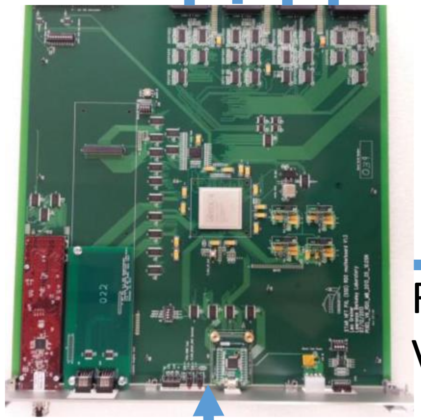
2 m

Clock, config, data, power

PXL sensor – continuous readout

11 m

Clock, config, data



RDO board w/ Xilinx Virtex-6 FPGA

Trigger, Slow control, Configuration, etc.

100 m fiber optics

PXL build events

DAQ PC with PORC

Highly parallel system
- 4 ladders per sector
- 1 Mass Termination Board per sector
- 1 RDO board per sector

Radiation damage in 2014 and remediation

- After the installation all 400 sensors working
- First damage found out in 14.5 GeV run after several beam loss events
- The damage seems to be radiation related and appears to be from latch-up events

- Measures taken:
  - Latch-up threshold decreased from 400 mA over operating current to 120 mA over operating current
  - Cycle digital power once every 15 min
  - HFT is switched off when the collision rate > 40 kHz
- Further damage has been stopped

- New detector for 2015 has only 4 bad sensors out of 400
- Is protected from the beginning

Layer	Inactive
PXL inner	14%
PXL outer	1%
IST	4%