Rare kaon signals from Au+Au collisions at HADES

ASY-EOS Workshop 2012

Siracusa, Italy
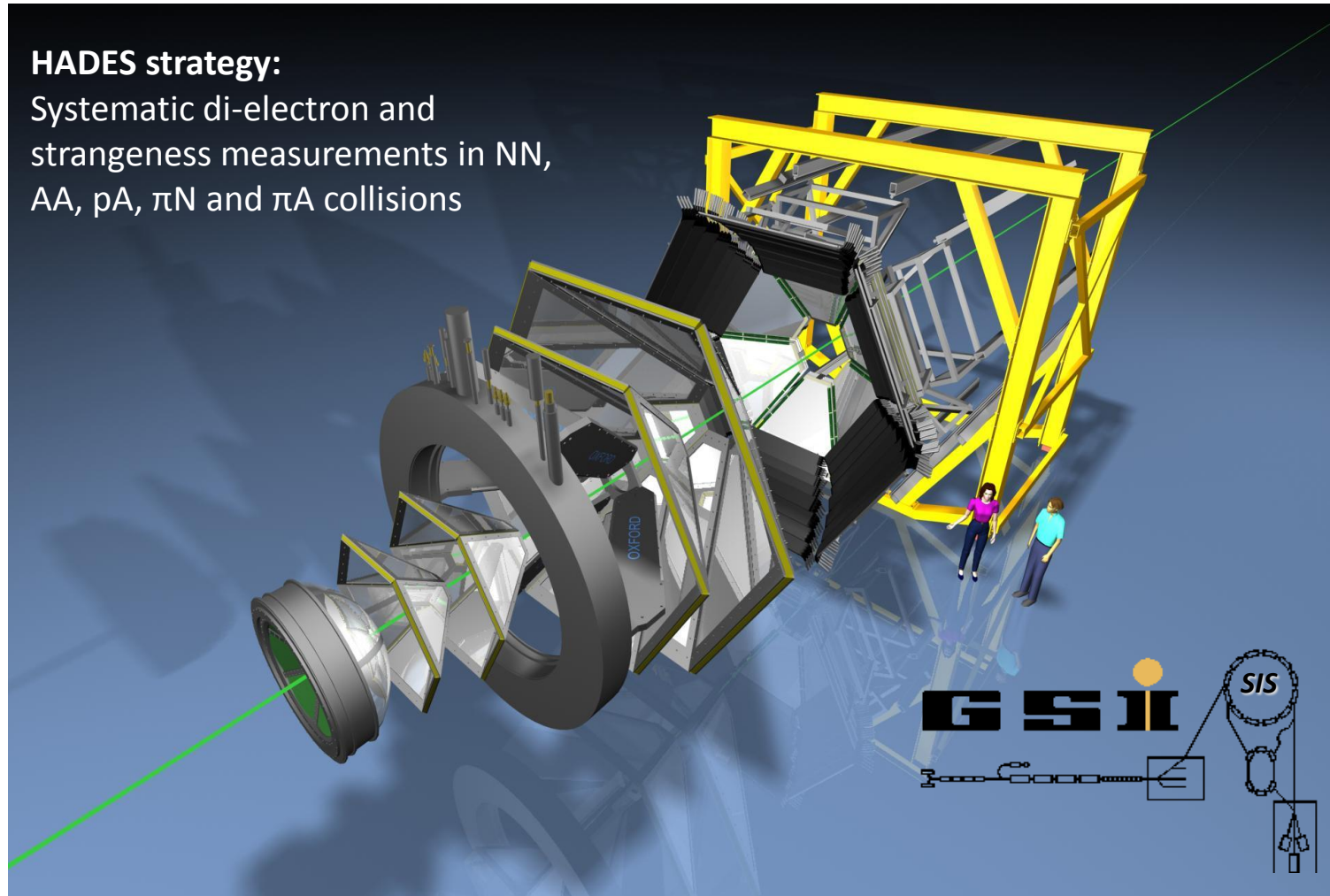
Katharina Gill for the HADES Collaboration

Goethe-Universität Frankfurt
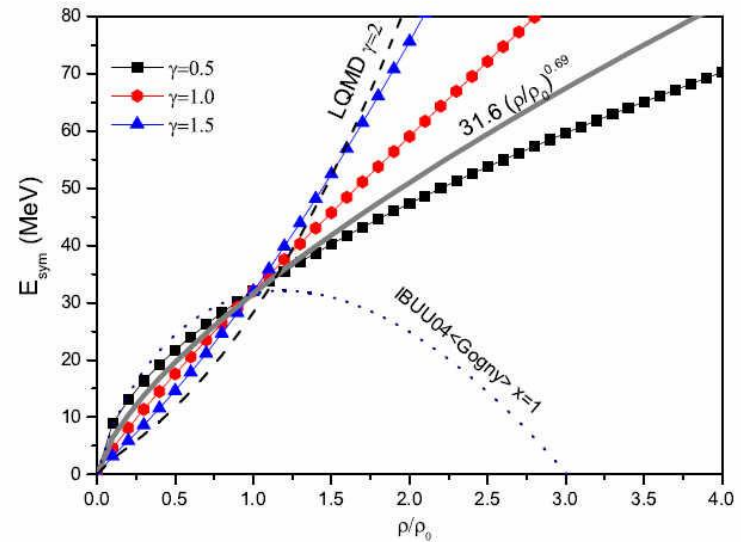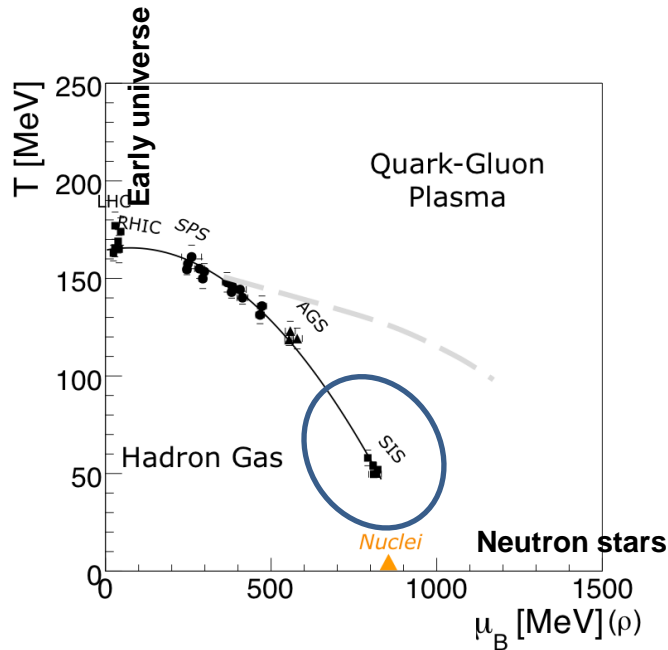
High Acceptance Di-Electron Spectrometer

HADES strategy:
Systematic di-electron and strangeness measurements in NN, AA, pA, πN and πA collisions

Probing the Symmetry Energy with HADES

Trautmann W., Wolter H.; Int.J.Mod.Phys. E21 (2012) 1230003

HIC at SIS energies

- Densities: $\rho_{max}/\rho_0 \cong$ 2-3
- Temperature: T < 100 MeV
- τ ~10 fm/c

Access to EOS and E_{sym} with HIC

- Isospin asymmetric system (Au+Au)
- Subthreshold production of kaons
- Measurement of ratio K^+/K^0

High Acceptance Di-Electron Spectrometer

- Beams provided by SIS18: p, π, nuclei
- Hadron and lepton identification
- Full azimuthal coverage

Detector components
- RICH and SHOWER detector for lepton identification
- Multi-wire drift chambers (MDC) with magnetic field for momentum measurement and tracking information
- Time of flight detectors (TOF, RPC) for timing and energy loss information

Replaced by RPC
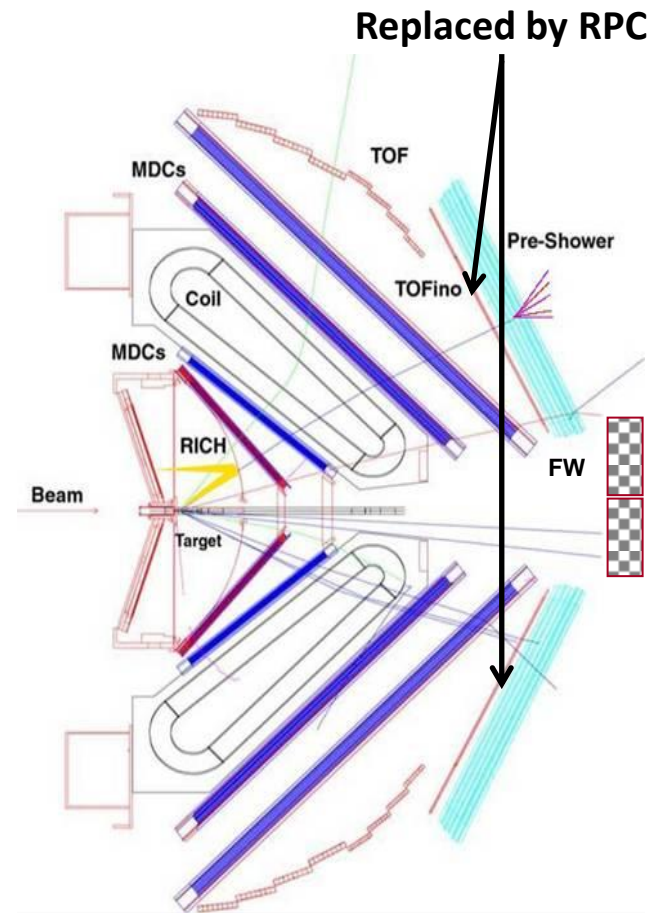
Upgrade for Au Au Run – RPC System

Resistive Plate Chambers (RPCs)
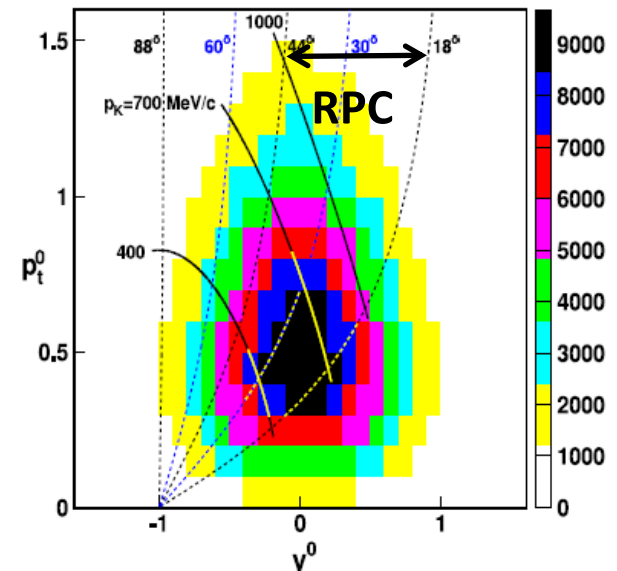

RPC
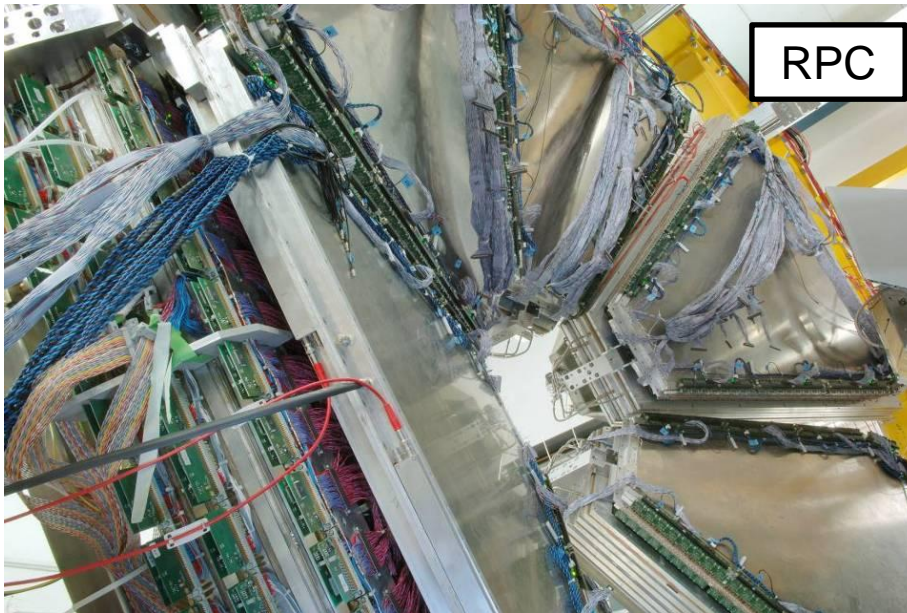
D. Belver et al . NIM A602(2008) 687, 788
E. Blanco et al. NIM A602(2008) 691
Leading institute: Coimbra, Portugal

+ Data acquisition Update

K⁻ acceptance (nice rapidity coverage!)
RPC: 18° - 45°

Full-system test results:

- $\sigma_t \leq 100$ ps
- $\sigma_x \leq 8$ mm
- $\varepsilon \sim 97\%$

Au Au Run @ 1.23 AGeV, April 2012

HADES DAQ performance during AuAu beam time

- 557 hours Au beam on Au target

- $(1.2 - 1.5) \times 10^6$ ions per second

- 8 kHz trigger rate

- 200 MByte/s data rate

- 7.3×10^9 events →**140 TByte of data**

- Beam energy 1.23 AGeV

- Segmented Au target

- Trigger on multiplicity in TOF ≥ 20 → $b_{max} \approx 9$ fm

Analysis based on the ONLINE data →
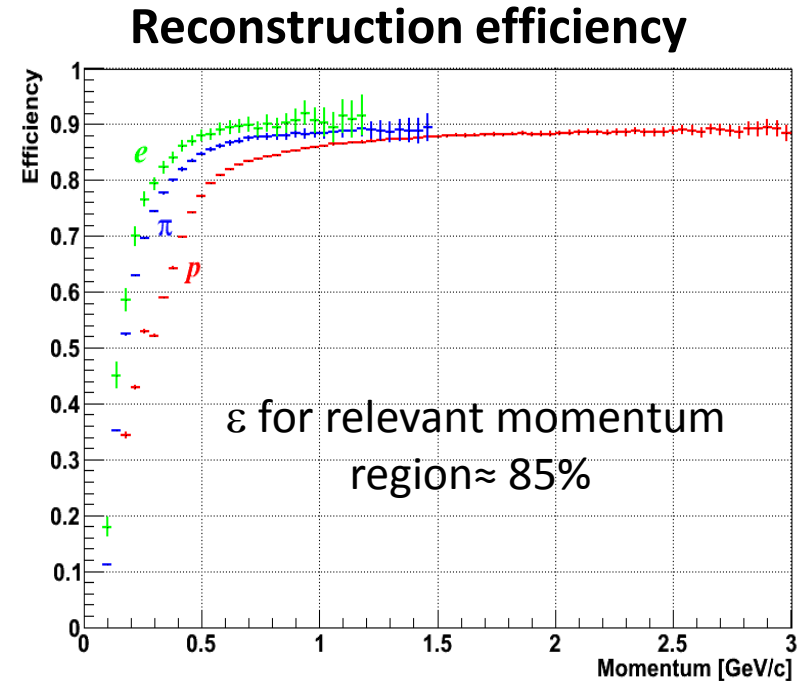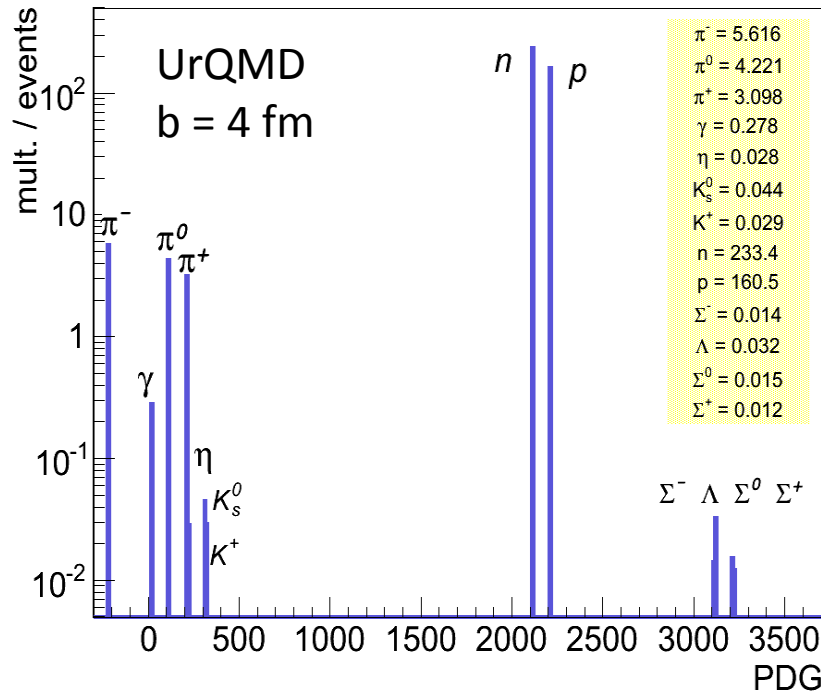**preliminary detector calibration and alignment**
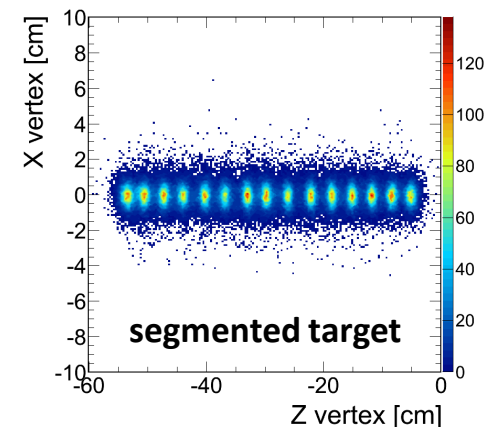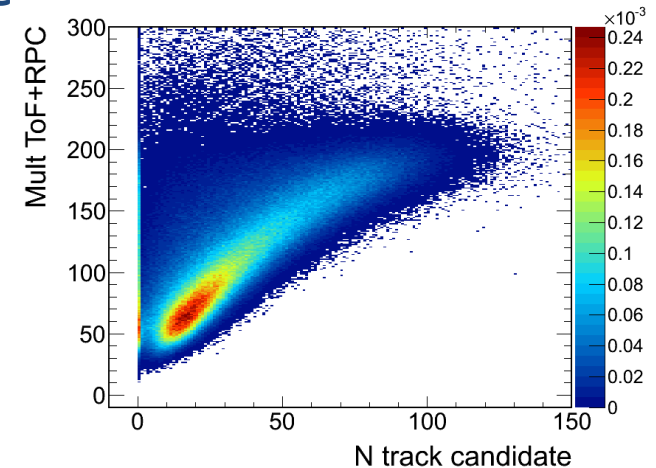
Tracking: The Challenge
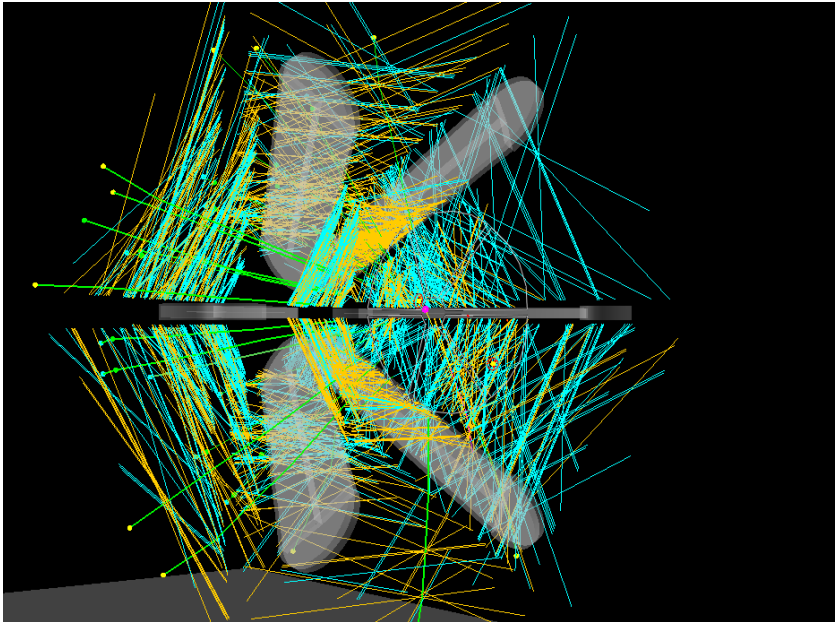
cyan: all fired MDC wires
orange: wires, used by track segment fitter

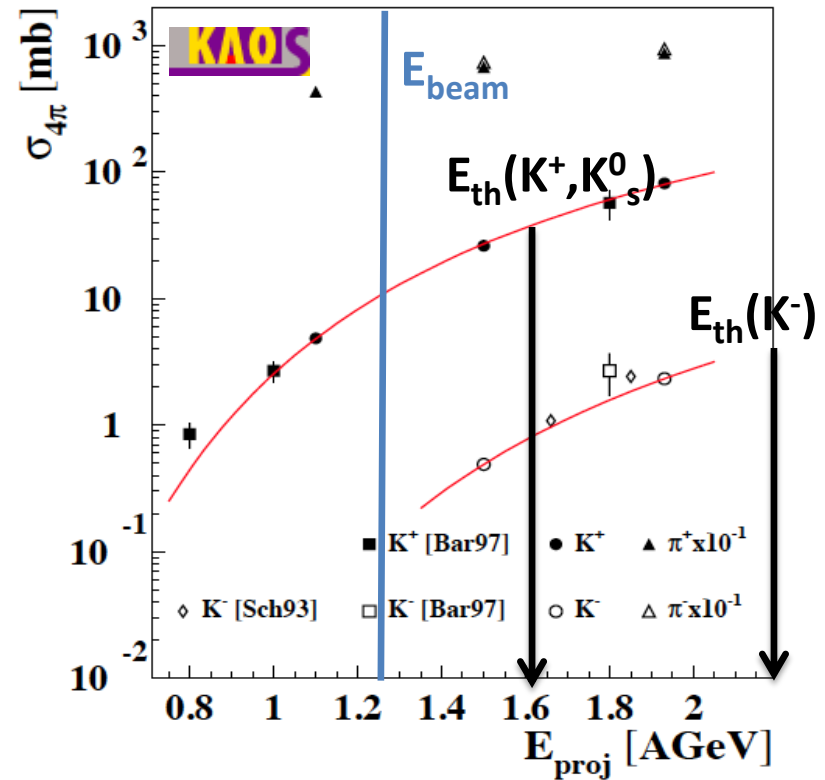**Reconstruction efficiency**

ε for relevant momentum
region≈ 85%

- Up to 140 charged particles in acceptance
- Double hit probability < 10% for MDCs
- Tracking issue: Wires introduce long range correlations between particle tracks

Expected Kaon Multiplicities

UrQMD
b = 4 fm

π^-	= 5.616
π^0	= 4.221
π^+	= 3.098
γ	= 0.278
η	= 0.028
K^0_s	= 0.044
K^+	= 0.029
n	= 233.4
p	= 160.5
Σ^-	= 0.014
Λ	= 0.032
Σ^0	= 0.015
Σ^+	= 0.012

Kaon multiplicity in Au+Au collisions
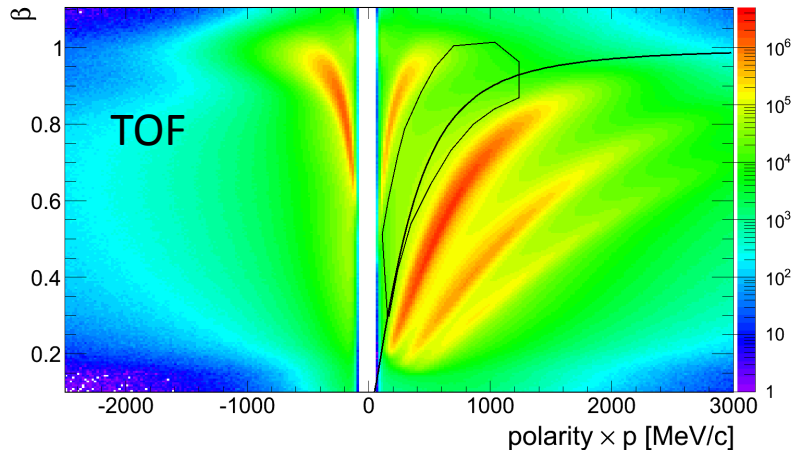
- K^+ = 0.029
- $K^- \approx K^+ / 100$
- K^0_s = 0.044
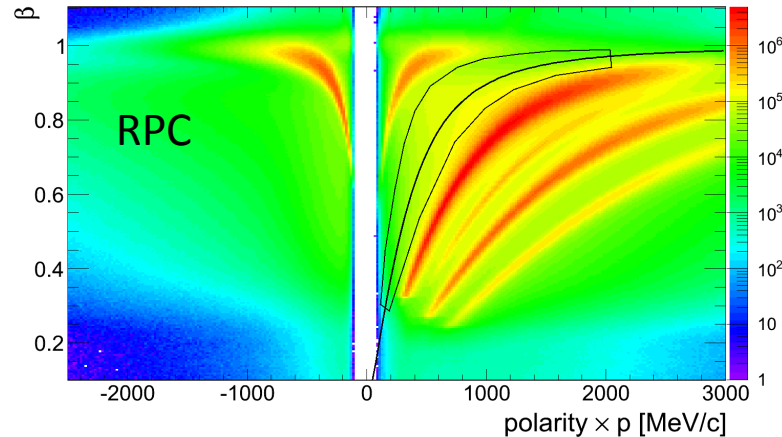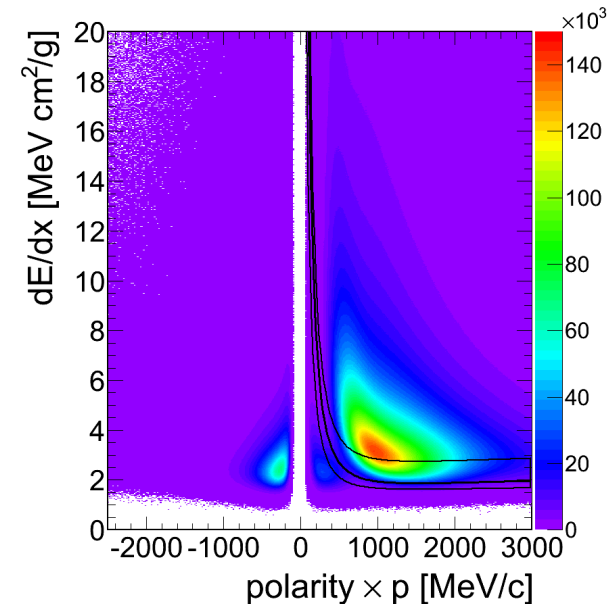

Florian Uhlig, PhD

K⁺ Analysis

Particle Identification

Particle identification via

- Velocity distribution (left)
- Energy loss in MDC distribution (right)
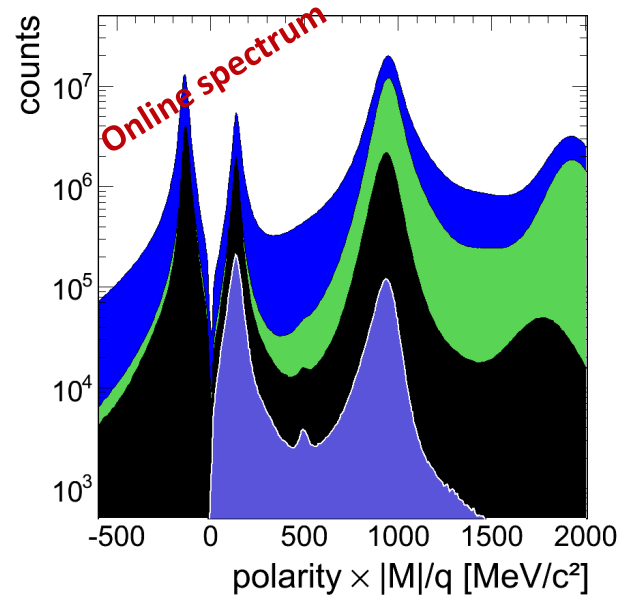- Cut on track quality parameters

- Black lines: β vs. momentum (left) and Bethe-Bloch (right) function
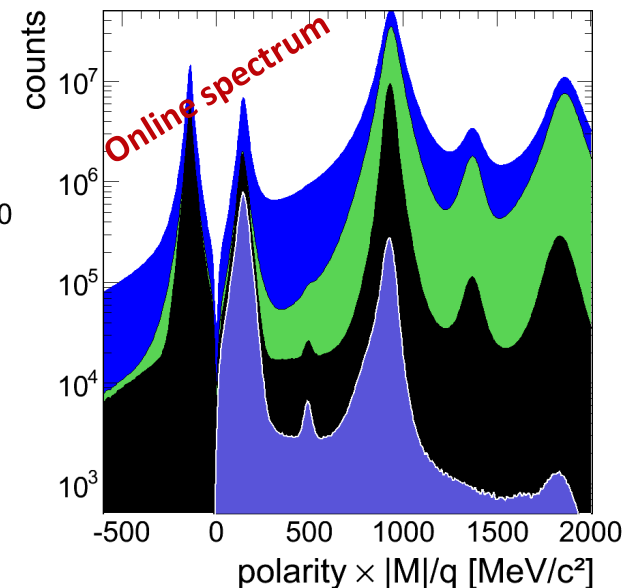- Cuts (black curves) are choosen to optimize S/B ratio and significance

Mass Spectrum in RPC and TOF Regions

- **Blue: all candidates**

- **Green**: additional **track quality cut**

- **Black**: additional **momentum cut**
  TOF: p < 750 MeV/c,
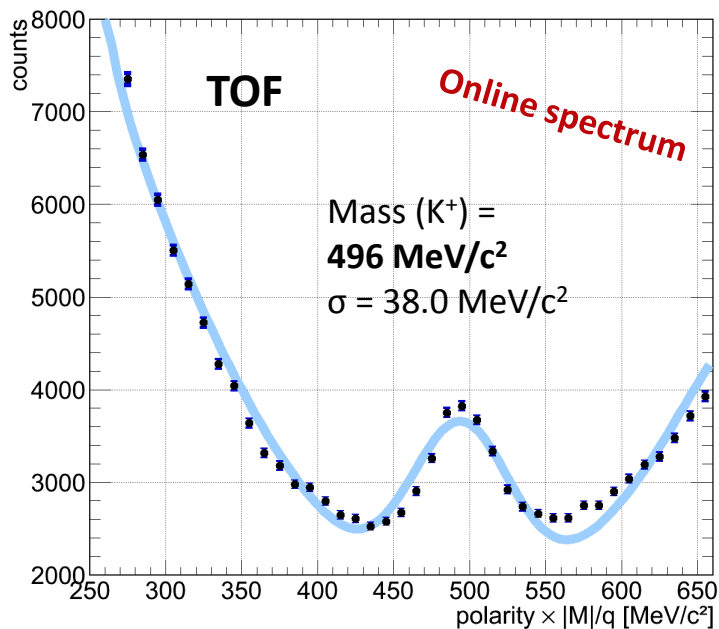 RPC: p < 1000 MeV/c

- **Purple**: additional **dE/dx cut in MDC**

TOF region, sector 5

RPC region, sector 5

Final K⁺ Peak in RPC and TOF

TOF — Online spectrum

Mass (K⁺) = **496 MeV/c²**
σ = 38.0 MeV/c²

TOF, sector 5

RPC — Online spectrum

Mass (K⁺) = **491 MeV/c²**
σ = 30 MeV/c²

RPC, sector 5

→ **~ 2100 K⁺/hour**
→ **~ 0.002 K⁺/event** (**data**)
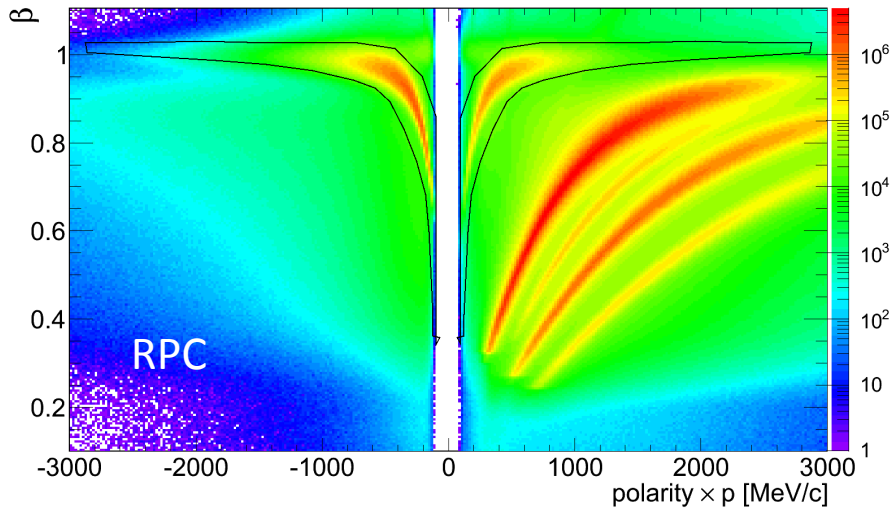Expected in **UrQMD 4π: 0.029**

→ **K⁺ reconstruction efficiency ≈ 10%**
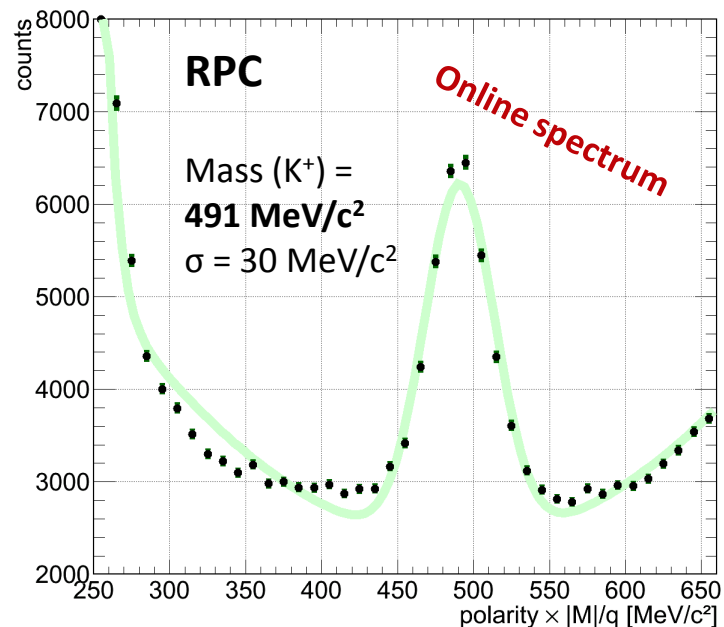
K⁰$_S$ Analysis

- Decay channels:

$$K_S^0 \rightarrow \pi^+ + \pi^-,\ 69.2\%$$
$$K_S^0 \rightarrow \pi^0 + \pi^0,\ 30.7\%$$

- Reconstruction via first channel → combination of identified π⁺ and π⁻

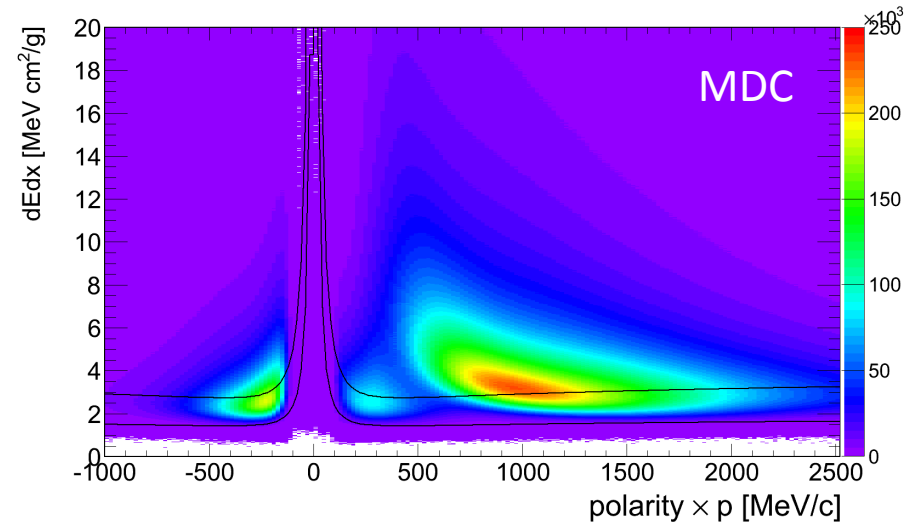- Cuts on vertex parameters for identification of π⁺ and π⁻ originate from K⁰$_S$ decay

Pion Identification Cuts

RPC

Identification via

- Velocity (left) and energy loss in MDC (right) distributions
- $|p| < 1000$ MeV/c
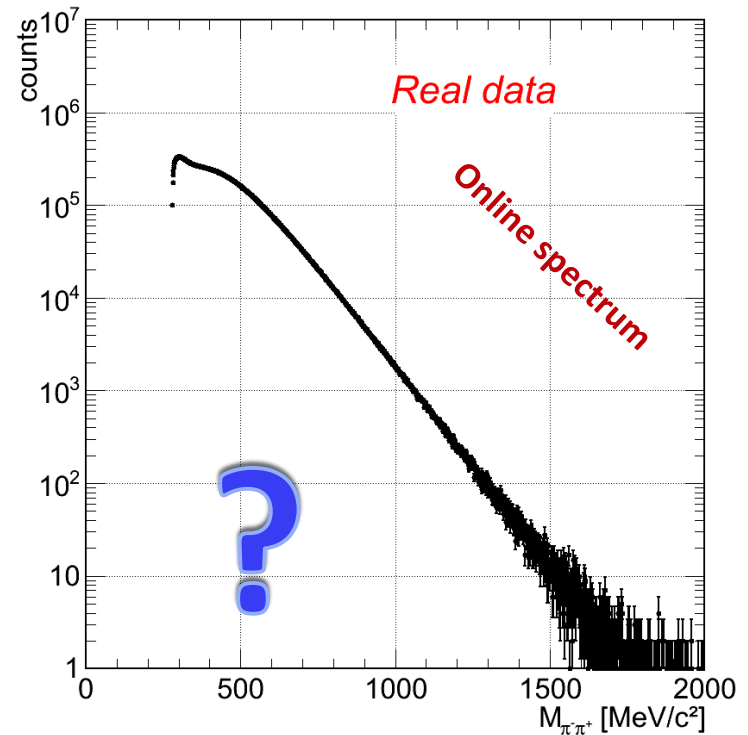- $m (\pi^+) < 300$ MeV/c^2
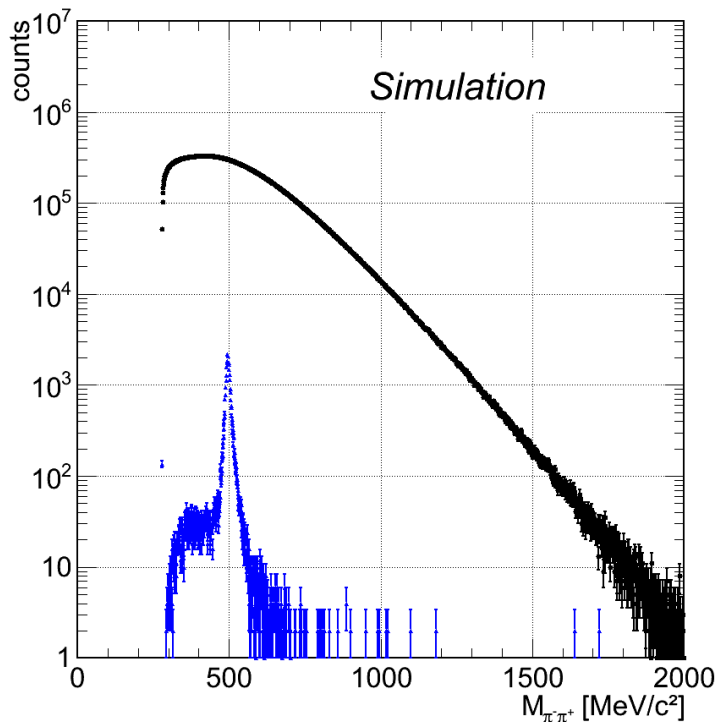
Cut on track quality parameters

- $\chi^2_{RK} < 750$
- $0 < \chi^2_{In}$
- MetaQa < 2.0

MDC

Invariant mass of π⁺ and π⁻

- Invariant mass of mother particle with daughter particles 1 (m_1, p_1) and 2 (m_2, p_2) with relative angle θ_{12}

$$m_{inv} = \sqrt{\left(m_1^2 + m_2^2\right) + 2 \cdot \left(\sqrt{m_1^2 + \left(\vec{p}_1 \cdot c^2\right)}\sqrt{m_2^2 + \left(\vec{p}_2 \cdot c^2\right)} - |\vec{p}_1||\vec{p}_2|c^2 \cos\theta_{12}\right)}$$

- Invariant mass of π⁺ and π⁻ for **K⁰ₛ candidates** (**black**) and **„true" K⁰ₛ** (**blue, simulation**)
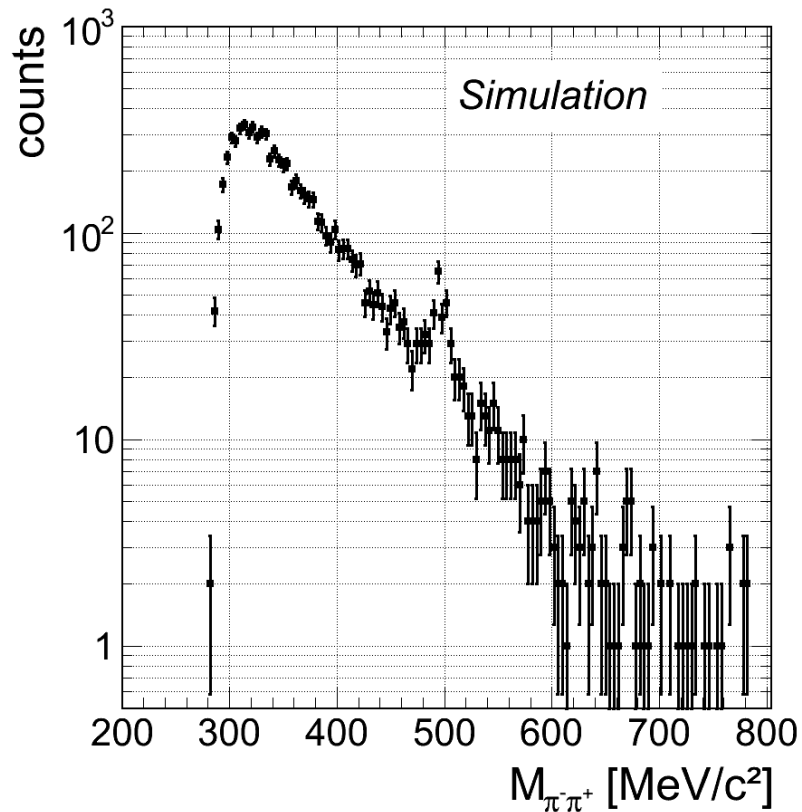
Vertex Cuts

Decay topology

- Distance decay vertex from event vertex (**DistX**)

- Minimum distance of π Track to event vertex (**DistA, DistB**)

- Minimum distance of K^0_s Track to event vertex (**DistC**)

- Minimum distance between two π tracks (**MinTrackDist**)

- Angle between π tracks (**Opening angle**)
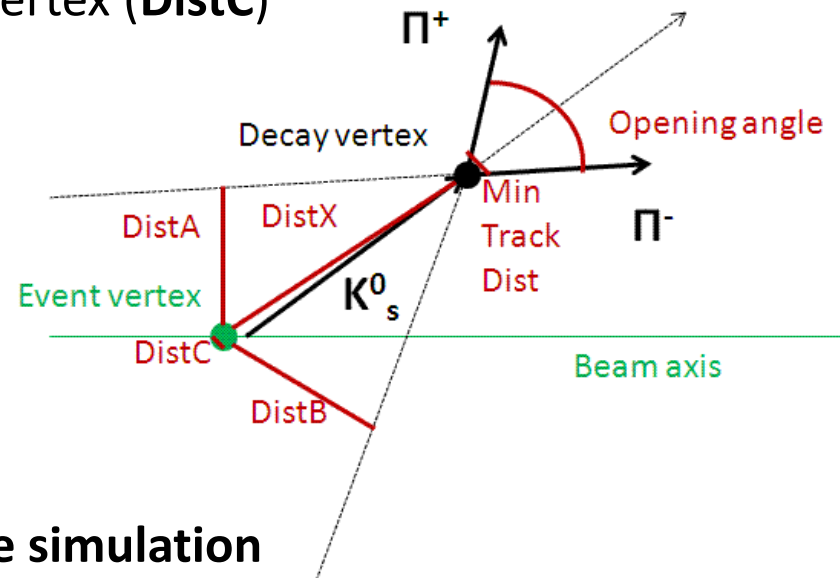
Optimized for ratio of S/B for K^0_s peak in the simulation

Invariant Mass after all Vertex Cuts

Invariant mass spectra for combination of π+π- pairs after all vertex cuts
for simulation (left) and real data (right)
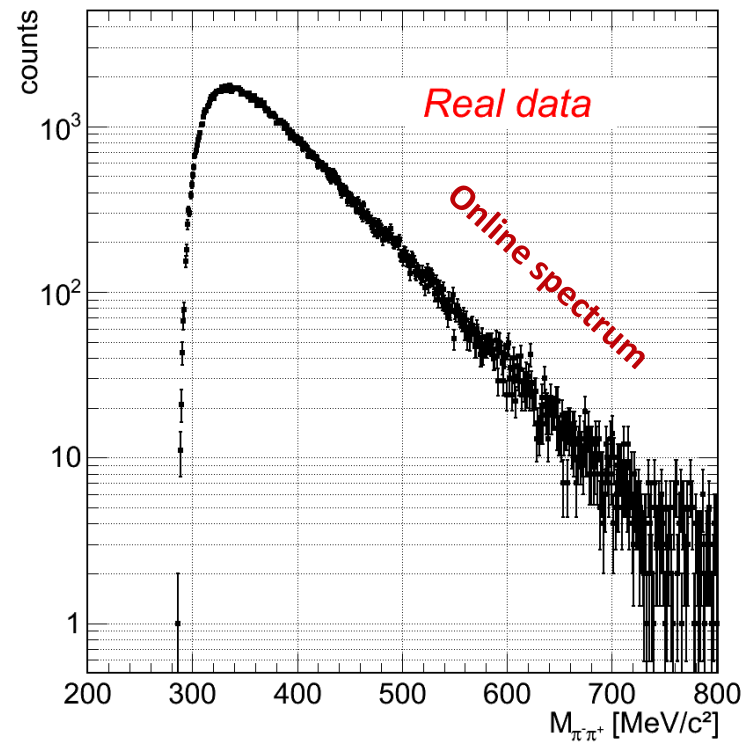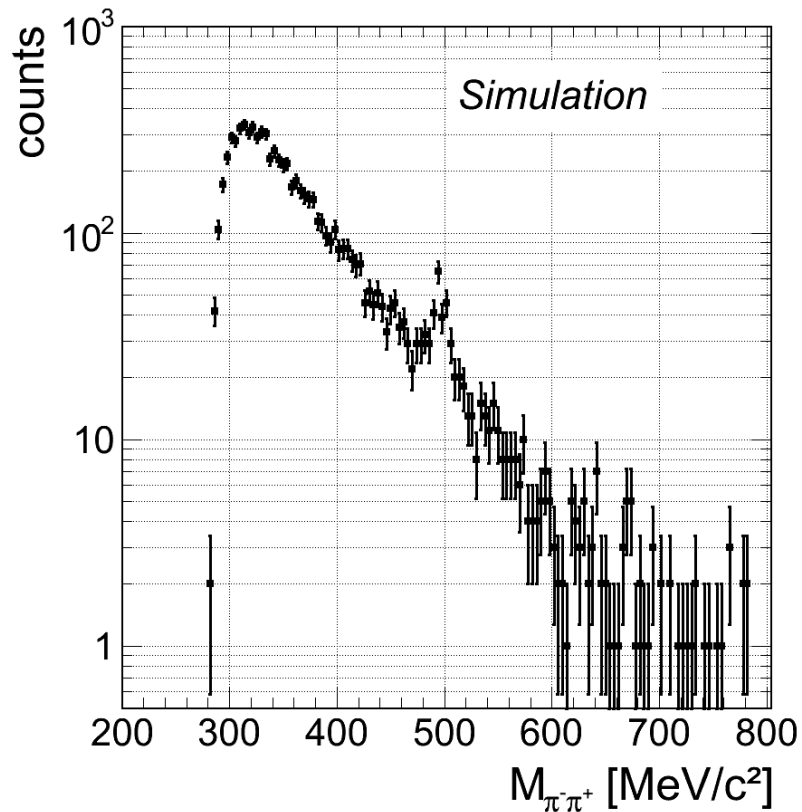
Invariant Mass after all Vertex Cuts

Invariant mass spectra for combination of π⁺π⁻ pairs after all vertex cuts
for simulation (left) and real data (right)

Invariant Mass after all Vertex Cuts

Simulation

counts vs $M_{\pi^-\pi^+}$ [MeV/c²]

Rome wasn't built in a day :-)
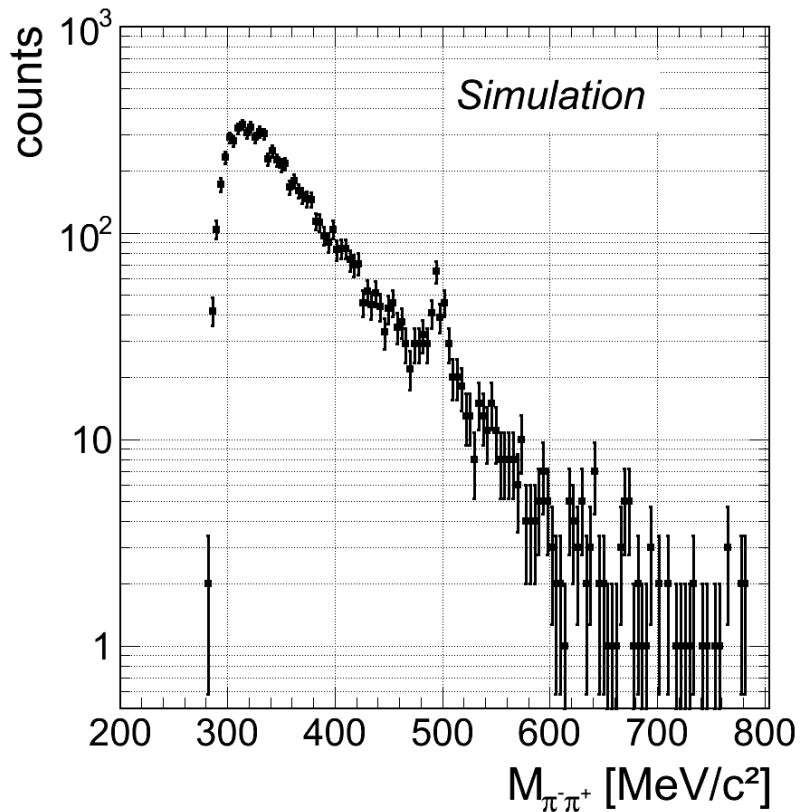
Invariant mass spectra for combination of $\pi^+\pi^-$ pairs after all vertex cuts
for simulation (left) and real data (right)

Summary and Outlook

Summary

- 7.3×10^9 events recorded (April 2012)

- We expect:

  - $N_{max} (K^+) \approx 14 \times 10^6$ K^+ (estimated from real data)
  - $N_{max} (K^0_s) \approx 2.5 \times 10^6$ (estimated from simulated data)

- Better performance after full detector calibration, alignment and optimized track reconstruction
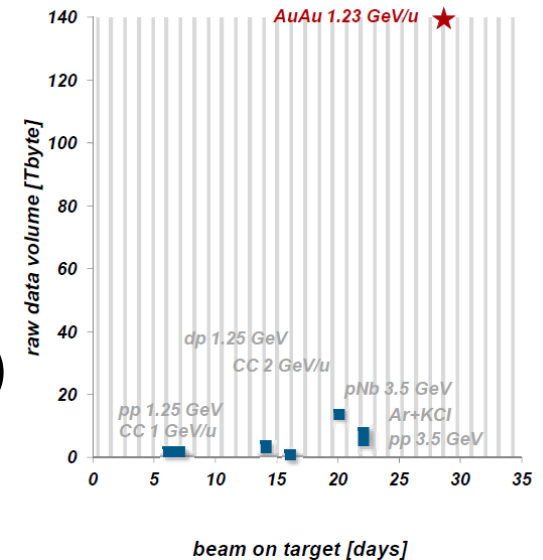
Outlook

- Analysis of lepton pairs and complete (multi-)strange particle production

- … and of cause **ratio of K⁺/K⁰**

The HADES Collaboration

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17 institutions
> 150 members