Simulations for the Heavy Flavor Tracker at the STAR experiment

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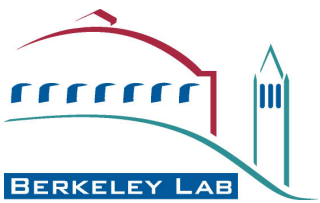
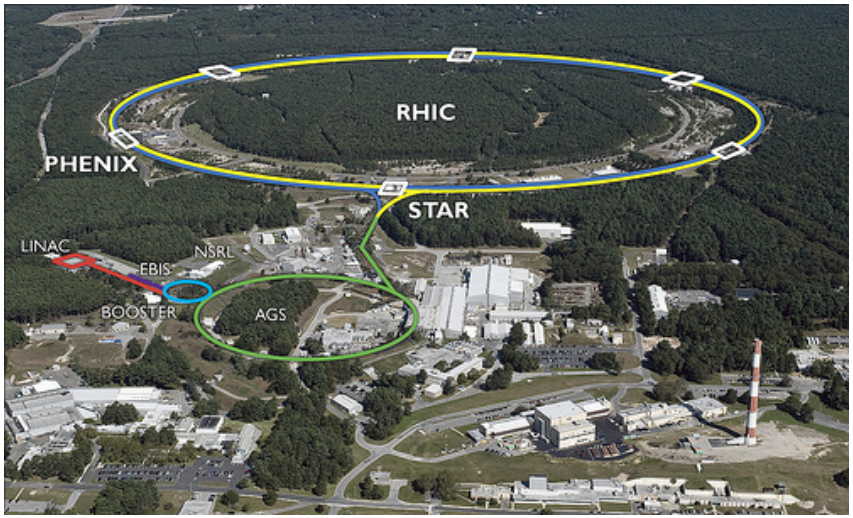
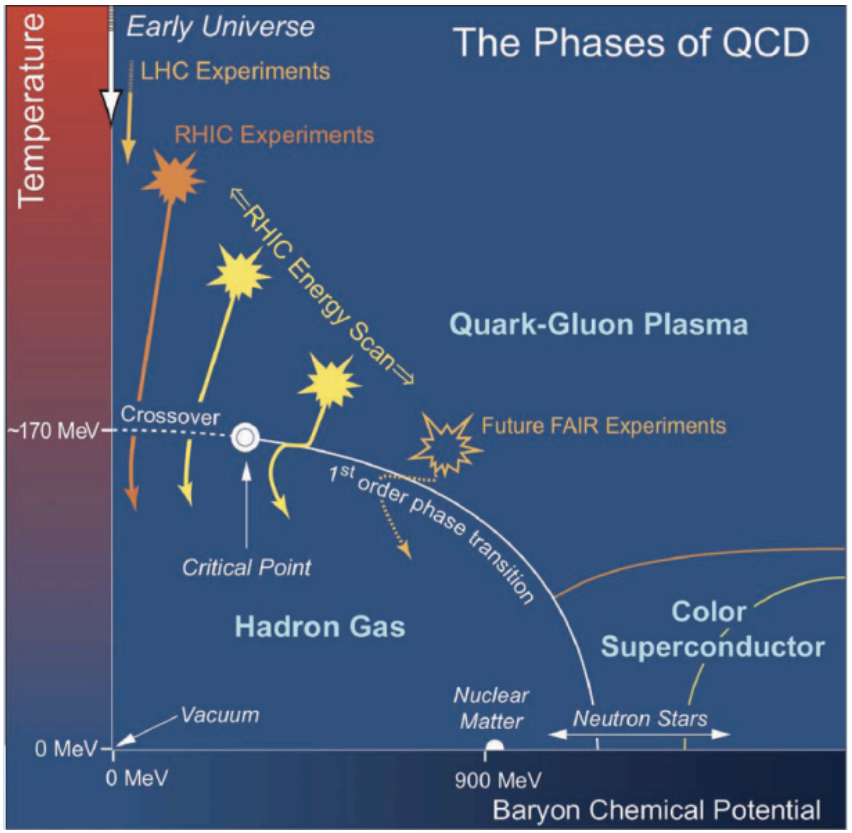


Experiment STAR at RHIC





- STAR experiment at RHIC
  - Heavy ion collider experiment
- Its main goal is to study the properties of Quark Gluon Plasma and the QCD phase diagram

Physics motivation

- Heavy flavor – Good probe to QGP
  - $m_{b,c} >> T_C, \Lambda_{QCD}, m_{u,d,s}$
  - Is produced in initial hard scatterings
- However very difficult to study
  - Low yields compared to light flavor particles
  - Large combinatorial background for open heavy flavor particles
- A precision secondary vertex finder is an important tool to study HF physics

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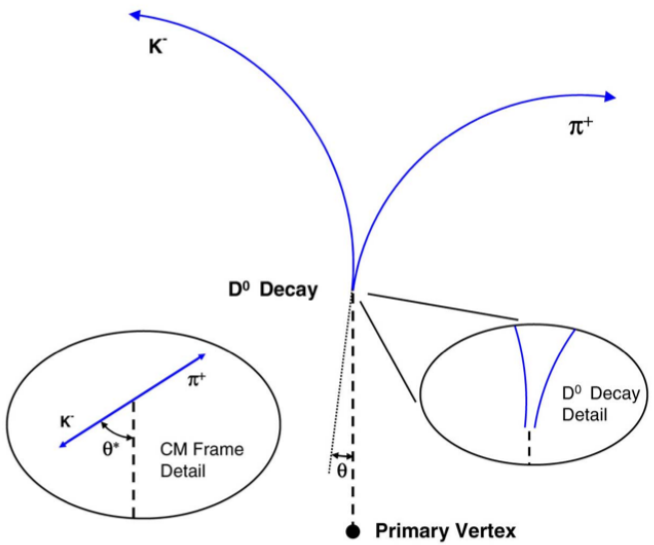
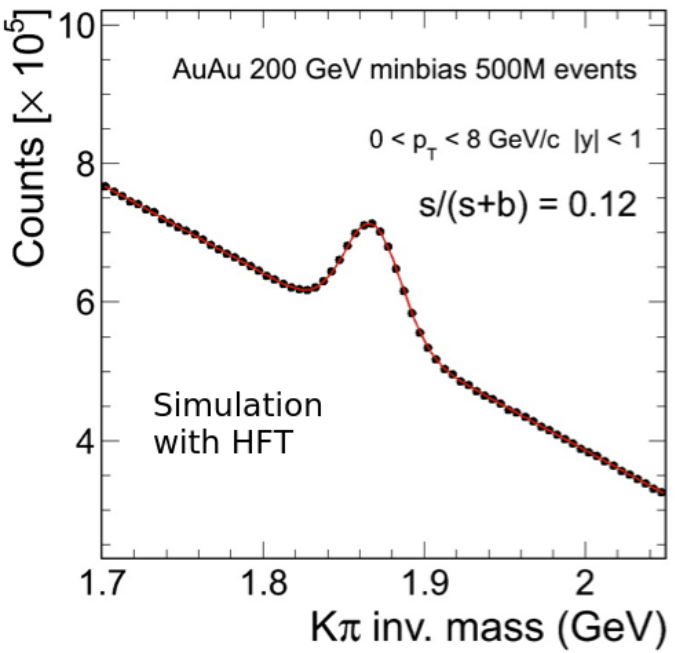
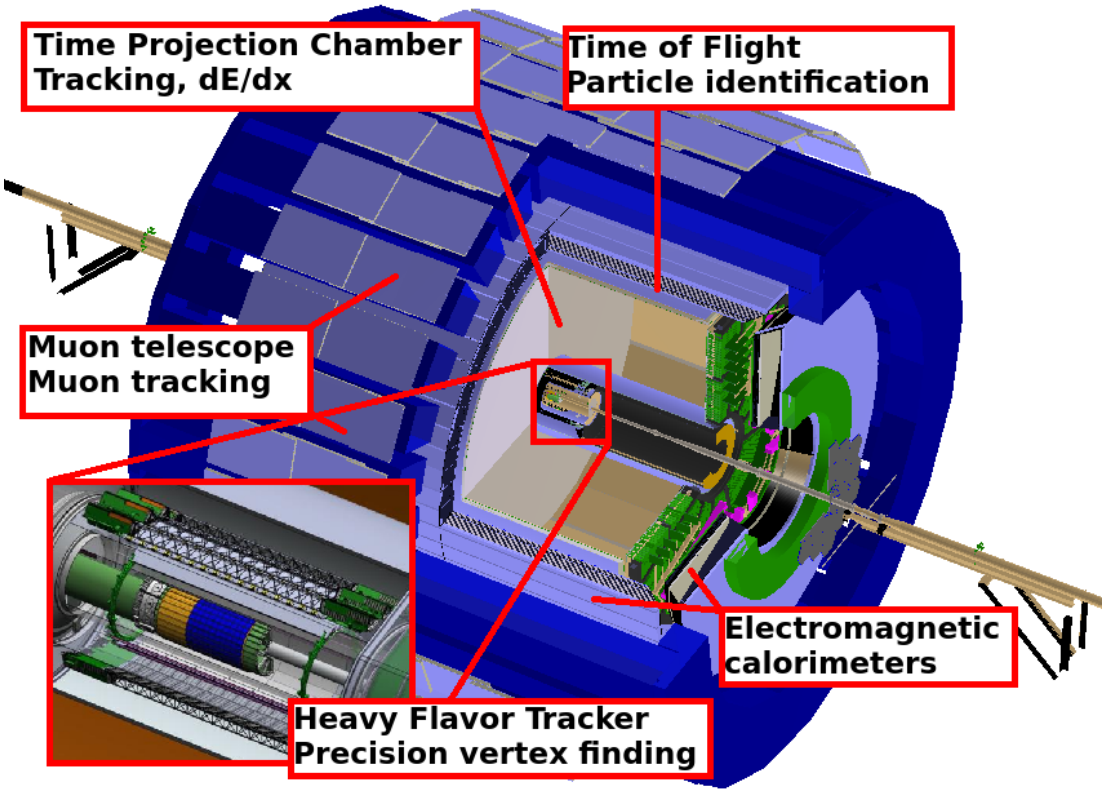
How Heavy Flavor Tracker helps

- Examples of displaced decay vertices
  - $D^0 \rightarrow K^- \pi^+$ BR $= 3.83$ % $c\tau \sim 120$ μm
  - $\Lambda_c^+ \rightarrow p\ K^- \pi^+$ BR $= 5.0$ % $c\tau \sim 60$ μm
  - B mesons $\rightarrow J/\psi + X$ or $e + X$ $c\tau \sim 500$ μm

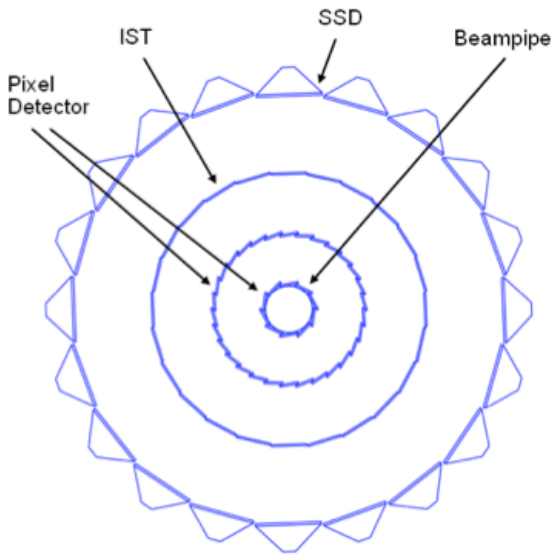




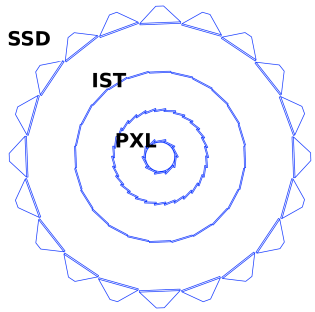
STAR Detector



- HFT: 4 layers of silicon detectors

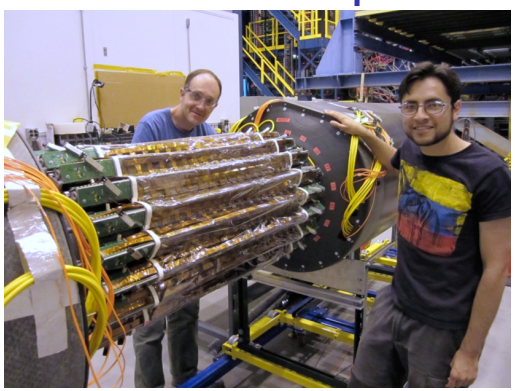


HFT design



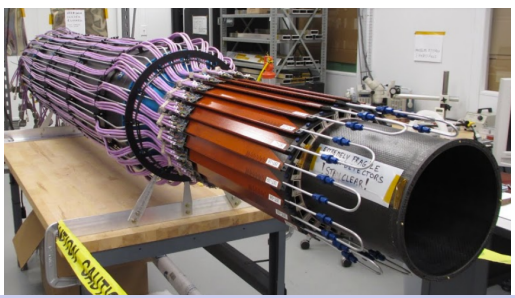
- The task of the SSD and IST is to guide the tracks from TPC to PXL

Silicon Strip Detector



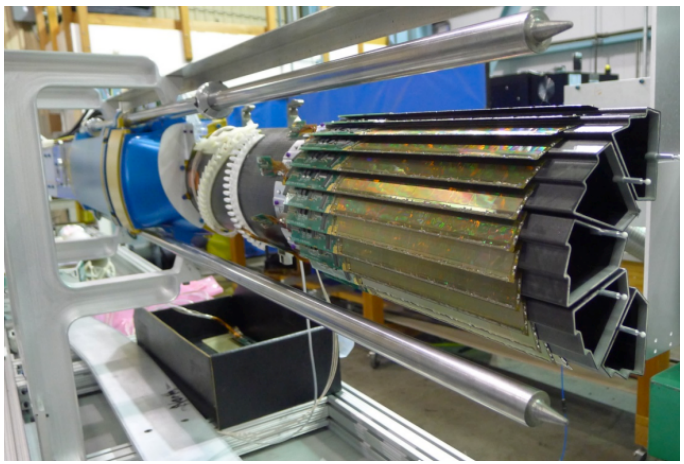
- Existing detector with faster electronics
- Double sided strip with 95 μm pitch
- $\sigma_{r\phi}$: 20 μm, σ_z: 740 μm

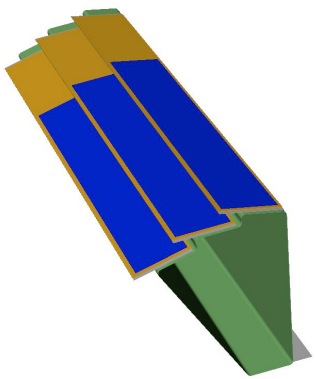
Intermediate Silicon Tracker



- Single sided double metal strip parallel to the beam pipe with pitch 600 μm $\times$ 6 mm
- $\sigma_{r\phi}$: 170 μm, σ_z: 1800 μm

Design of the Pixel detector





- First Monolithic Active Pixel Sensors (MAPS) used in a collider experiment
- 10 sectors $\times$ 4 ladders $\times$ (1 inner, 3 outer) $\times$ 10 sensors
- Light carbon fiber support
- Hit resolution in the wafer σ: 7.8 μm
- Radius: 8.2 and 2.8 cm (very close to the beam pipe)
- Very fast insertion mechanism
- 2 sets of pixels were made to replace damaged detector when needed

Monolithic Active Pixel Sensors

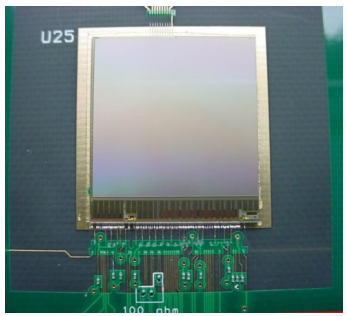
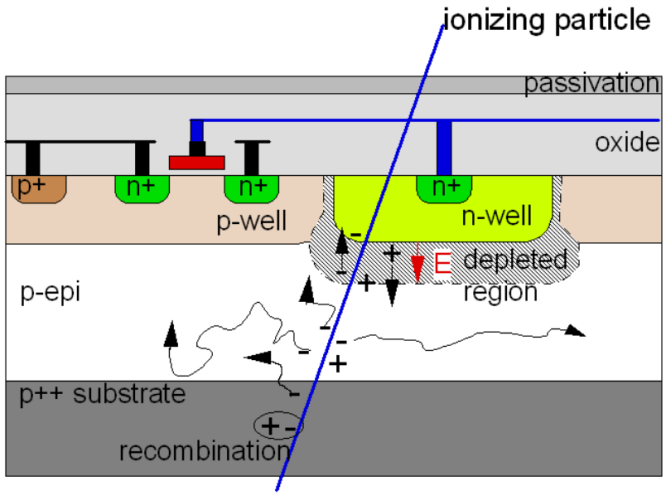
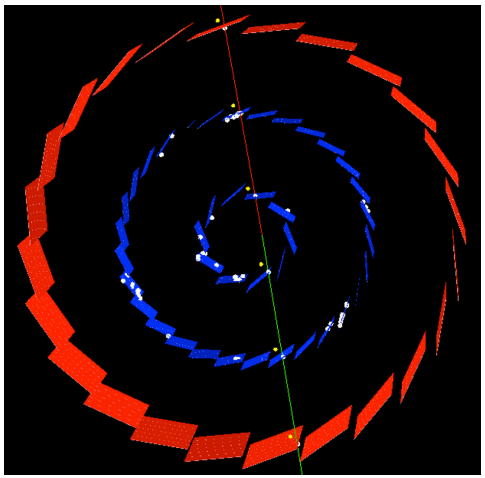


Photo of a sensor

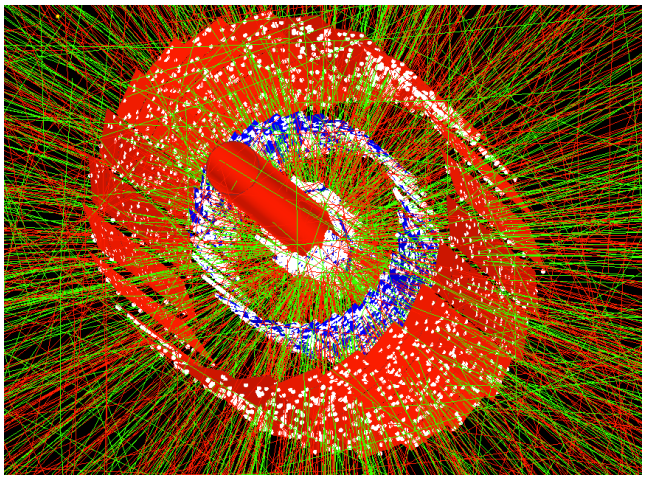


- Sensors 2×2 cm with 928×960 pixels
- Depleted region with p and n wells
- Epitaxial layer with low doping
- Electron cloud is created in epitaxial layer
- Usually multiple pixels pick up signal $\Rightarrow$ better resolution

HFT status



a cosmic event

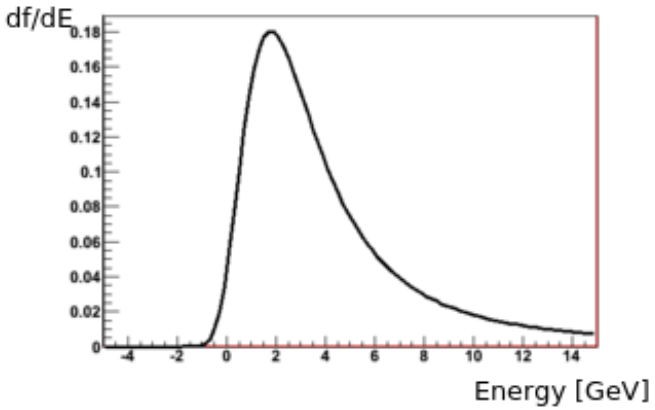


a Au+Au 200 GeV event

- The whole HFT has been installed for RHIC 2014 running
- Cosmic data for calibration of the detector, 14.5 GeV and 200 GeV Au + Au
- SSD under commissioning (its role taken by the IST)
- HFT is running as expected with pointing resolution for the reconstructed vertices $\sim$ 30 μm

Pixel simulations

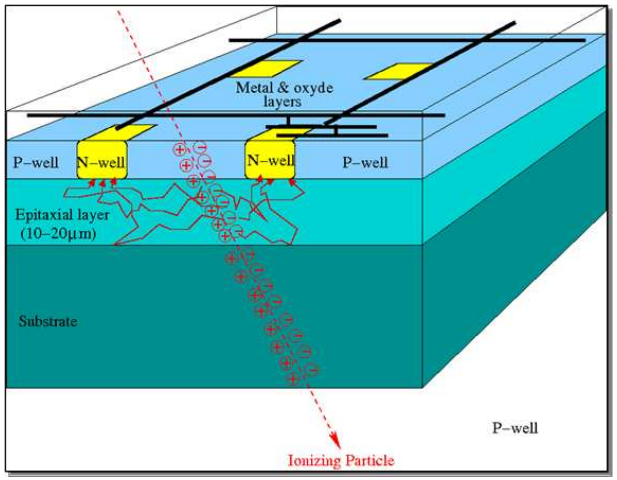
- A part of every analysis is an efficiency study
- To produce them, detailed simulations are needed
- Simulation of energy deposition in MAPS is not trivial (GEANT does not describe thin silicon well)
- The energy distribution can be approximated by Landau Distribution

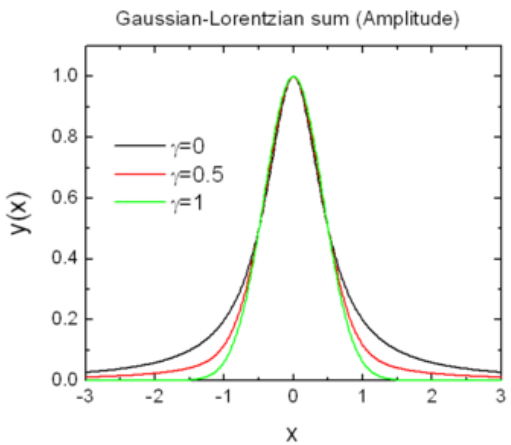


Landau distribution

Simulation tool DIGMAPS

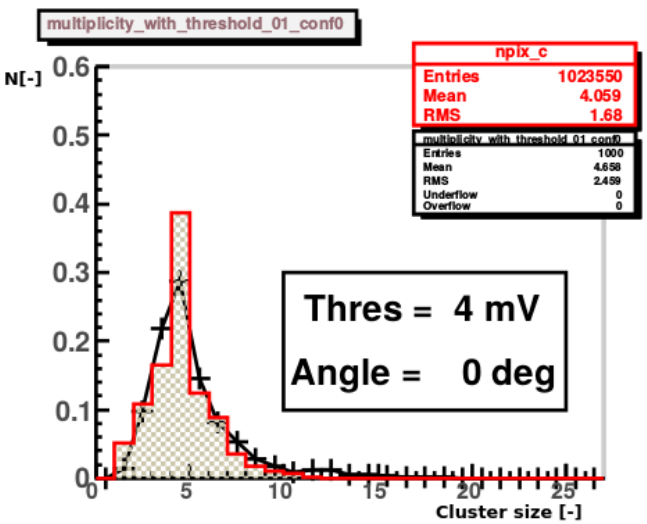
- Simulation tool DIGMAPS was developed at IPHC – CNRS – Université de Strasbourg – A. Besson et Al.
- It describes the behavior of the pixel sensors
  1. Particle deposits energy in the epitaxial layer (Landau distribution)
  2. An electron cloud is created
  3. Collected charge (vs distance) is simulated by sum of Lorentzian and Gaussian
  4. ADC threshold is applied (low electron yields are not used)





Sum of Lorentzian and Gaussian

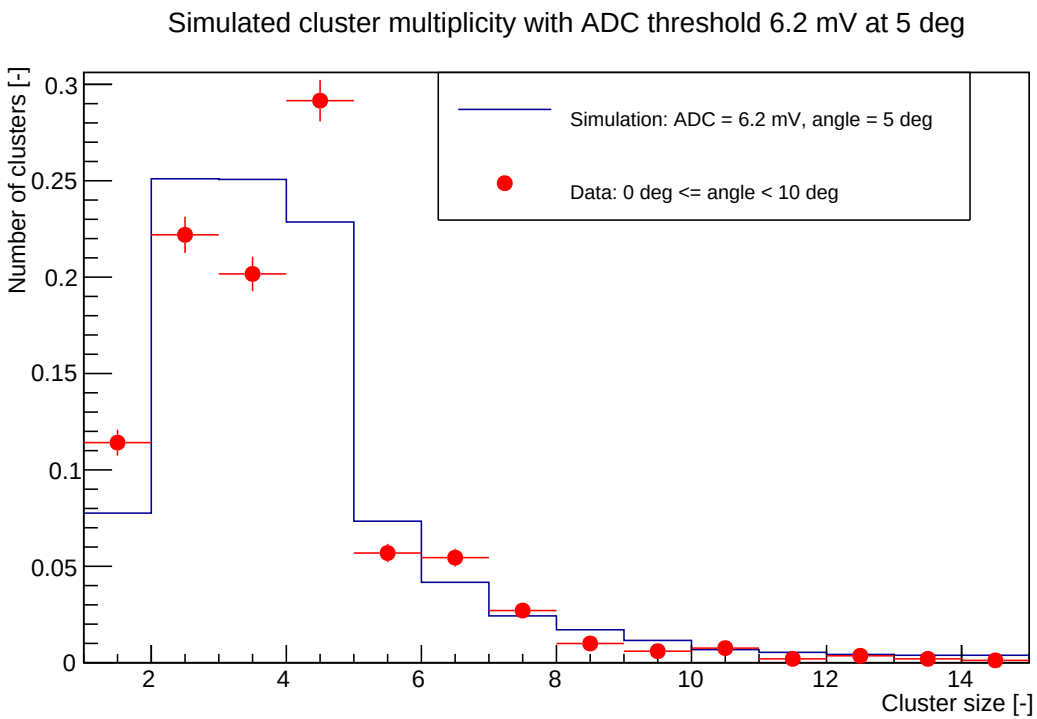
Comparison of the simulations to the test beam data



- Electron cloud created by an ionizing particle usually fires more than one pixel
- The best way to compare simulation to the measured data: number of pixels fired (cluster multiplicity)
- Test beam in Desy (e^+, e^- beam) in 2012 by IPHC
- DIGMAPS was tuned on this data by the Strasbourg group

Cosmic data from 2014

- Test if the simulation is accurate enough with the tuning from test beam
- Done for several angles
- Signal had to be cleared from the noise (signal to noise $\sim 1/400$) without the use of TPC
- Simulations describe data well enough



Summary

- State-of-art MAPS technology has been used for the first time in a collider experiment
- All three subdetectors (PXL, SDD, IST) are successfully installed in STAR
- HFT is fully functional and taking data
- Slow simulator has been completed
- It describes cosmic data well
- More thorough comparison with Au+Au 200 GeV data is being currently produced

Thank you for your attention