Λ_c baryon reconstruction in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV

Miroslav Simko

for the STAR Collaboration

Nuclear Physics Institute,
Czech Academy of Sciences

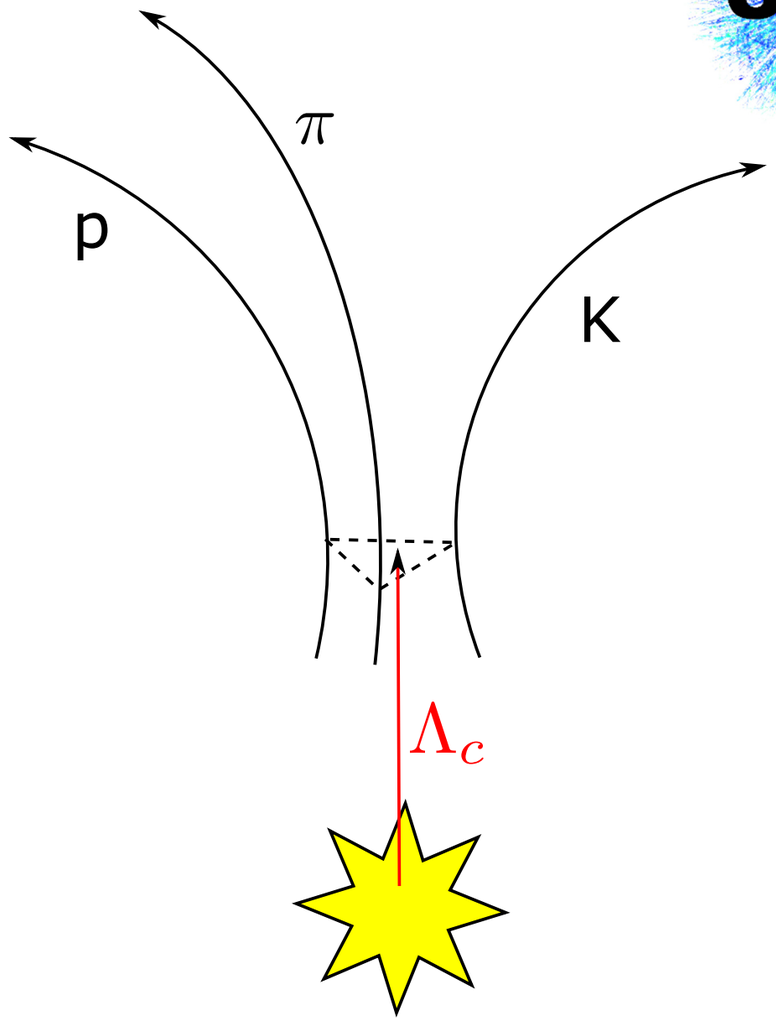
Faculty of Nuclear Sciences
and Physical Engineering,
Czech Technical University in Prague

BERKELEY LAB

STAR

Outline

- Physics motivation of Λ_c analysis
- STAR with Heavy Flavor Tracker
- Reconstruction of Λ_c
- Simulations and cuts optimization
- Run 2016 expectation at STAR

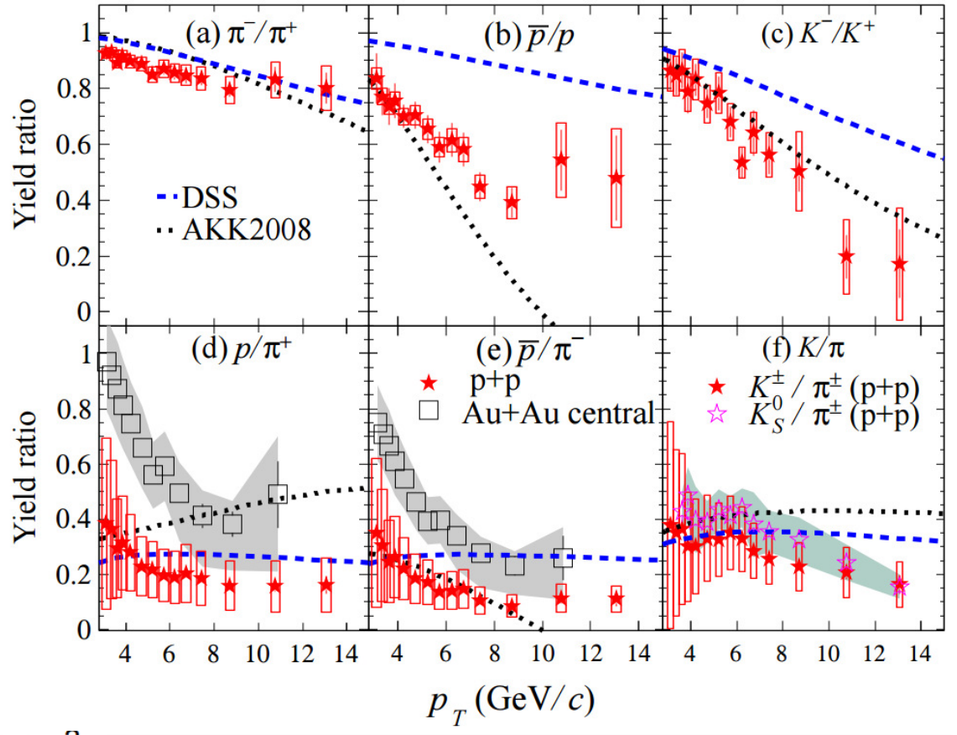


Motivation

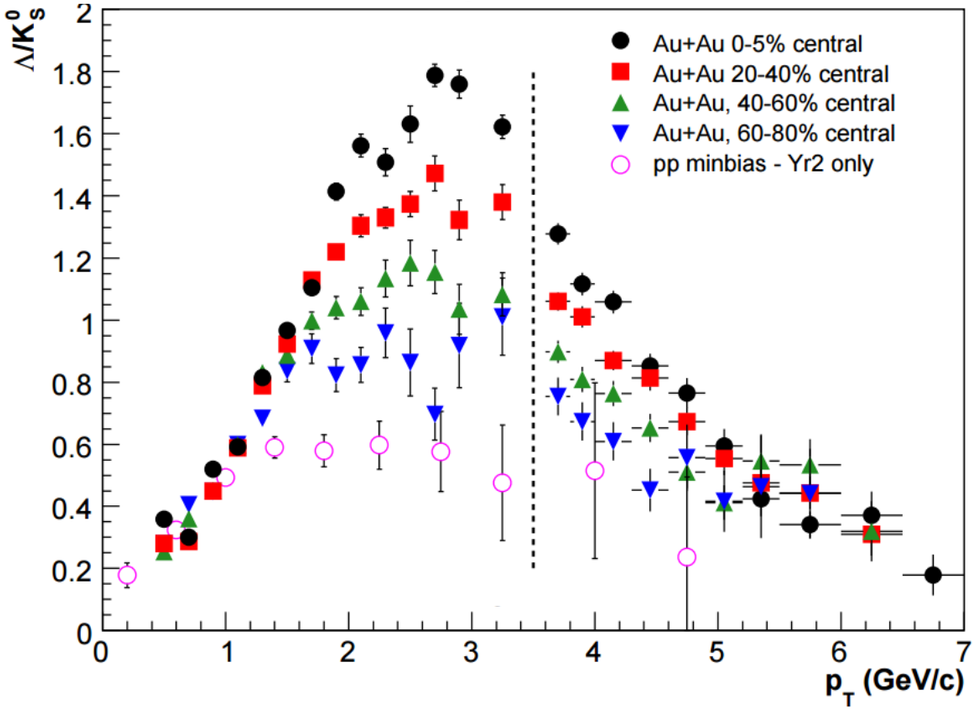
[Phys. Rev. Lett. **108** (2012) 72302]

- Never observed in heavy-ion collisions
- Quarks: udc

- Baryon to meson ratios (such as p/π, Λ/K^0) are significantly enhanced in heavy-ion collisions compared to p+p
- Similar enhancement expected in Λ_c/D^0
- Λ_c would bring more insight into coalescence of charm quarks
- Λ_c/D^0 enhancement is one of the signatures of quark gluon plasma



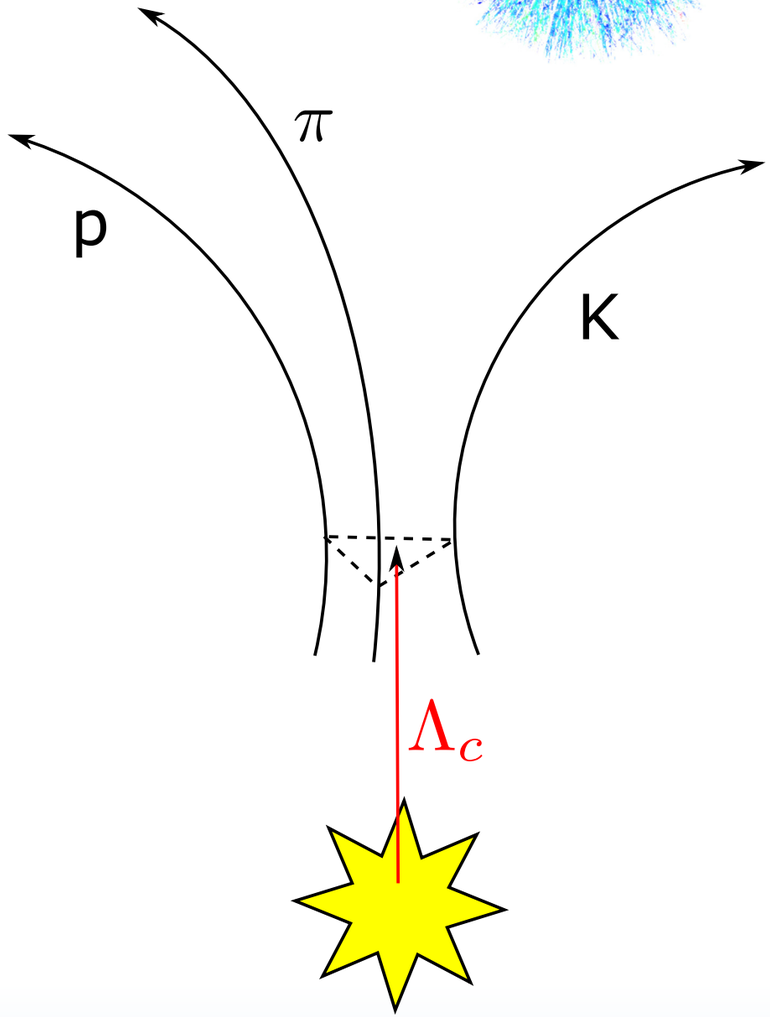
[J.Phys.Conf.Ser. 50 (2006) 192]



Λ_c baryon

- Challenging to measure, $c\tau \sim 60\ \mu$m

- Three body decay branching ratios:
- $\Lambda_c^+ \rightarrow \mathrm{p\ K^-}\pi^+$ (5.0±1.3)%
  - $\Lambda_c^+ \rightarrow$ pK* (1.6±0.5)%
  - $\Lambda_c^+ \rightarrow \Lambda(1520)\ \pi^+$ (1.8±0.6)%
  - $\Lambda_c^+ \rightarrow \mathrm{K^-}\Delta^{++}$ (0.86±0.3)%
  - Nonresonant (2.6±0.8)%



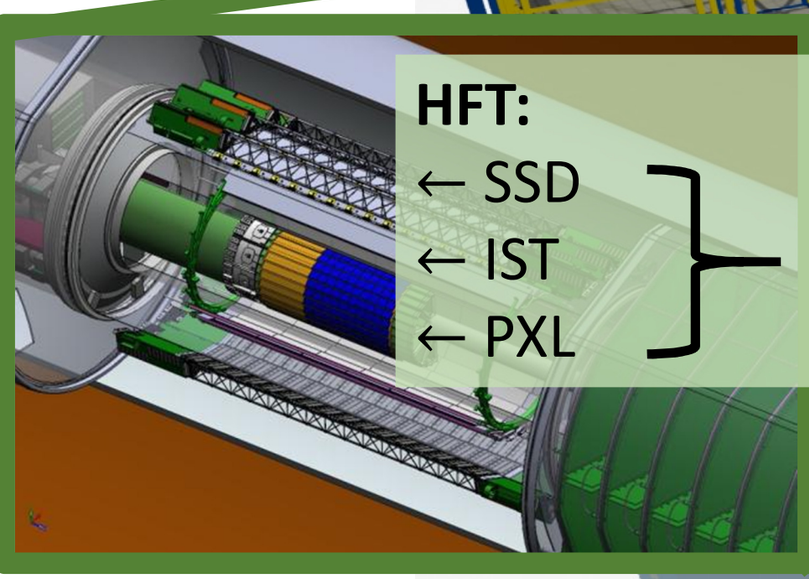
[Particle Data Group, Chin. Phys. C38 (2014) 090001]

STAR detector

2π acceptance in azimuth

TOF:
$1/\beta$
(PID) $\rightarrow$

TPC: Tracking
dE/dx (PID)
$\leftarrow$ $-1 < \eta < 1$

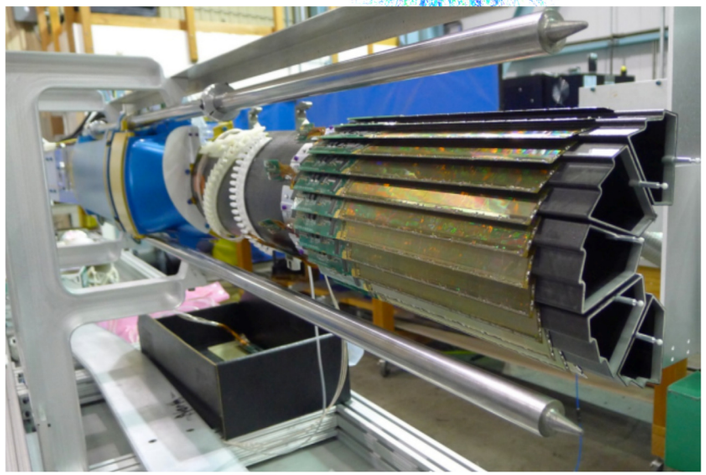


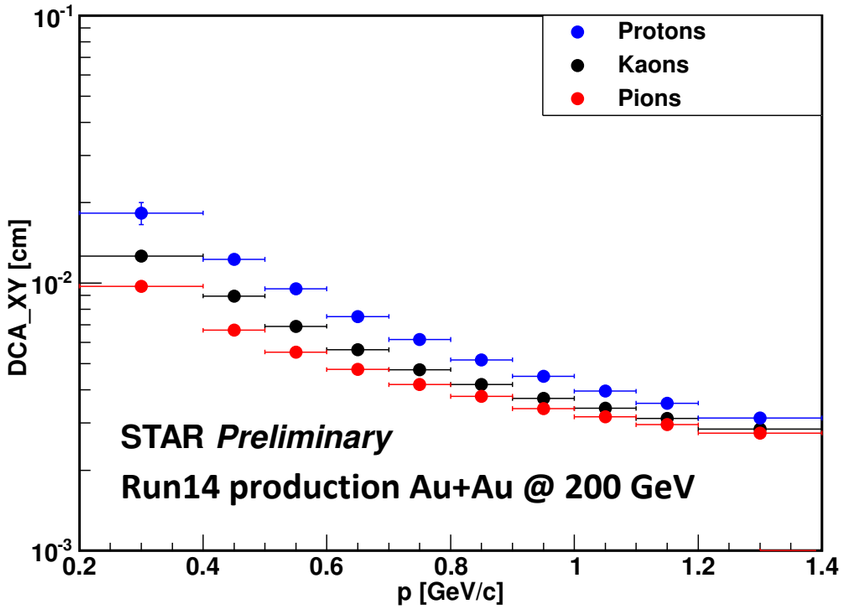
HFT:
$\leftarrow$ SSD
$\leftarrow$ IST
$\leftarrow$ PXL

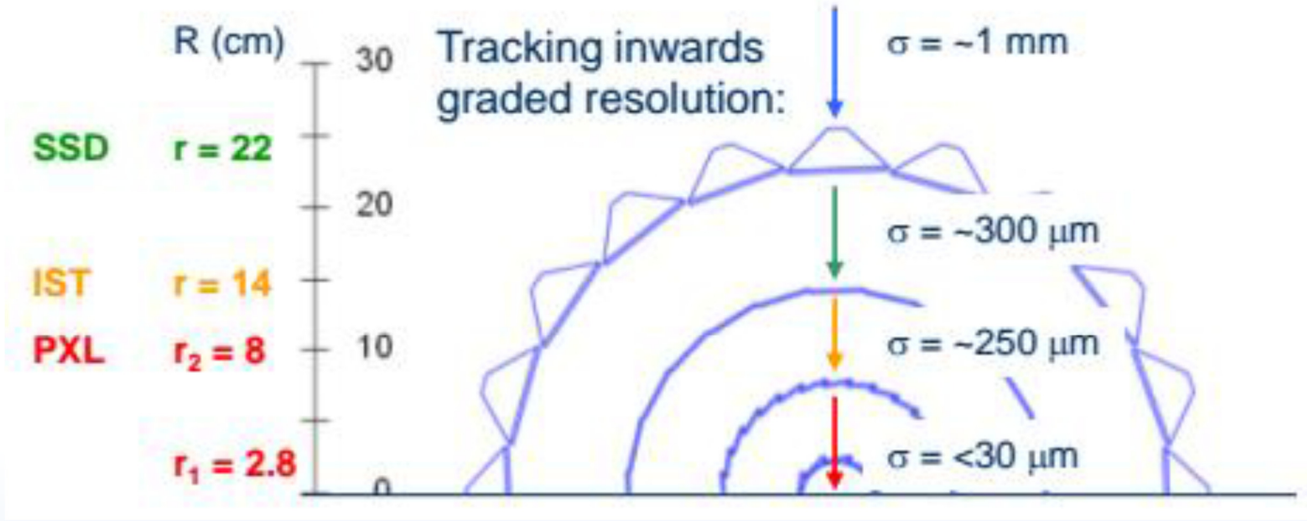
Silicon vertex detector

HFT performance

- New pixel detector based on MAPS technology
- Pitch: 20.7×20.7 μm^2, thickness: 0.4% X_0
- Pointing resolution: ~30 μm at high p_T
- 1.2×10^9 events at 200 GeV recorded in 2014
- See Jakub Kvapil's talk (Wednesday 10:00am)

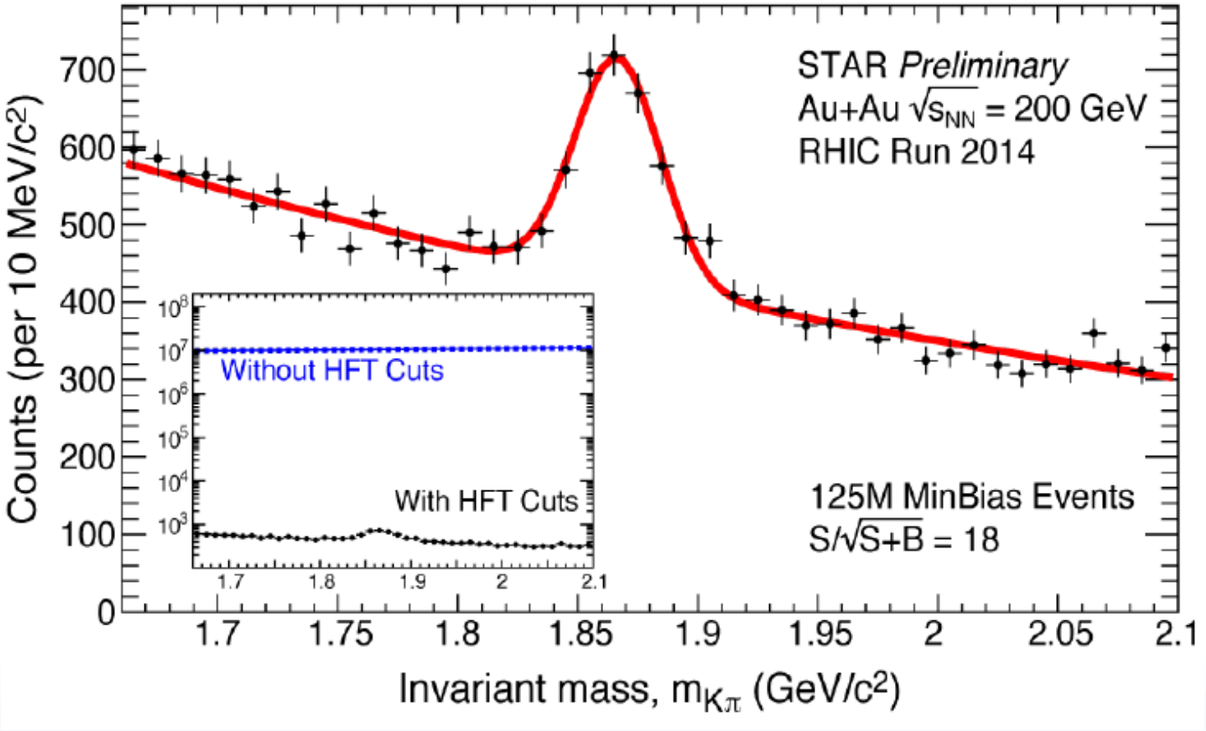


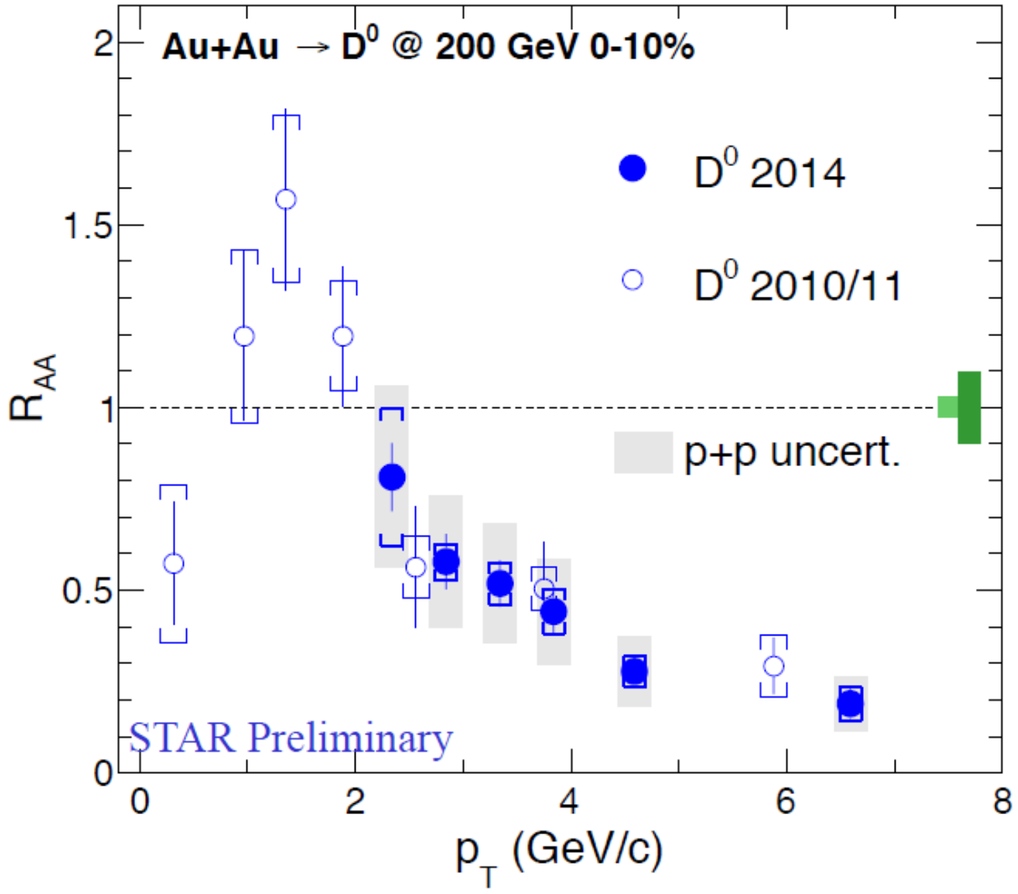




New D^0 measurement in run 2014

- Combinatorial background greatly reduced
  - Thanks to the HFT
- Significance rose by a factor of 4 to 51
- Much more precise measurement
- New p+p data taken in 2015 will improve uncertainties

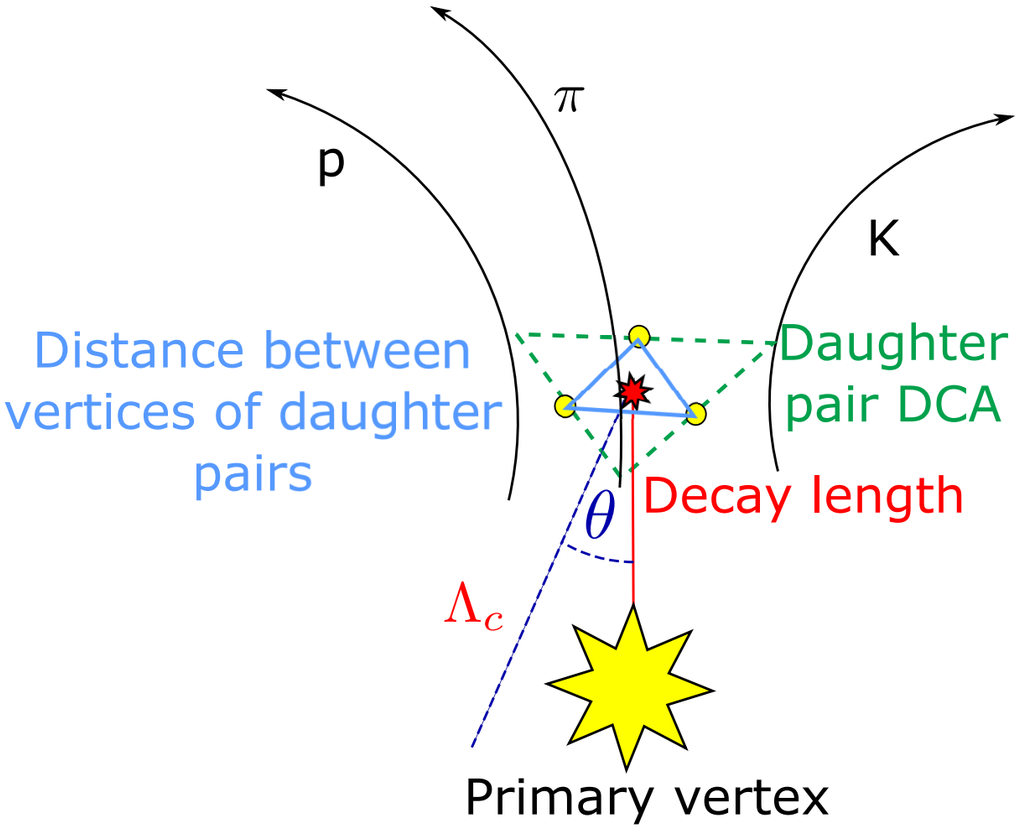




Quark Matter 2015

Λ_c reconstruction

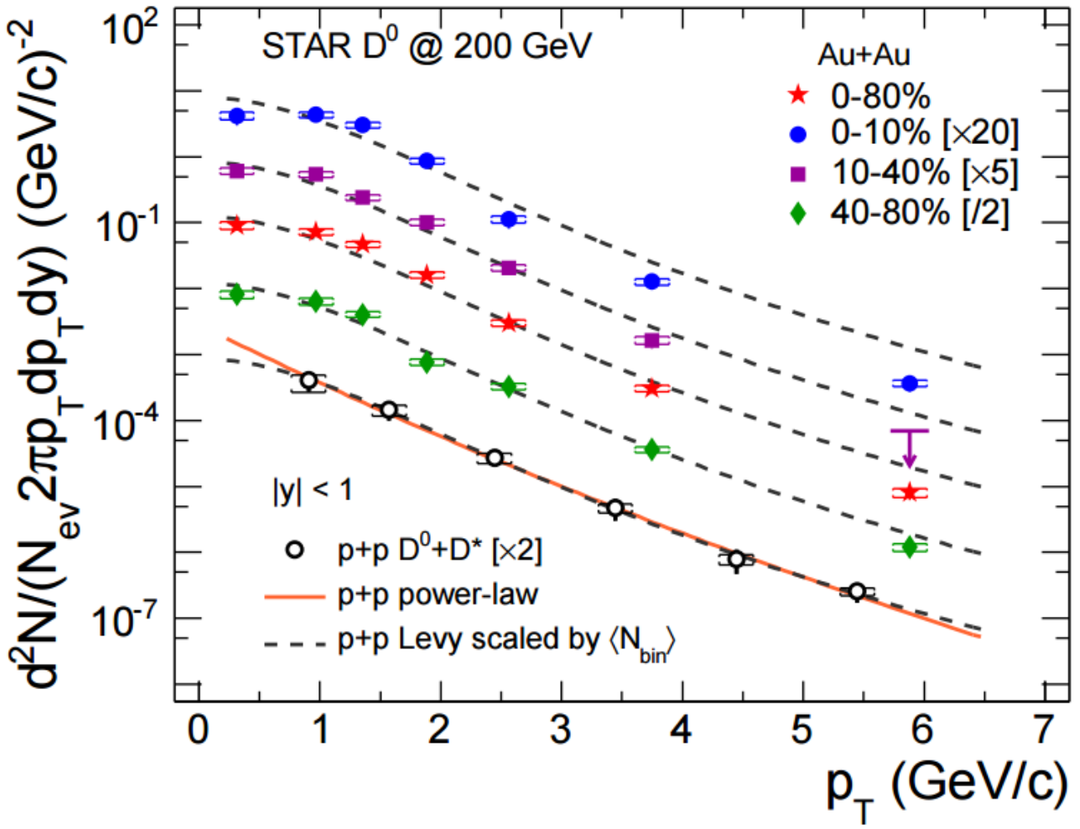
- Three particle decay: BR = 5%, $c\tau \sim 60$ μm
- Particle identification using TOF $1/\beta$ information and dE/dx in the TPC
- Significant background reduction with the HFT
- Cuts have to be optimized using simulations



Data driven Monte Carlo simulation for cuts optimization

- Λ_c decayed in PYTHIA
- Momenta and track positions smeared according to data

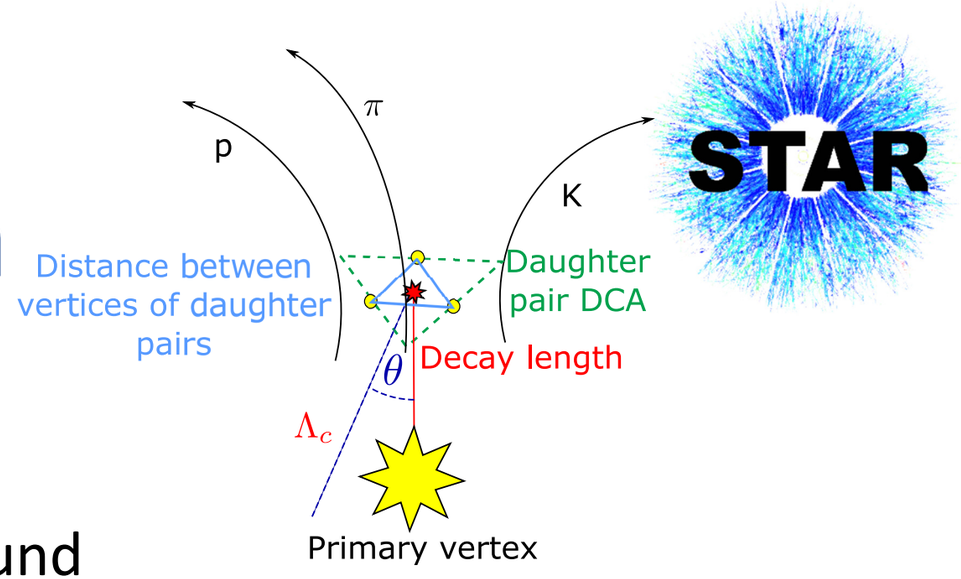
- Rough estimate of Λ_c behavior
  - Λ_c with flat rapidity
  - p_T distribution from published D^0 minimum bias Au+Au spectrum
  - Λ_c/D^0 ratio obtained from e+p data (ZEUS)
    [Eur. Phys. J. C44 (2005) 351]
  - Scaling with N_{coll}

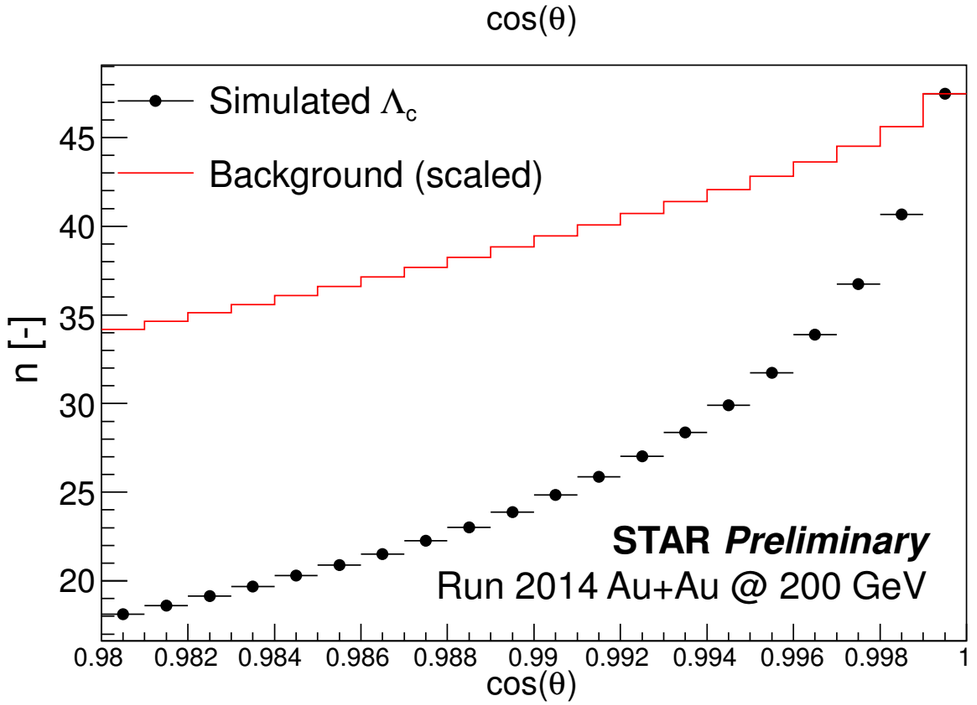


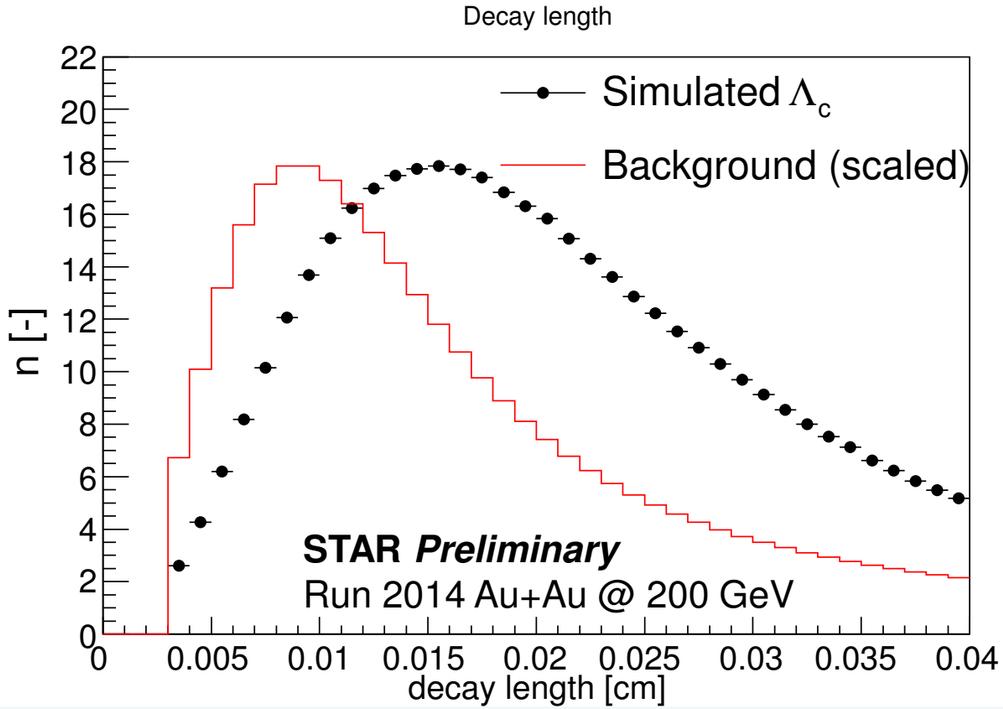
[Phys. Rev. Lett. **113** (2014) 142301]

Comparison: simulation and background from data

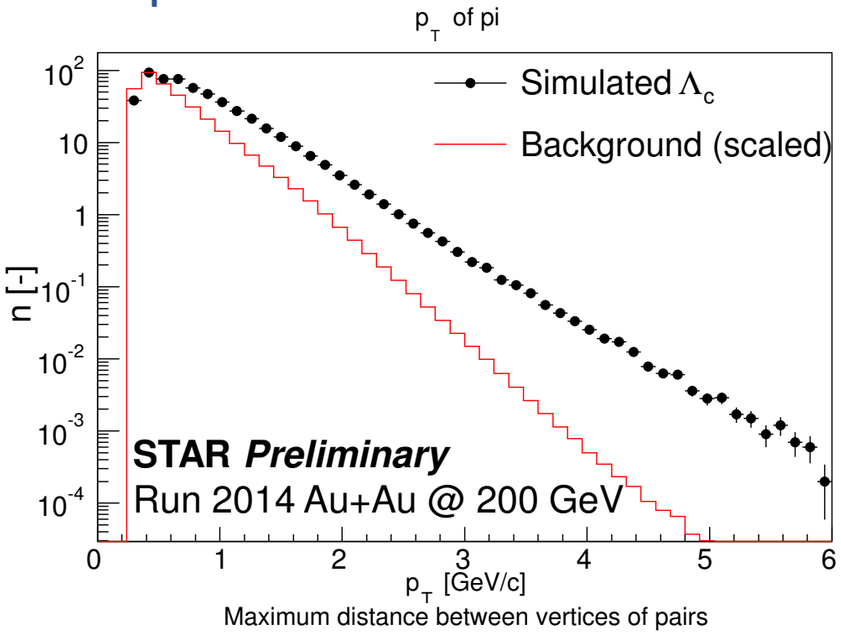
- Background from run 2014 Au+Au data
- Background: Wrong charge sign combinations
- Same cuts applied on simulation and background

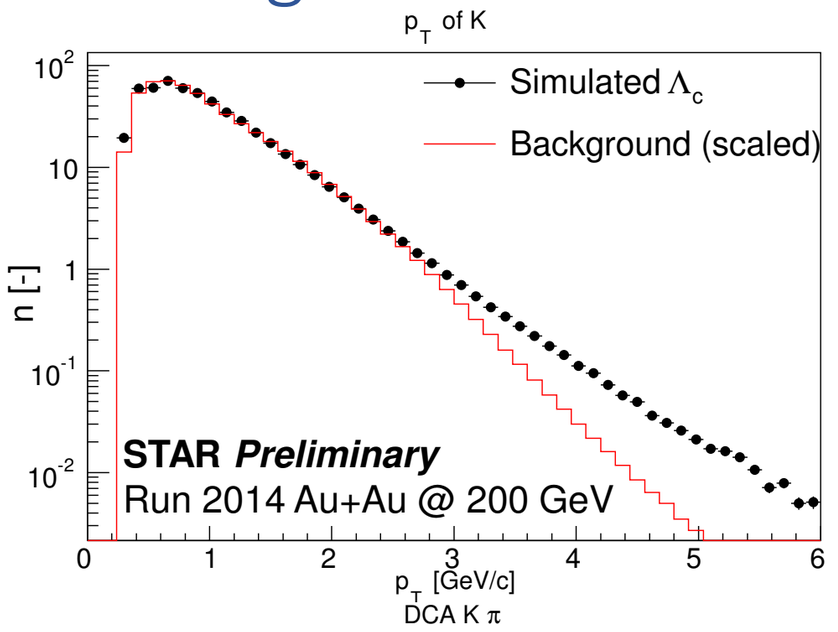


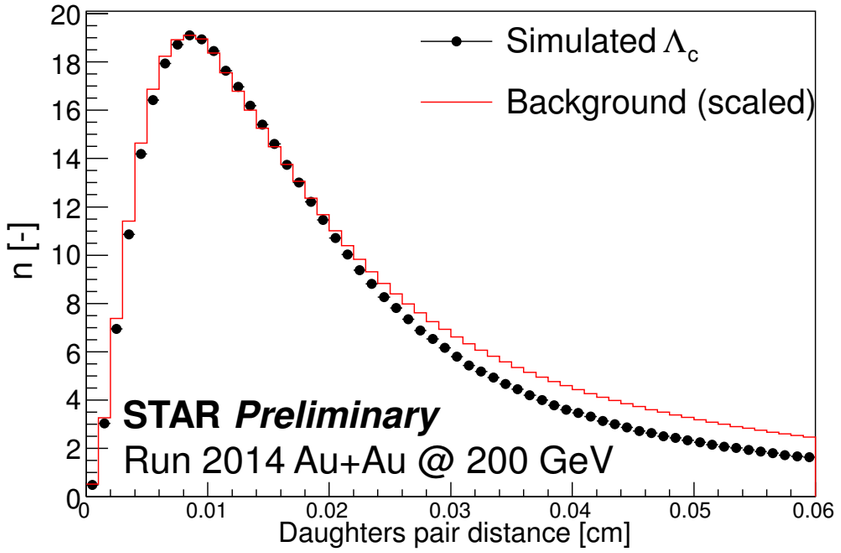


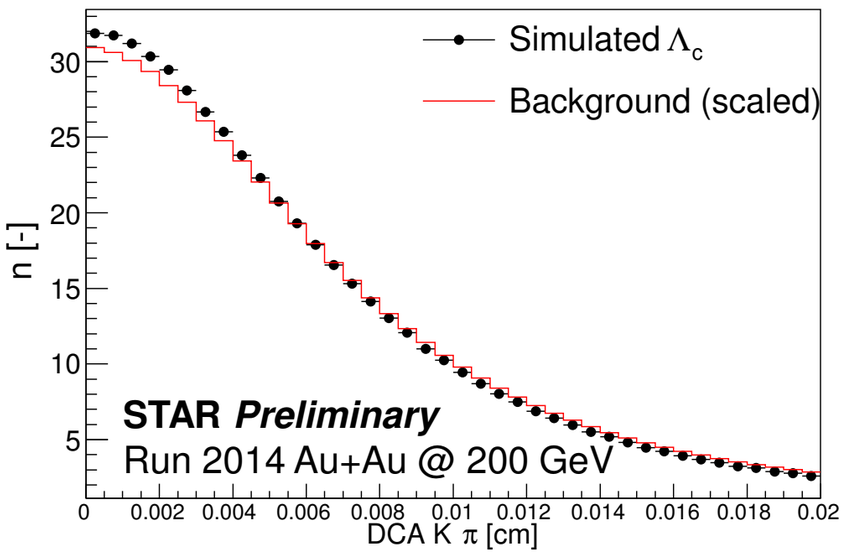


Comparison: simulation and background from data (2)

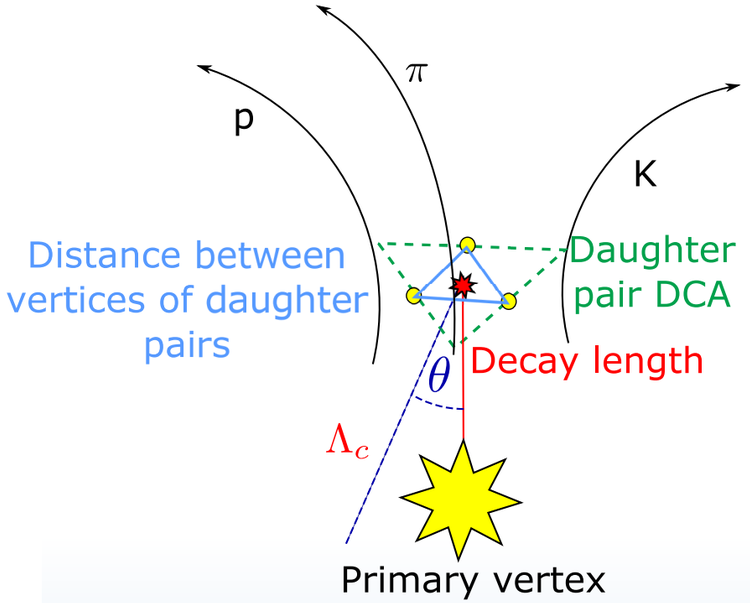








- Decay length, cos(θ), and p_T cuts most powerful
- The variables are strongly correlated
- Multivariate analysis



Multivariate analysis for cuts optimization

- Cuts variables highly correlated
- Multivariate analysis
  - Can create complicated cut structures in N-dimensional spaces

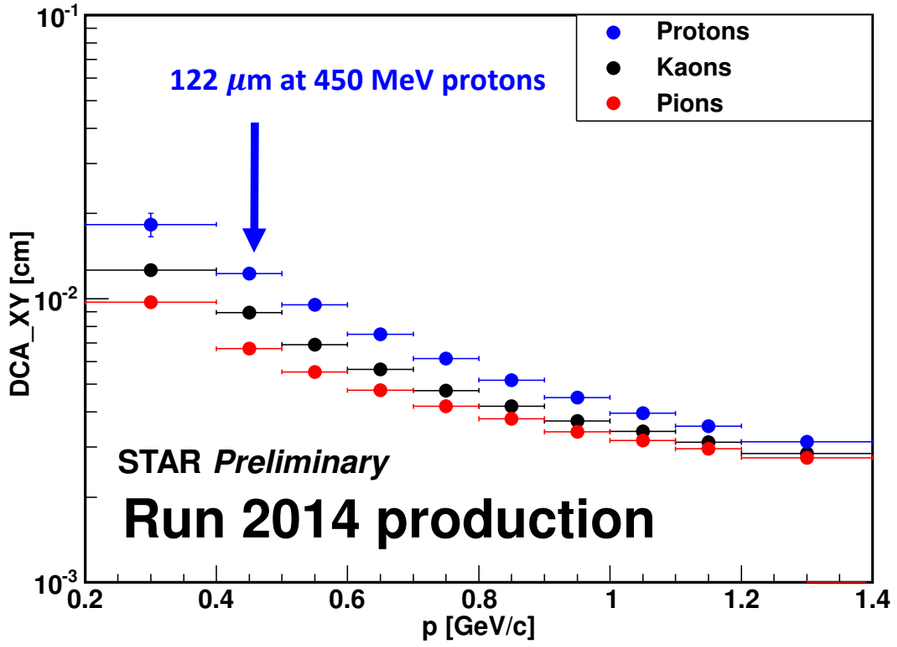
- Toolkit for MultiVariate Data Analysis (TMVA)

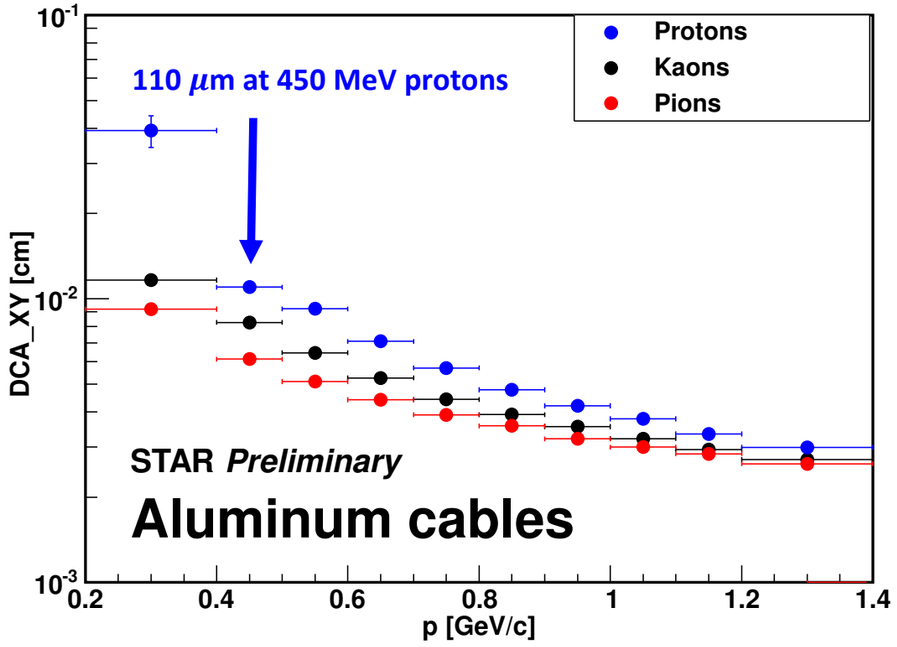
  [PoS ACAT 040 (2007), arXiv:physics/0703039]
  - Rectangular cuts, Neural networks, Boosted decision trees,…
  - Ongoing work

- Preselection for TMVA:
  - *N*-dim array of cuts for *N* variables with small increment
  - Maximizing significance: $s = \frac{N_{\mathrm{sig}}}{\sqrt{N_{\mathrm{sig}}+N_{\mathrm{bg}}}}$
  - Select Signal and Background
  - Few iterations

Outlook: Run 2016 Au+Au at 200 GeV

- 1.2×10^9 events recorded in run 2014 – 2×10^9 are expected in Run 2016
- Pixel improvements:
  - Changed cable material copper→aluminum
  - Replacement of non-working sensors – better efficiency
  - Pointing resolution improved





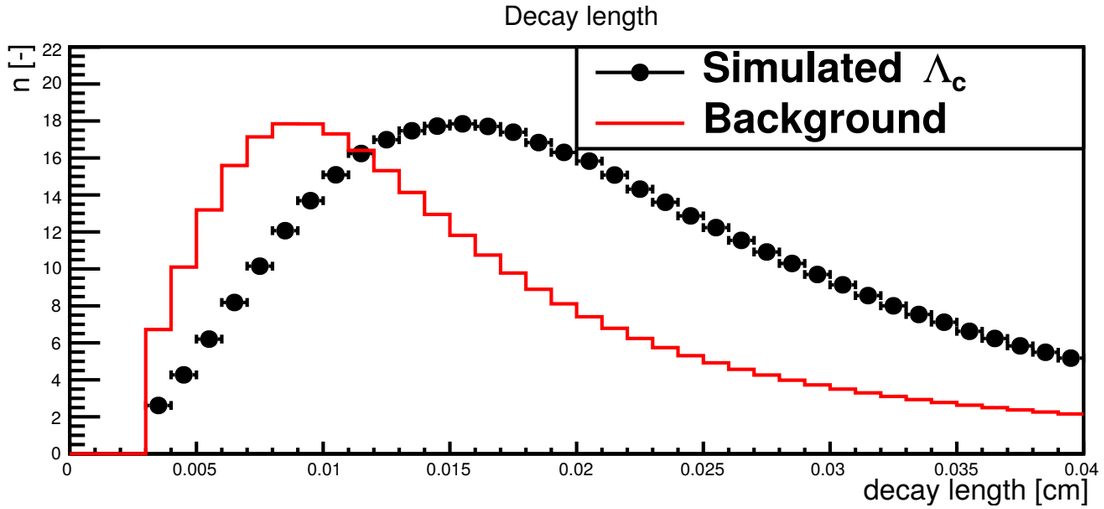
Conclusion

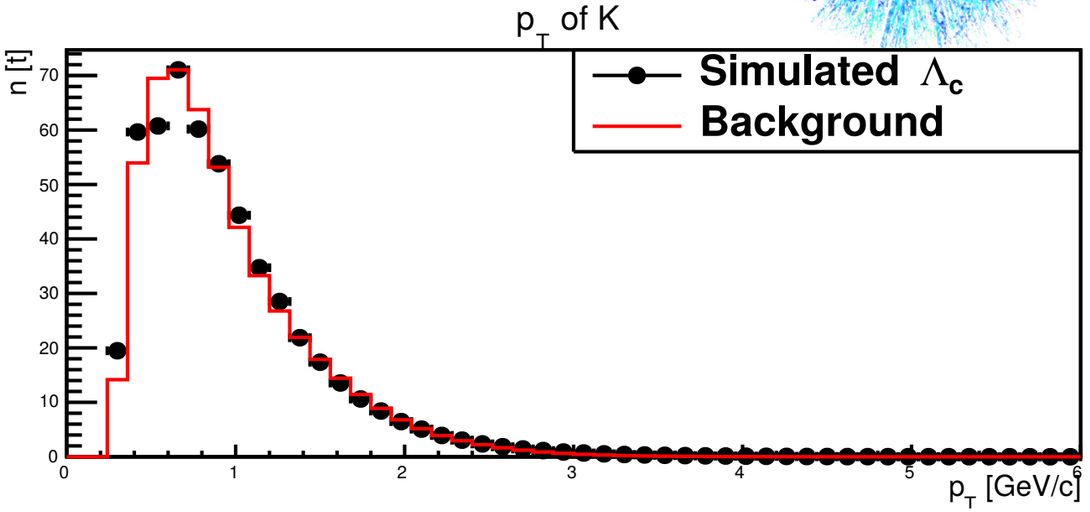
- STAR may be able to measure Λ_c baryons for the first time in heavy-ion collisions thanks to excellent pointing resolution of the HFT
- Important probe for coalescence of c-quarks
- Cuts optimization using data driven simulation
- Multivariate analysis – a powerful tool for cuts
- 2016: More statistics with better HFT

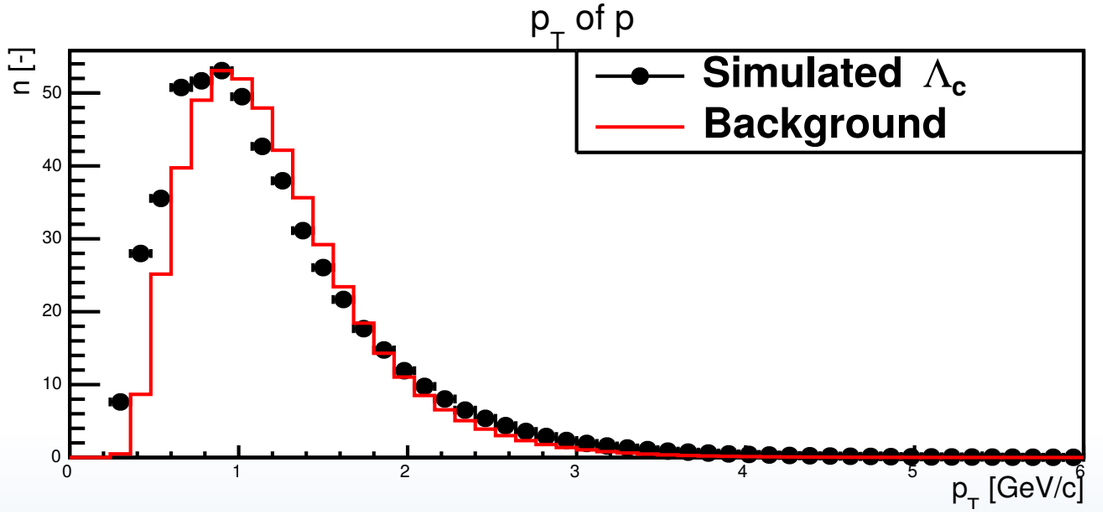
Thank you for your attention

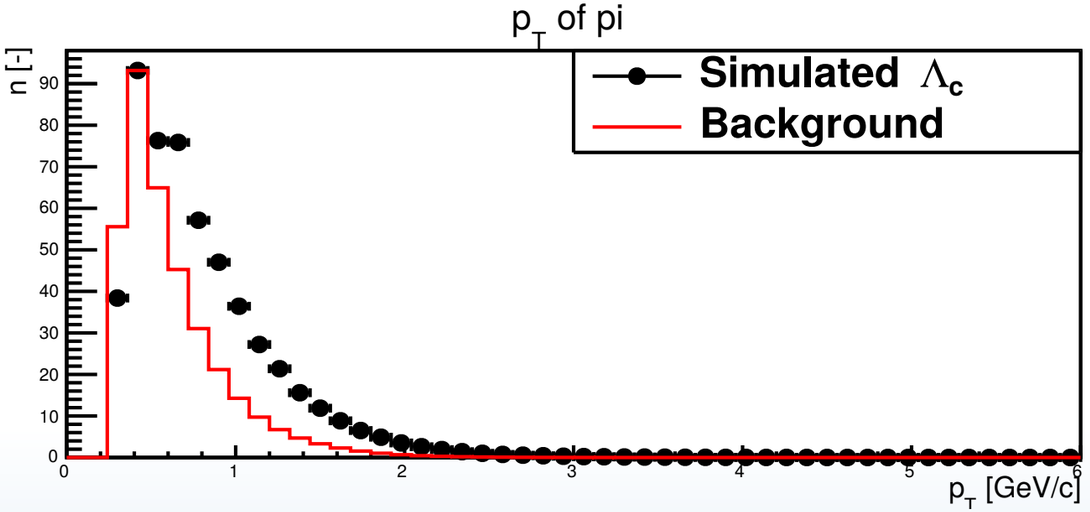
Backup

Daughters p_T

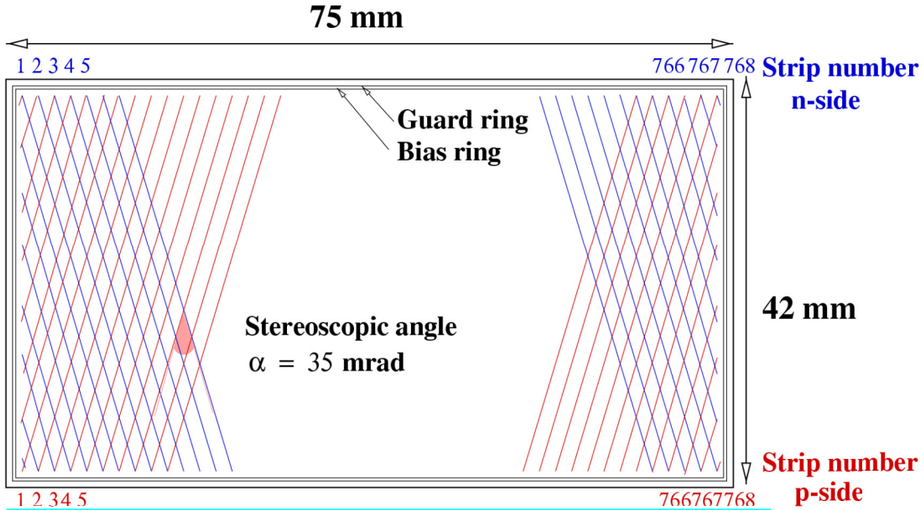


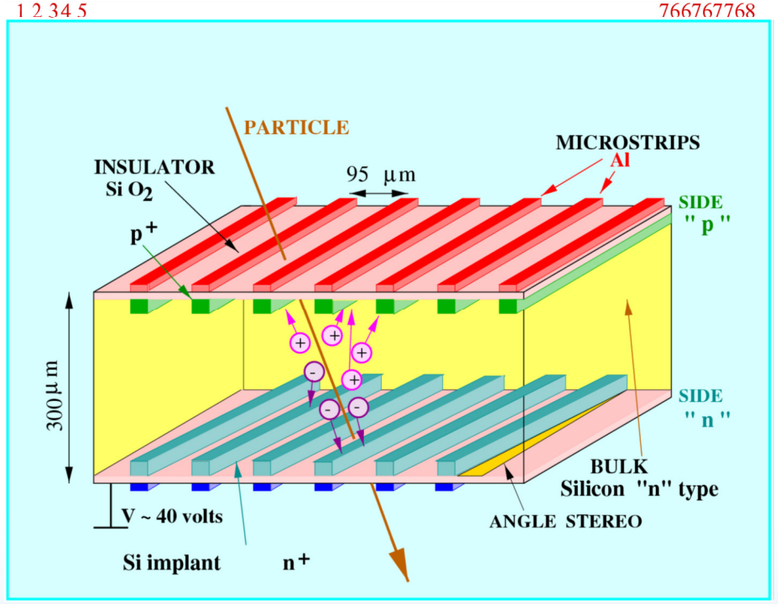


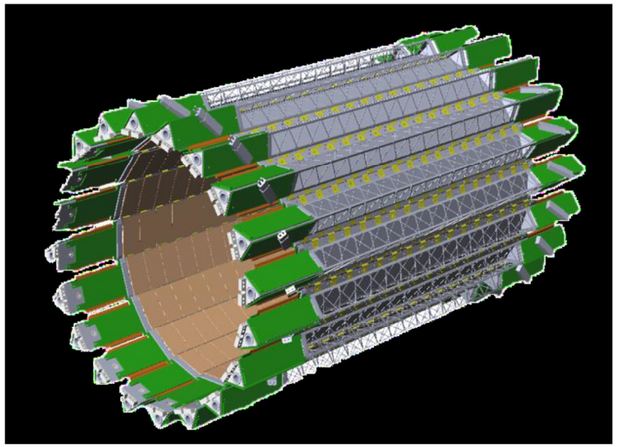


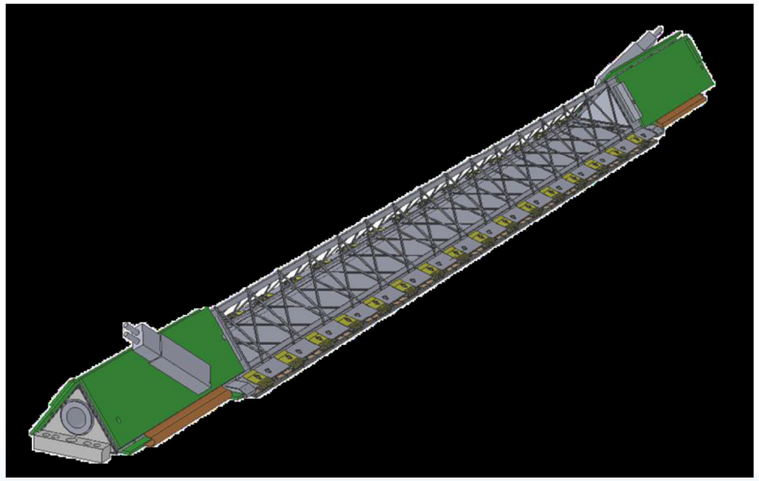


Silicon Strip Detector (SSD)





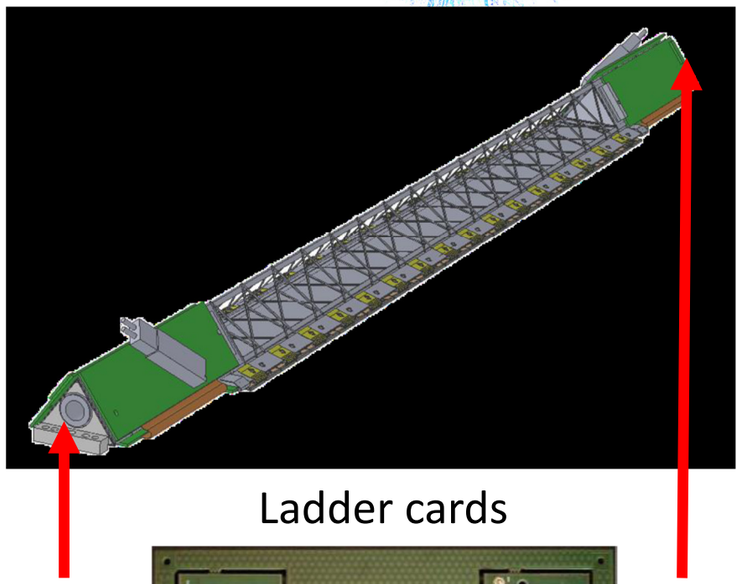




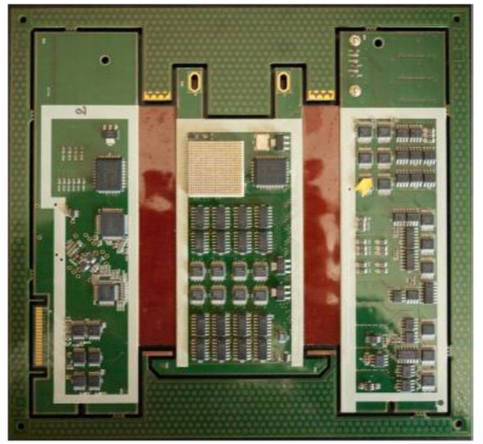
SSD radius	22 cm
SSD length	106 cm
$\|\eta\|$ coverage	< 1.2
Number of ladders	20
Number of wafers per ladder	16
Total number of wafers	320
Number of strips per wafer side	768
Number of sides per wafer	2
Total number of channels	491520
Silicon wafer size	75 × 42 mm
Silicon wafer sensitive size	73 × 40 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

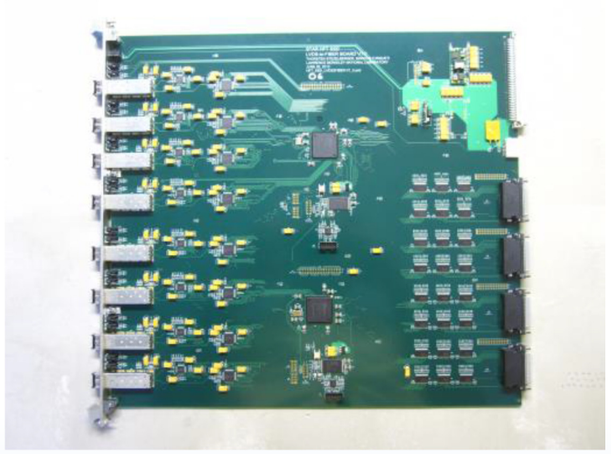
- Upgrade from 200 Hz to 1 kHz
- New
  - 40 ladder cards on detector
  - 5 RDO cards
  - 5 Fiber-to-LVDS boards



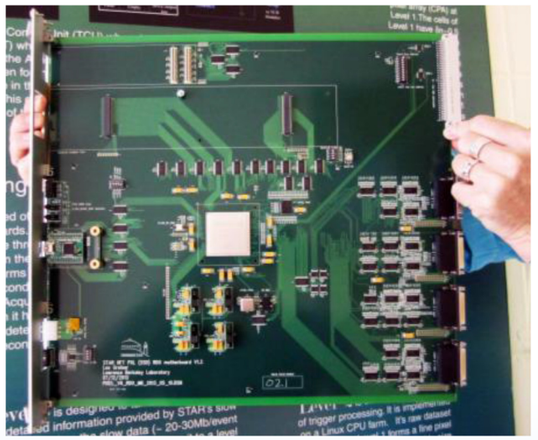
Ladder cards



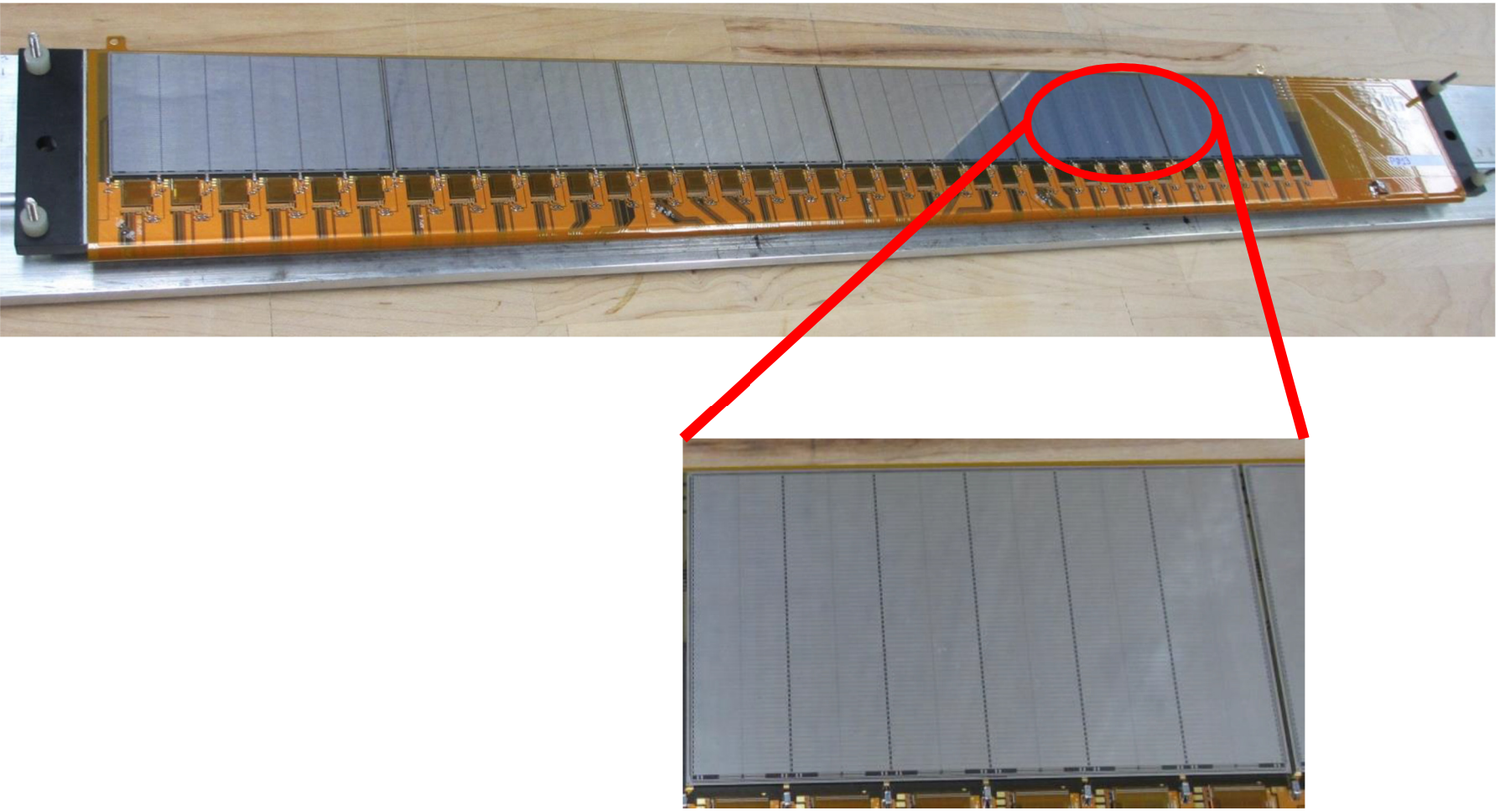
Fiber-to-LVDS



RDO board – adapted from PXL



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	$(12 \oplus 24\ \text{GeV}/p_T c)$
Radii	Layer 1 at 2.8 cm Layer 2 at 8 cm
Pixel size	$20.7\ \mu\text{m} \times 20.7\ \mu\text{m}$
Hit resolution	$3.7\ \mu\text{m}$
Position stability	6 μm RMS (20 μm envelope)
Radiation length	Layer 1: $X/X_0 < 0.4\%$ Layer 2: $X/X_0 < 0.5\%$
Number of pixels	~ 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	~ 1 day