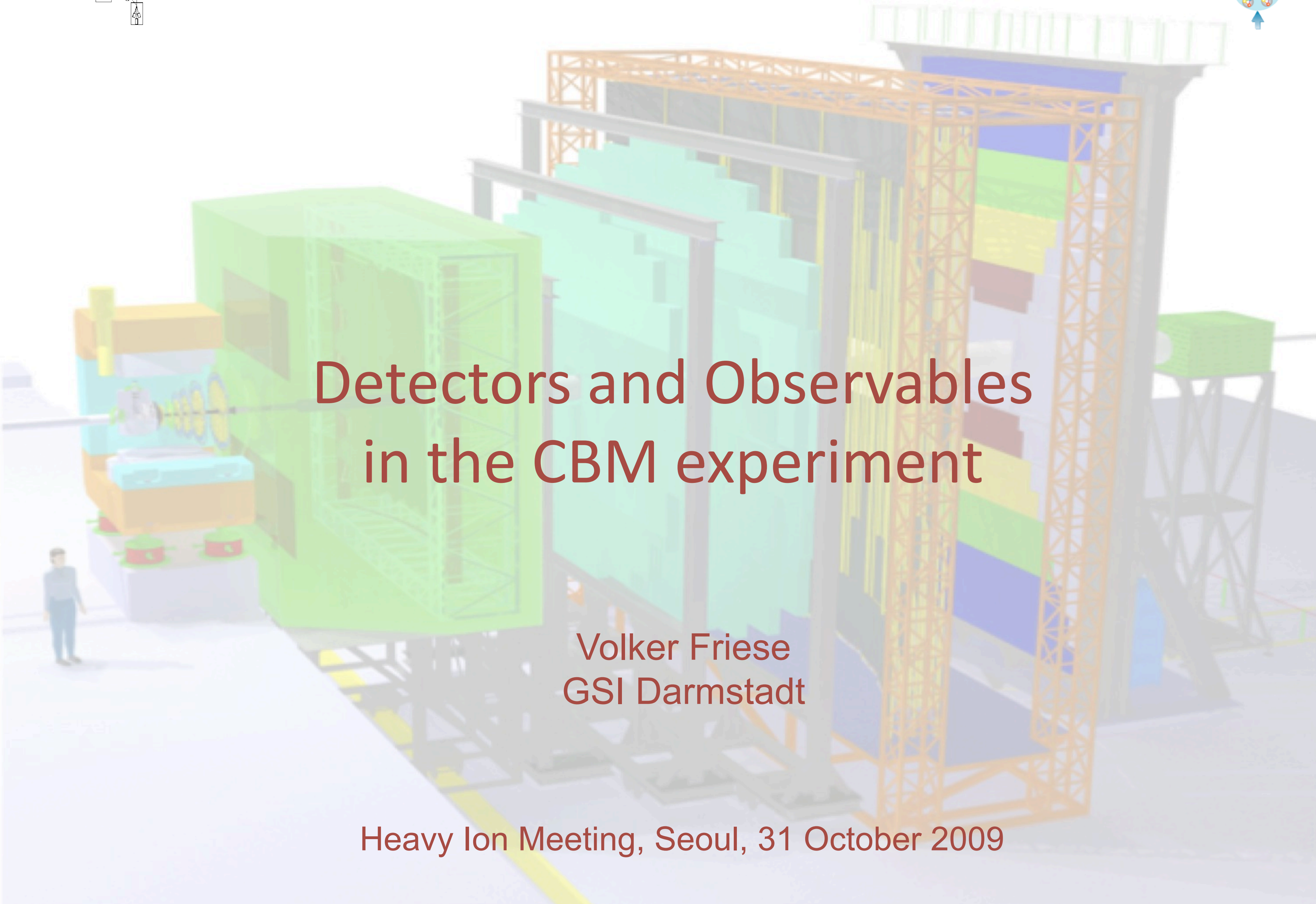


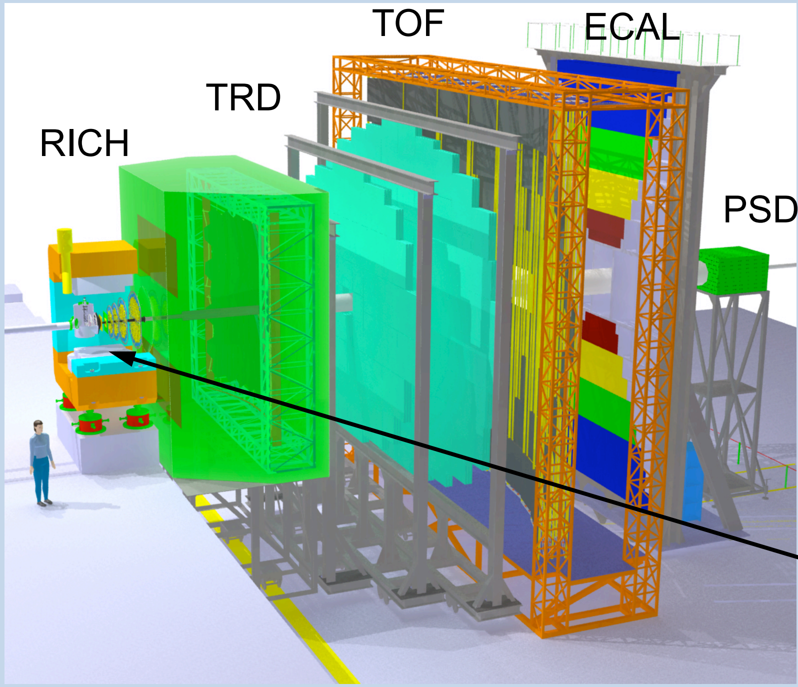
Detectors and Observables in the CBM experiment

Volker Friese
GSI Darmstadt

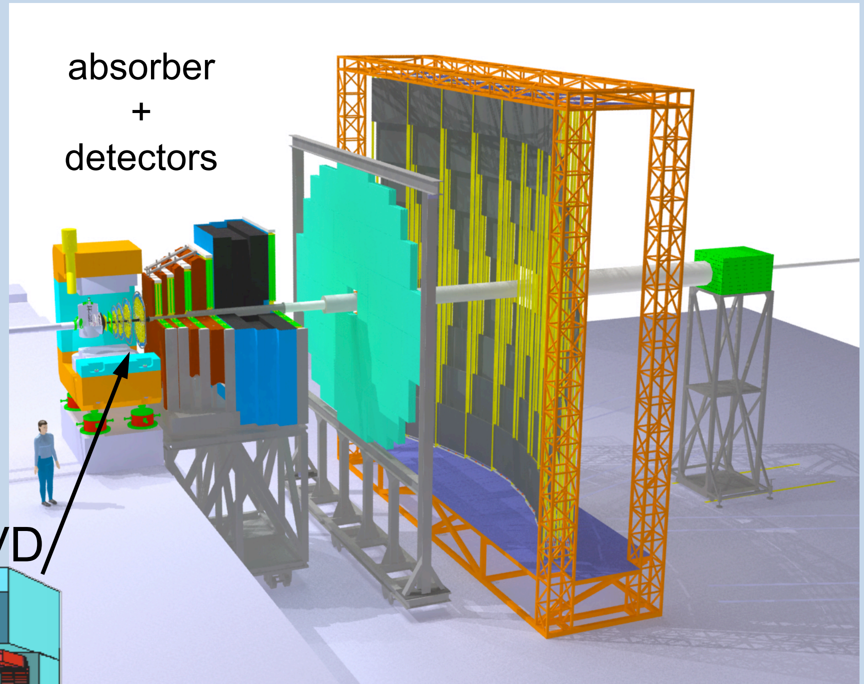
Heavy Ion Meeting, Seoul, 31 October 2009

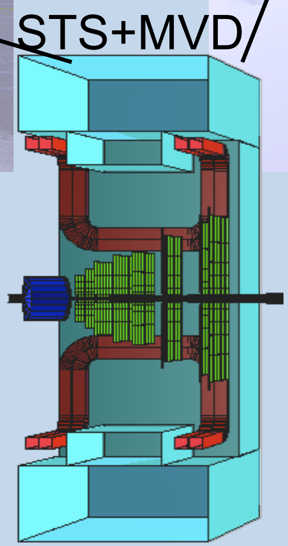
CBM: experimental setup

Electron + Hadron setup



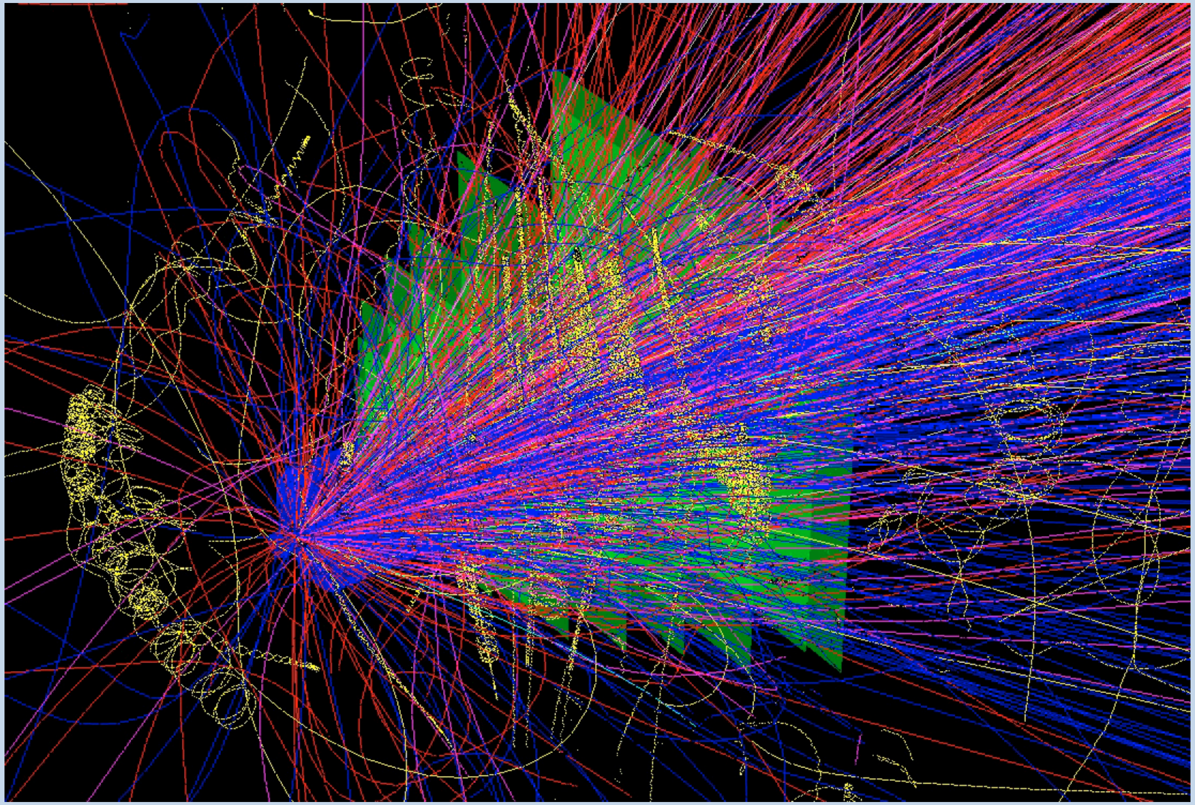
Muon setup





- Tracking in STS
- Vertexing in MVD
- Electron ID in RICH + TRD
- Hadron ID in TOF
- γ in ECAL
- Centrality in PSD
- μ ID in absorber system

STS – The Main Tracker

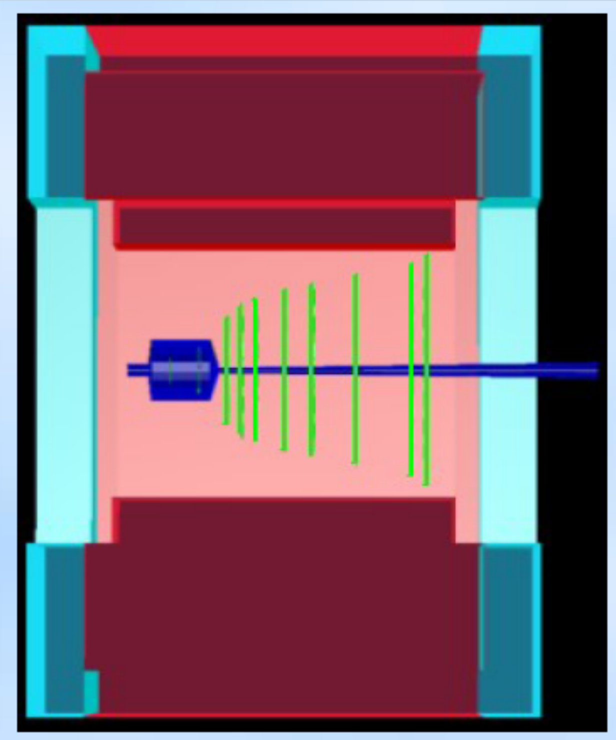


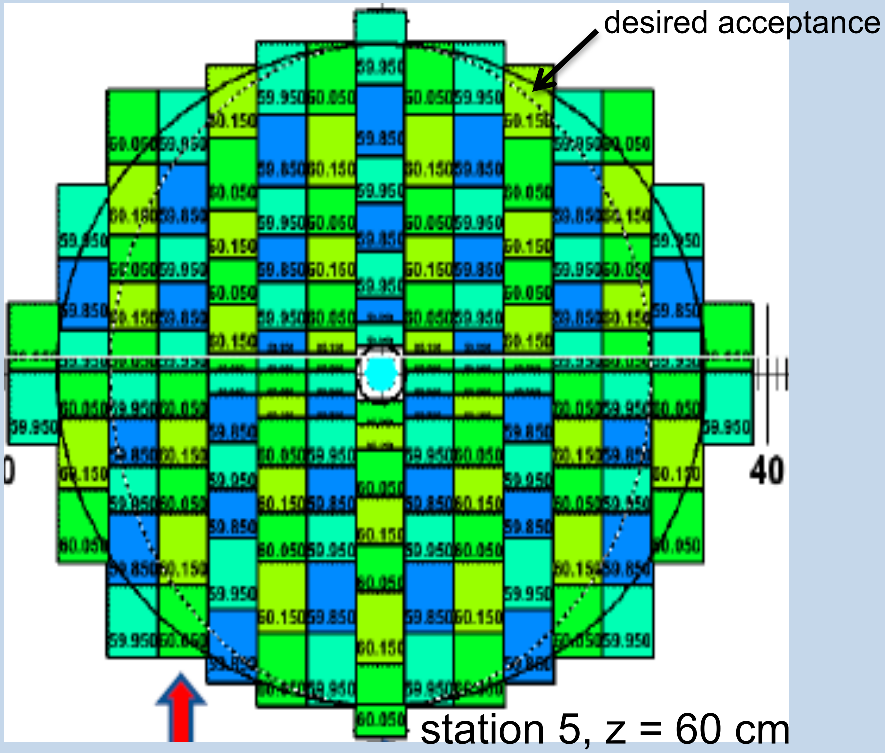
UrQMD central Au+Au @ 25A GeV

Silicon Tracking System Tasks

- Reconstruction of up to 600 charged particle tracks per event
- Fast response: should resolve 10 MHz interaction rate
- Radiation hardness of sensors and electronics
- Low material budget
- Should enable fast (online) reconstruction algorithms

STS Detector Layout

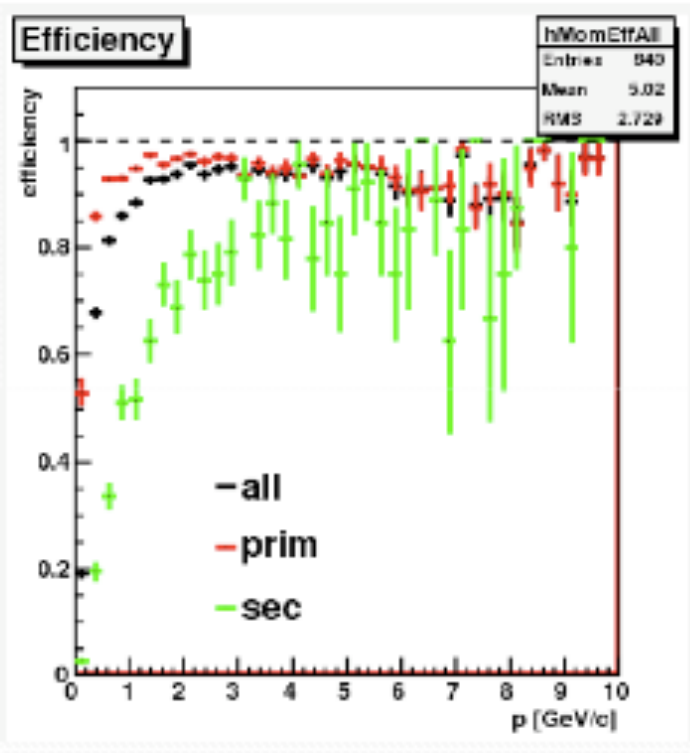


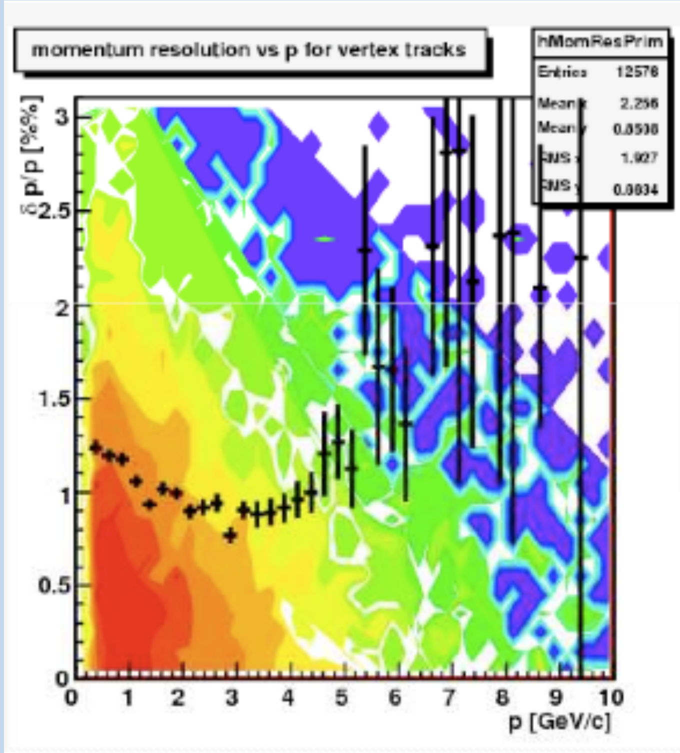


- 8 stations of micro-strip silicon detectors inside dipole field (1.2 Tm)
- Double-sided sensors with 15 degrees relative stereo angle
- Strip pitch 60 μm
- Modular design with 4, 6, and 8 cm long strips

Track reconstruction in STS

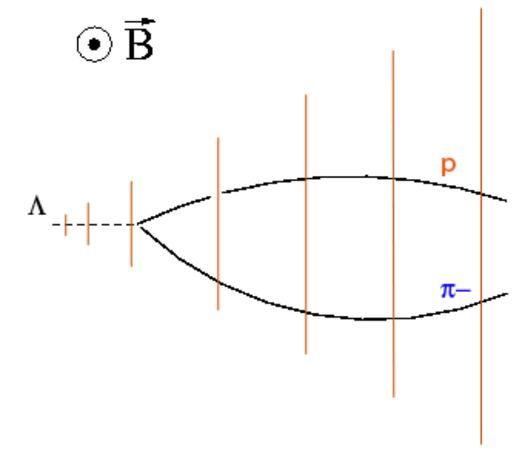
simulation and reconstruction: central Au+Au @ 25A GeV



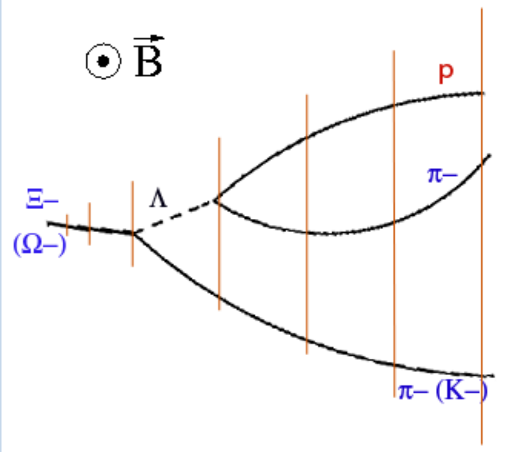


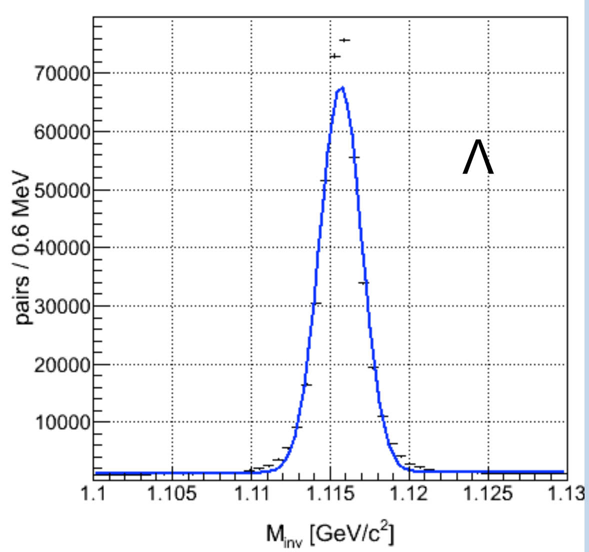
- Algorithm: Cellular Automaton + Kalman Filter
- Efficiency for fast primary tracks: 96 %
- Momentum resolution ≈ 1.1 %

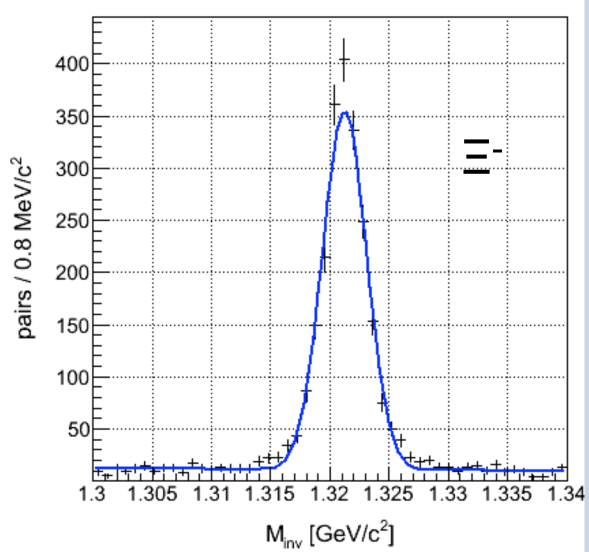
Hyperon measurements

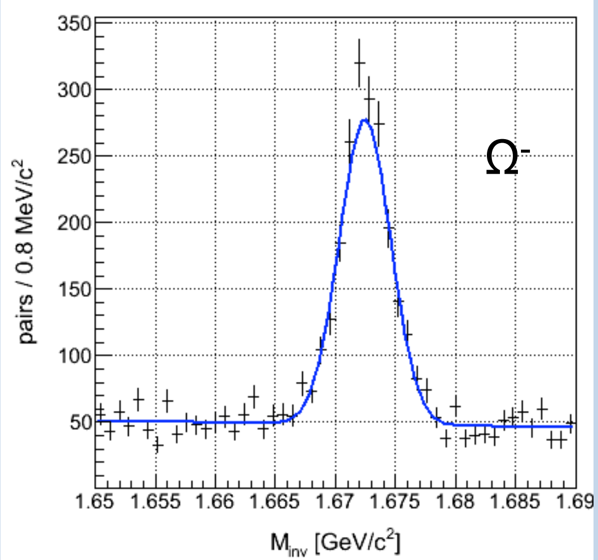


- Identified by decay topology in STS + inv. Mass
- New and fast rec. Software
- Clean signals: almost background free for Λ and Ξ
- No identification of secondaries required



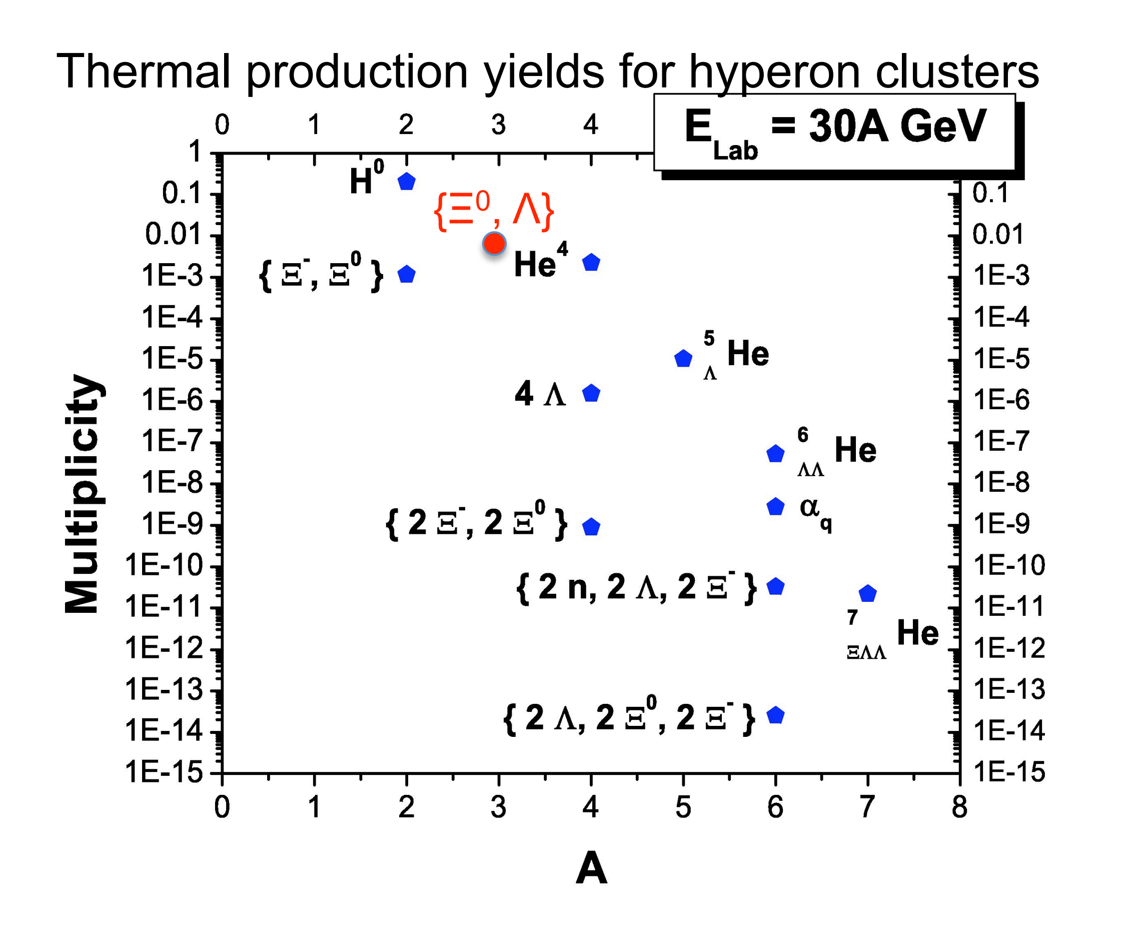






simulation and reconstruction: central Au+Au @ 25A GeV

Multi-strange di-baryons



J. Steinheimer, priv. comm.

Started to study
$\{\Xi^0, \Lambda\} \rightarrow \Lambda\Lambda$

Assuming:

$m = m_\Lambda + m_\Xi$

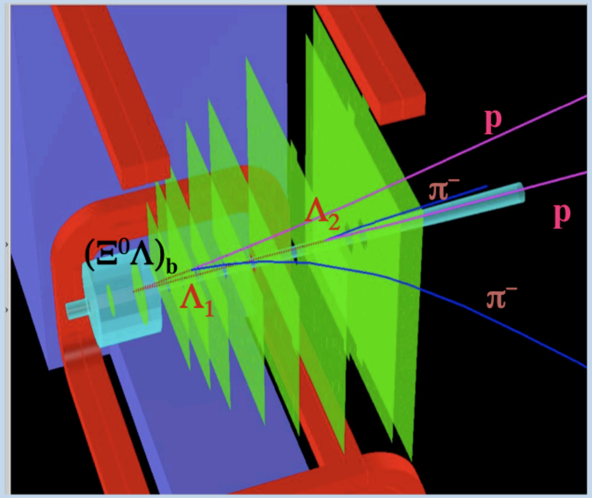
$c\tau$ = 3 cm (1–5 cm)

BR = 2 % (1–10 %)

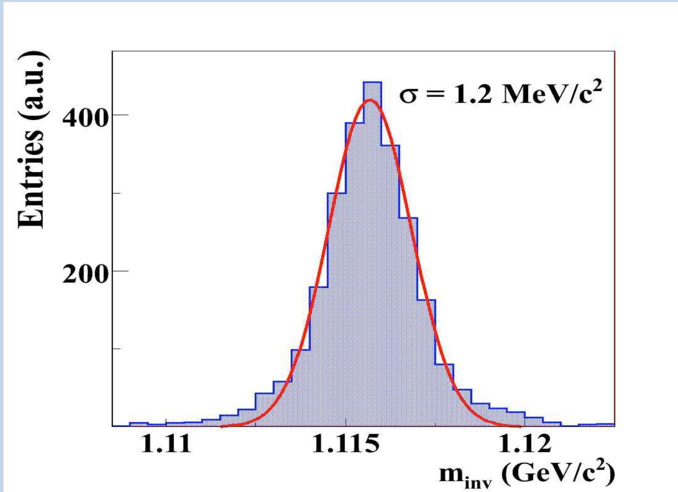
J. Schaffner-Bielich, R. Mattiello and H. Sorge, 1999

ΛΛ simulation and analysis

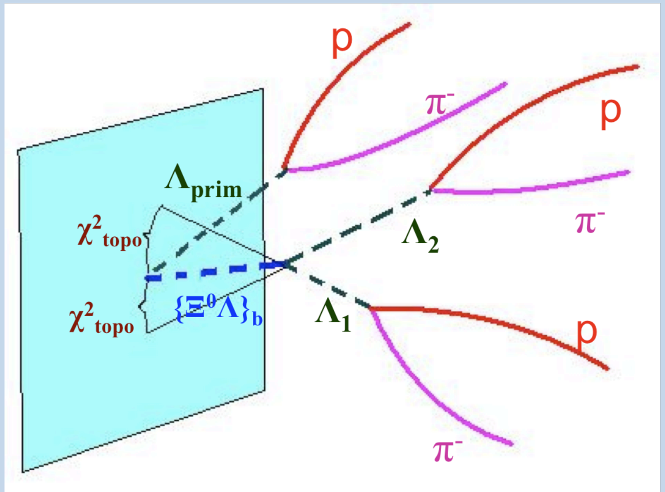
Transport event display



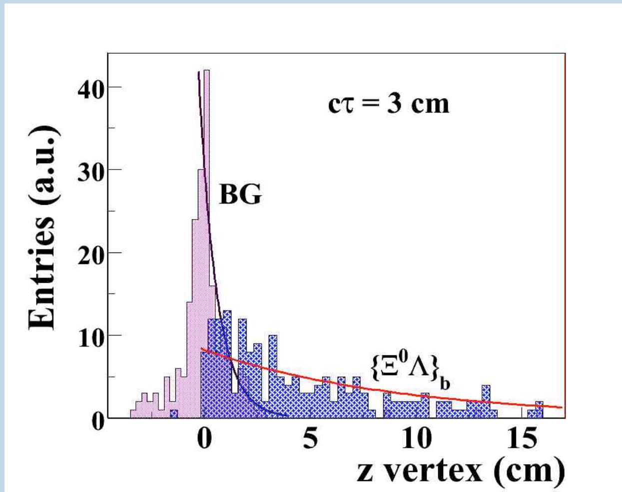
Λ reconstruction



Require off-vertex Λ



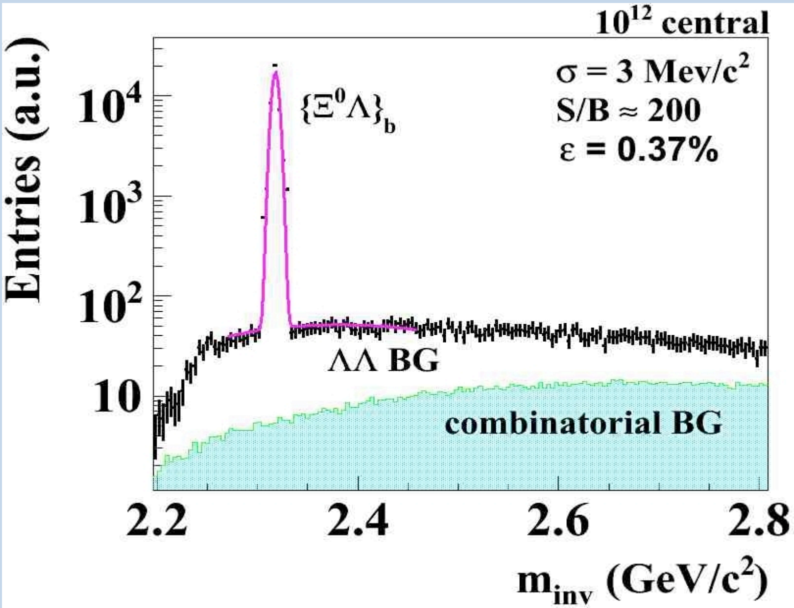
Cut on ΛΛ vertex



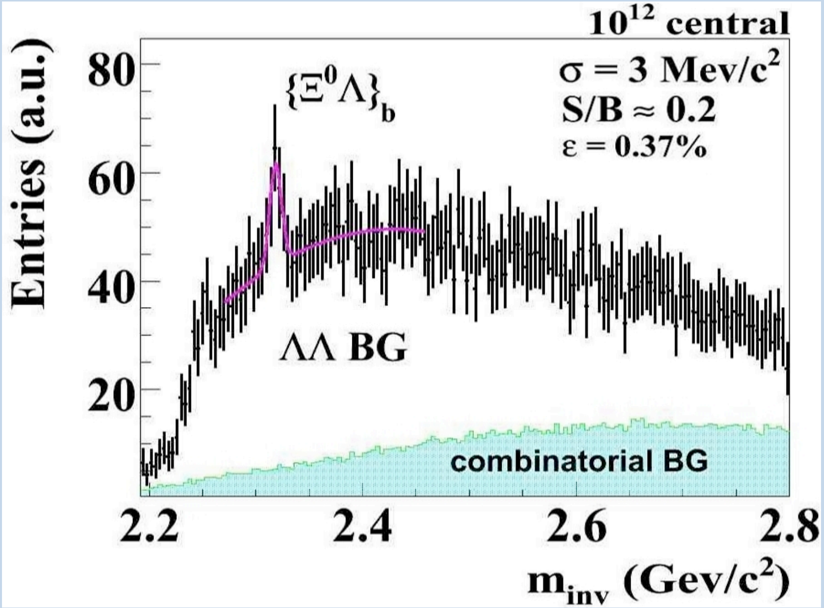
Results and sensitivity for {Ξ^0, Λ}

≈ 30 d data taking at 10^7 MHz

Thermal multiplicity (7 • 10^{-3})



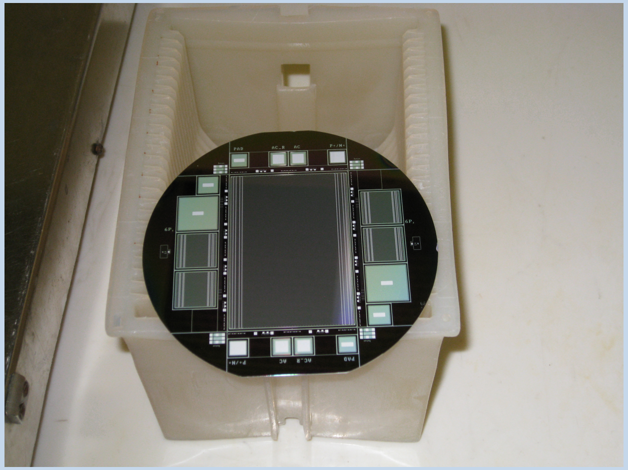
Sensitivity limit: 7 • 10^{-6}

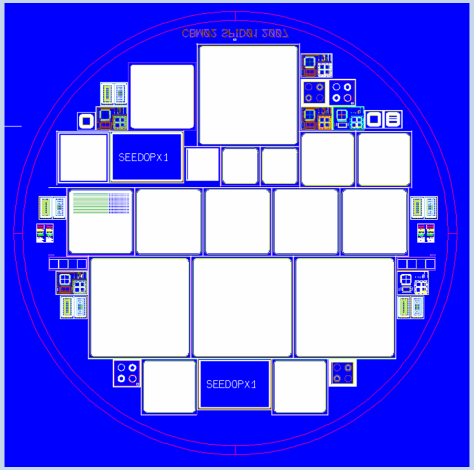


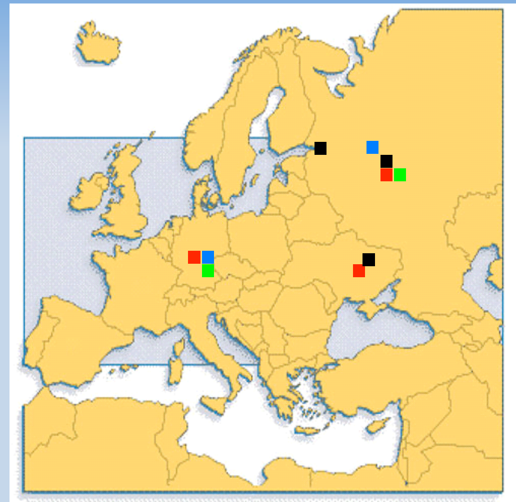
CBM will see {Ξ^0, Λ} with thermal yields

Evene three OOM below the signal will be visible above BG

STS – R&D

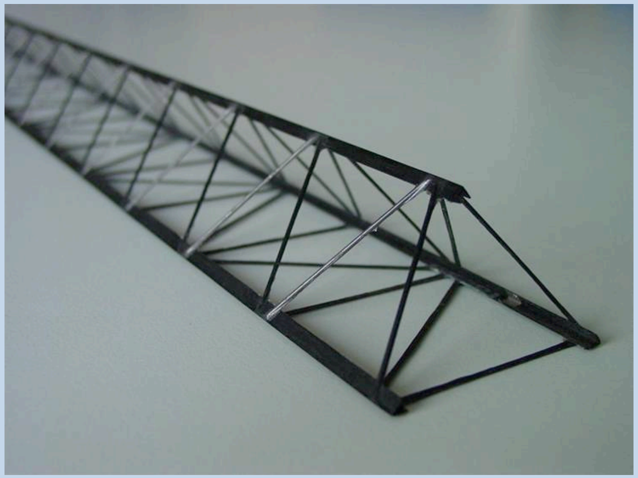






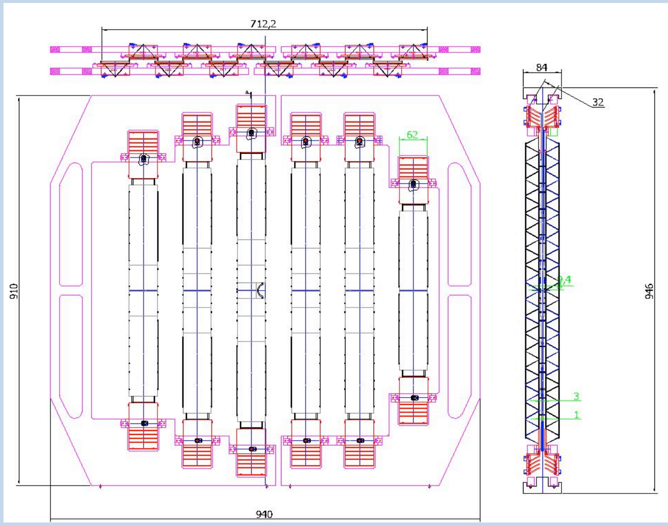
CBM-MPD STS Consortium

First sensor prototypes produced 2008
2nd generation to come spring 2010

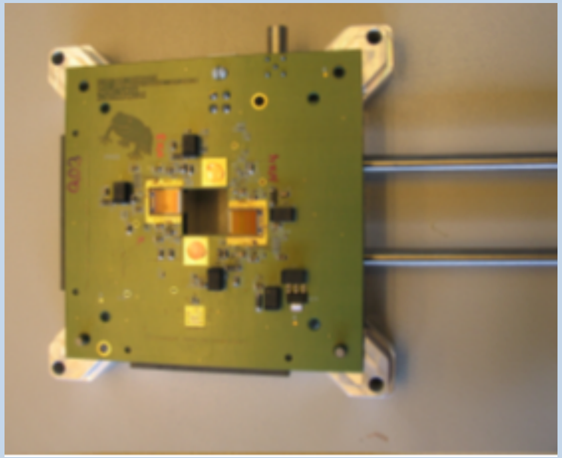


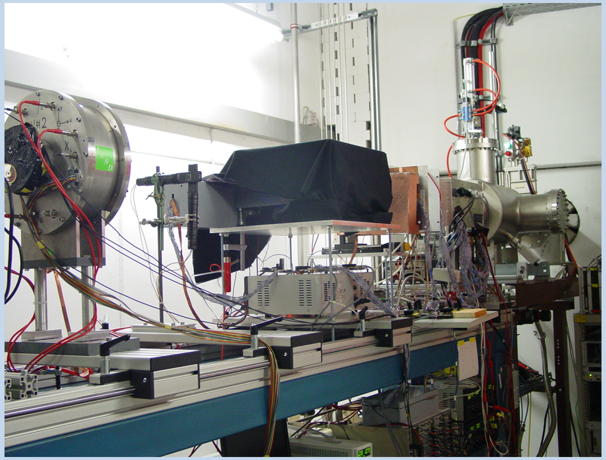
Light-weight carbon fibre support

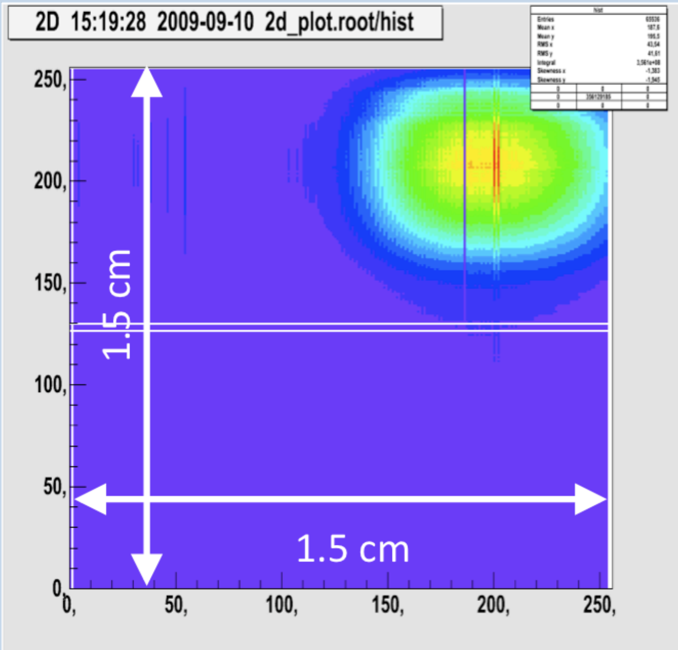
Mechanical design



STS – In-beam Test August 2009 @ GSI





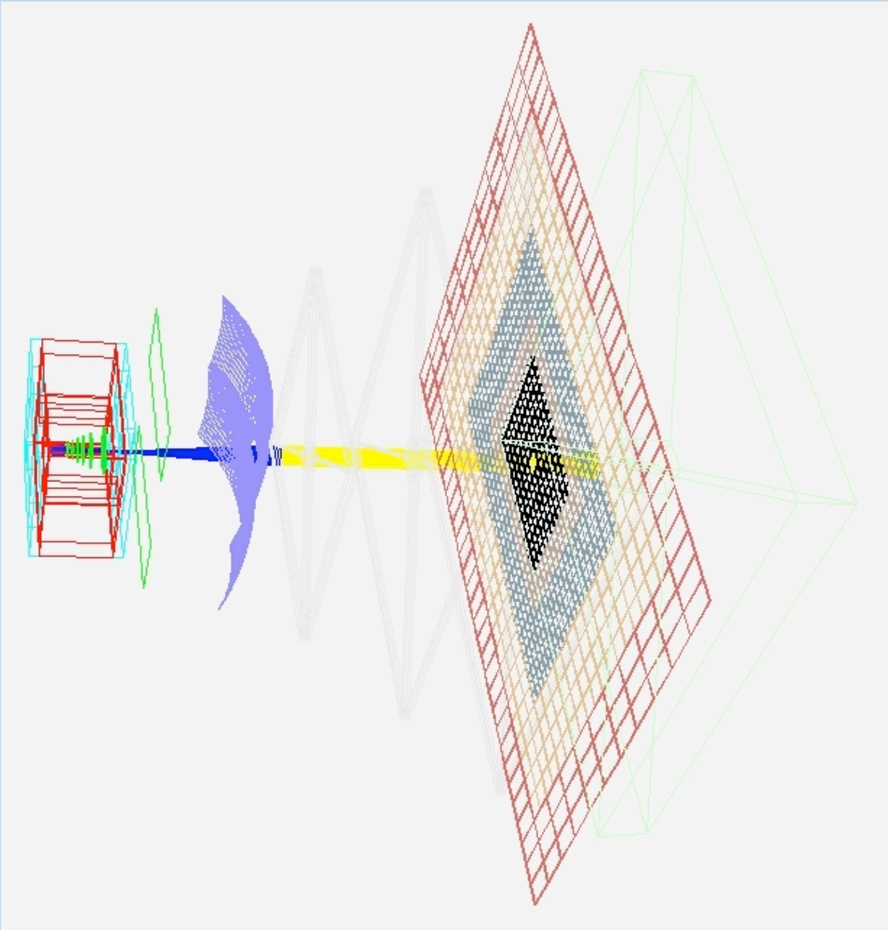


Successful operation in proton beam (2 GeV, 10^4 / s)

Self-triggered readout via NXYTER chip

Beamspot clearly visible

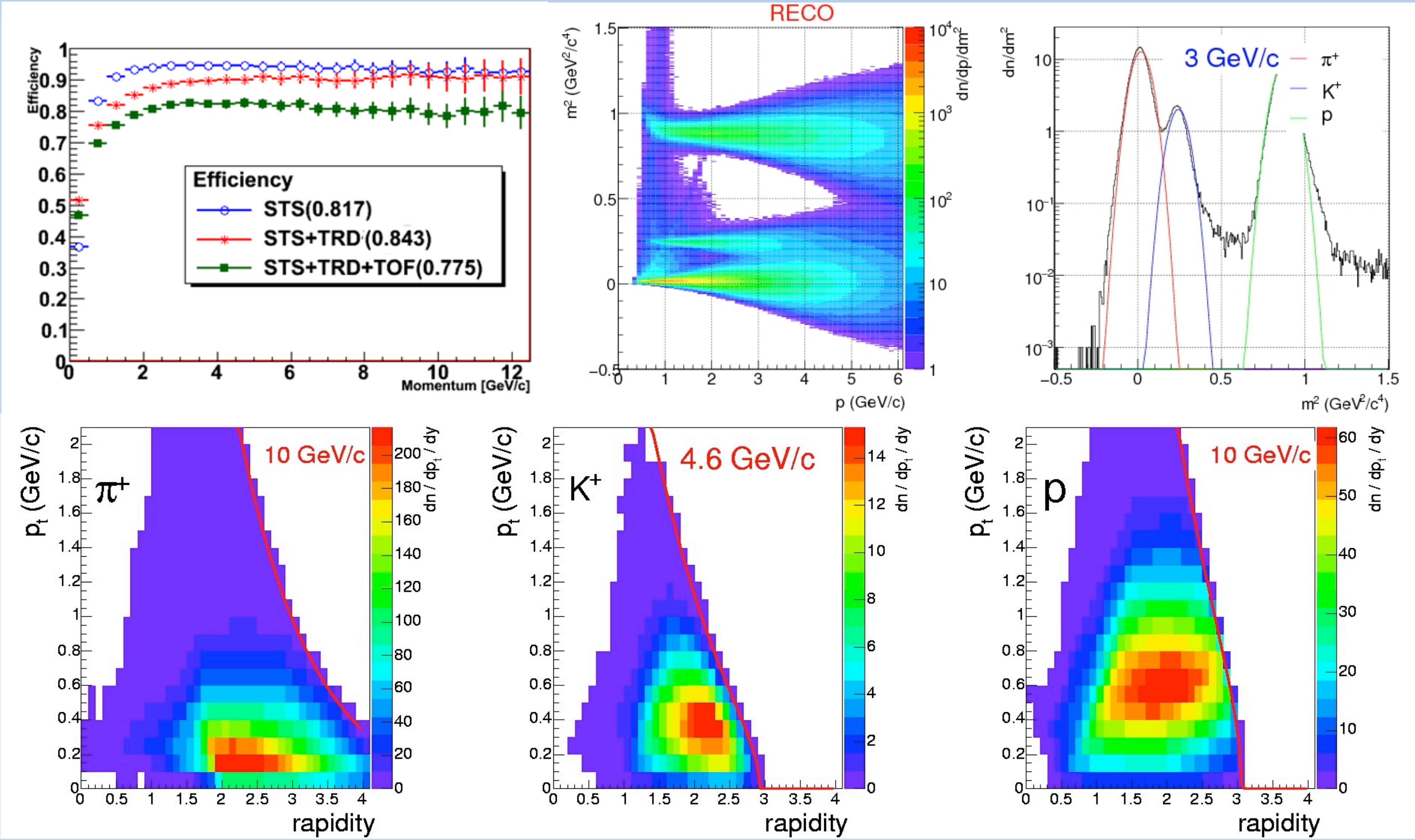
Time Of Flight for Hadron Identification



- Separation of π, K, p at z = 10 m
- Resolution < 80 ps required
- Large-area coverage (150 m^2)
- High rate capability (up to 20 kHz/cm^2)

- Realisation: timing RPCs

Hadron identification by TOF



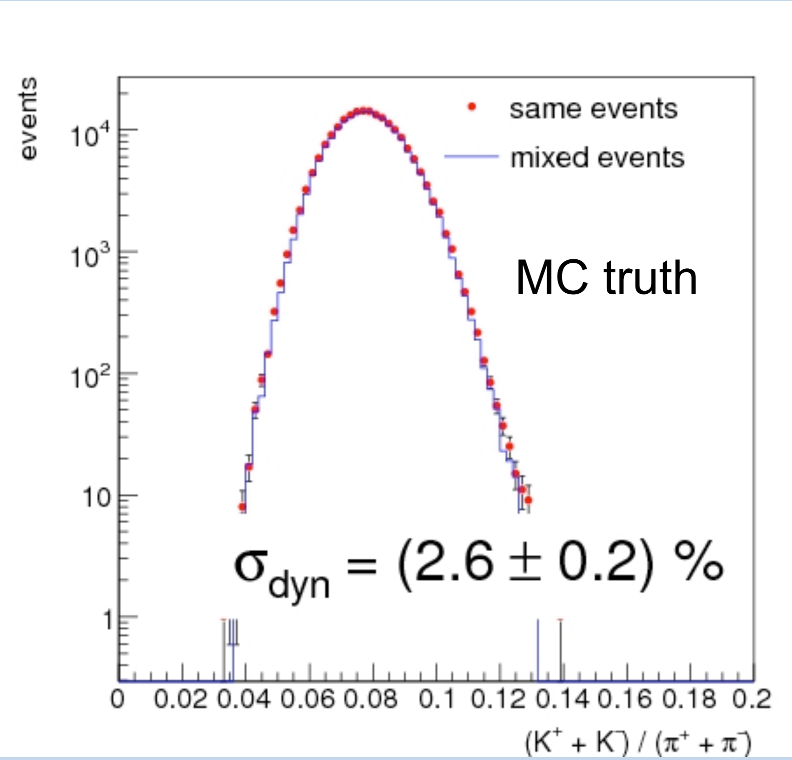
Charged kaon identification track-by-track up to p ≈ 4 GeV
Good global tracking efficiency, large acceptance: essential for EbE fluctuations

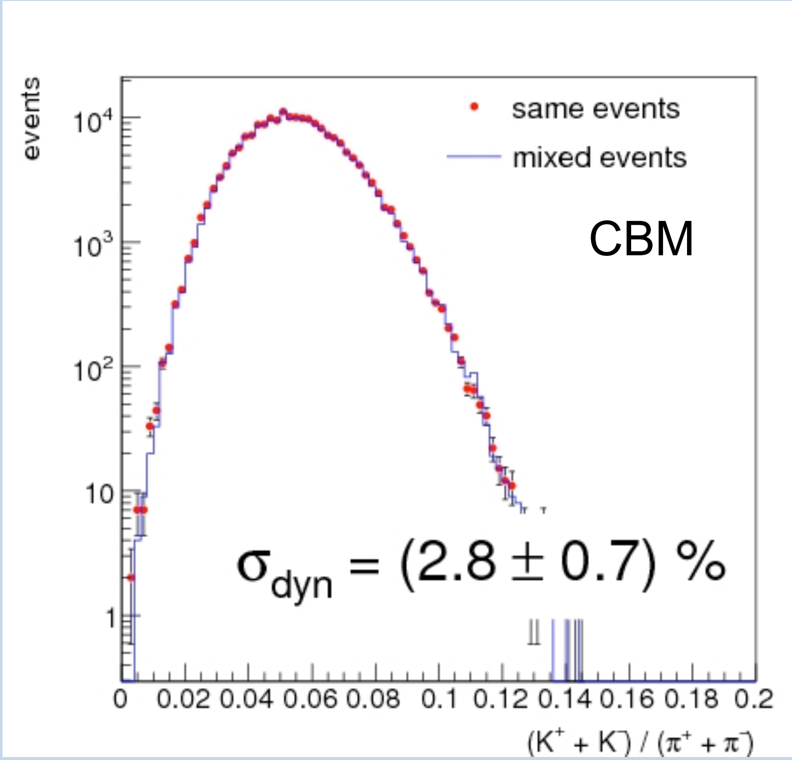
Particle ratio fluctuations

Sensitivity to K/π fluctuations studied with UrQMD input (central Au+Au, 25A GeV)

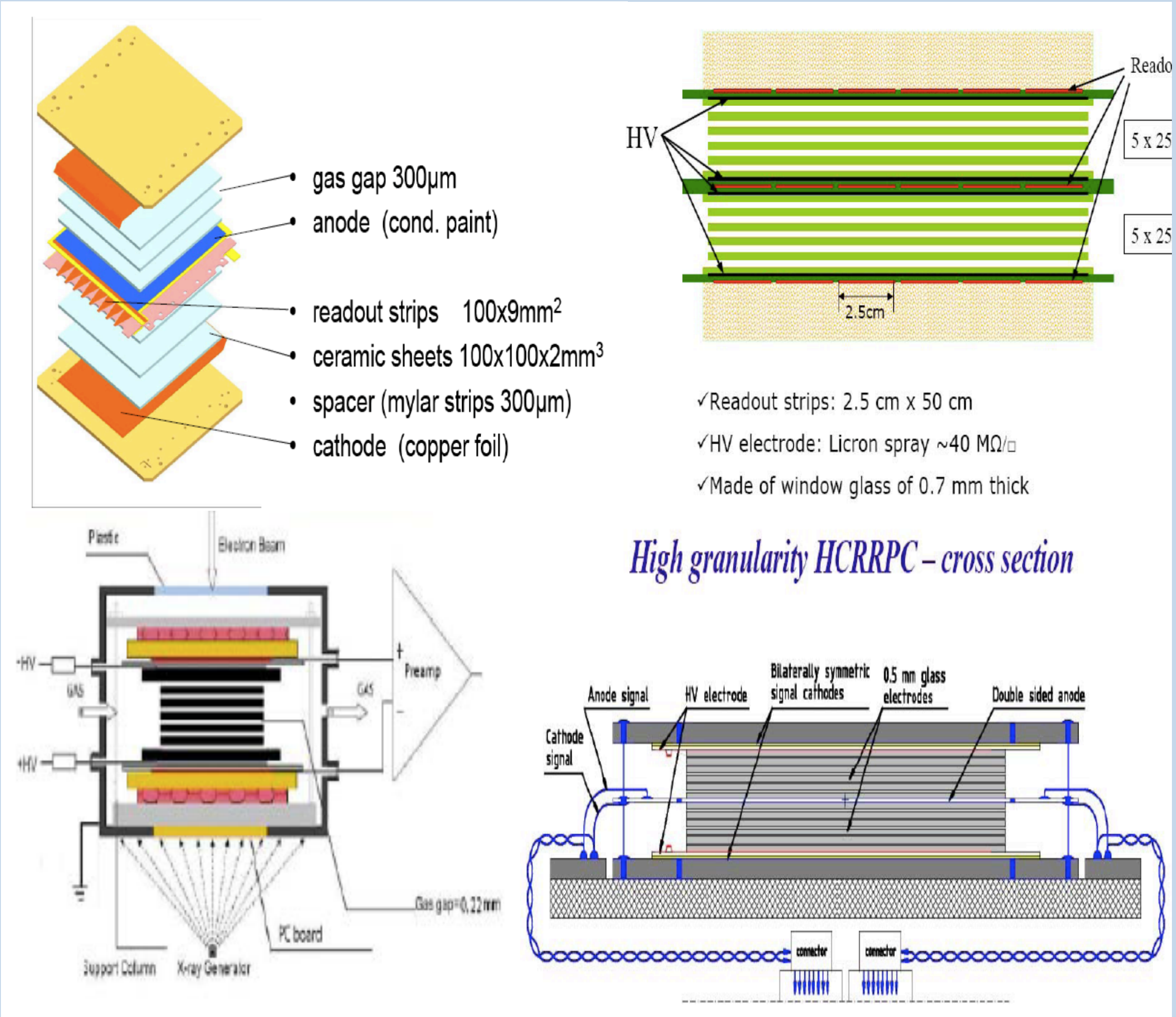
No large bias compared to MC truth found after full reconstruction and identification

CBM acceptance appears well suited for fluctuation studies



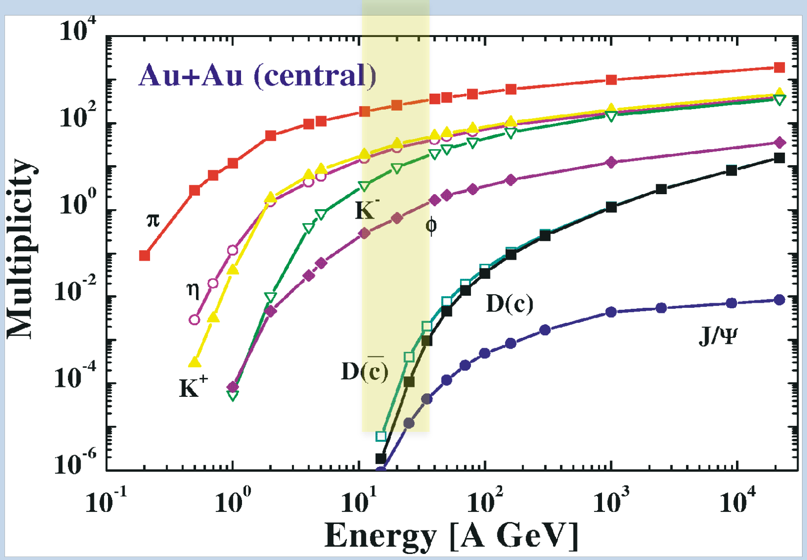


TOF – R&D on Large-Area RPCs



- Several developments ongoing (float glass, SC glass, ceramics)
- Design goals (resolution, rate capability) seem in reach
- Design choice to be done

The Key to Open Charm - MVD



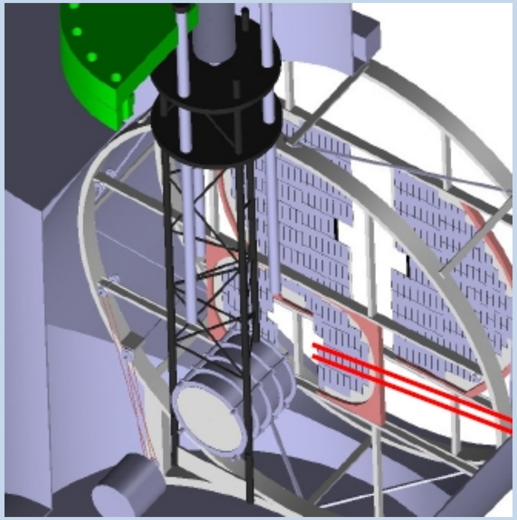
Extremely rare probe at SIS-300 energies

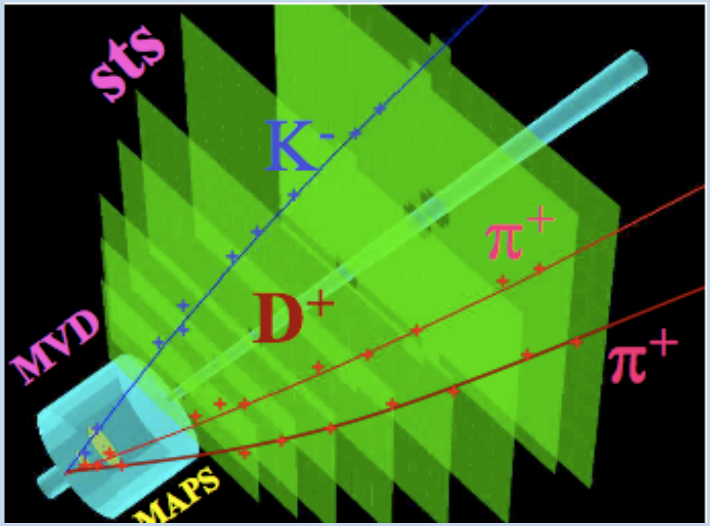
Requires efficienct background suppression

Secondary vertex detection with high precision indispensible

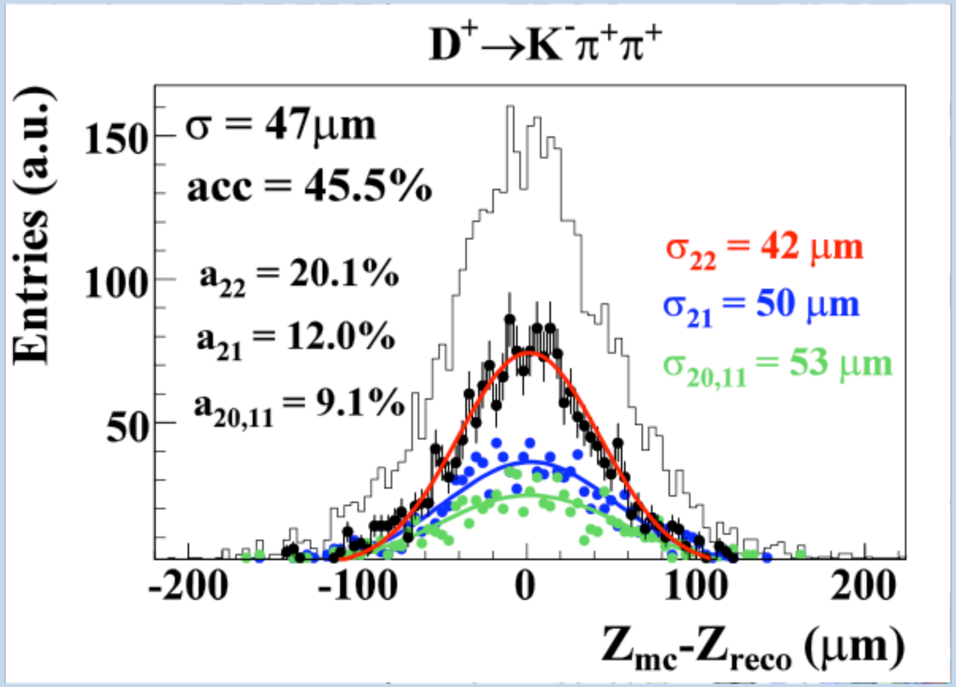
Requires high-resolution, ultra-thin detector

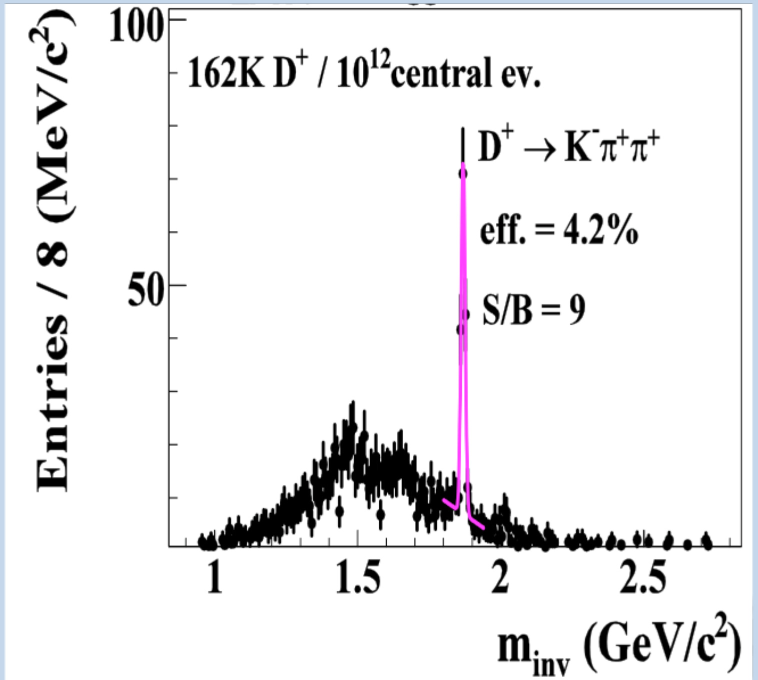
CBM choice: 2 stations of MAPS at z = 10, 20 cm operated in vacuum





Detection of Open Charm





Simulation of D^+->$K^-\pi^-\pi^+$ in 25 AGeV central Au+Au @ 25A GeV

Seccondary-vertex resolution of ≈ 50 μm obtained in full reconstruction

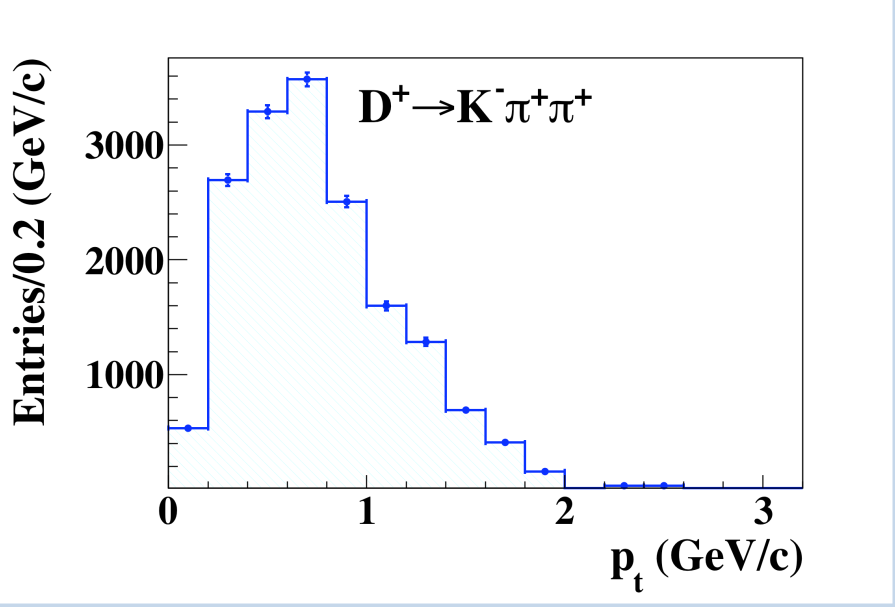
D^+ signal well observable above background

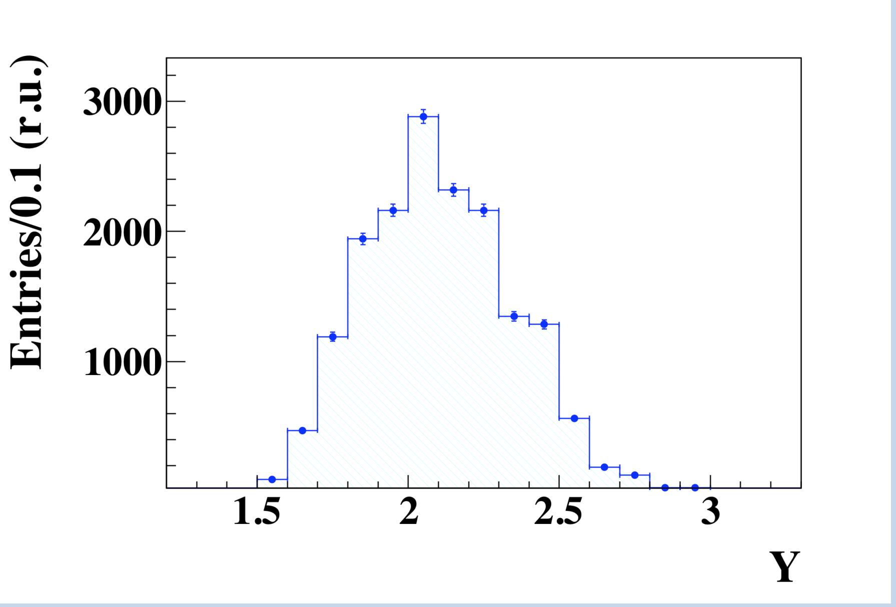
Open Charm : Statistics

Typical runtime 25 d @ 10^6 events / s

≈ 16 k D^+ decays measured

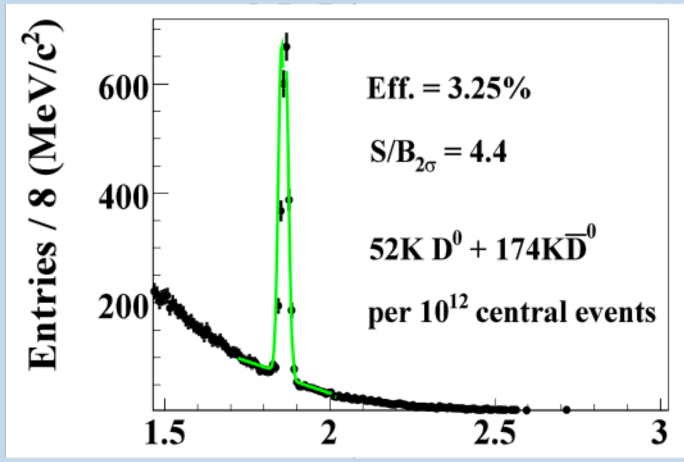
Good rapidity and p_t coverage



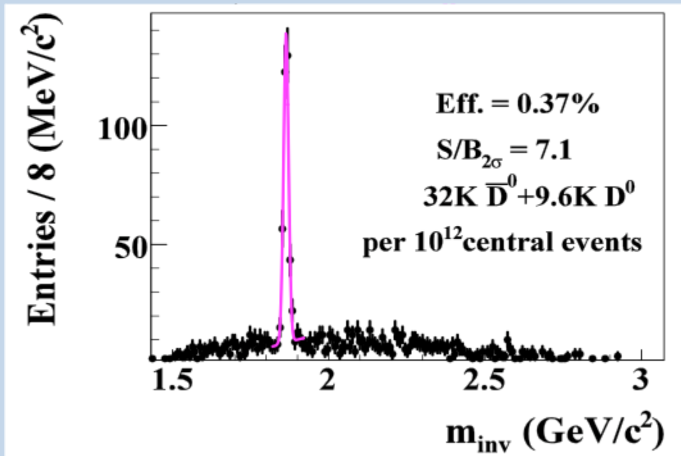


Open Charm: Other Channels

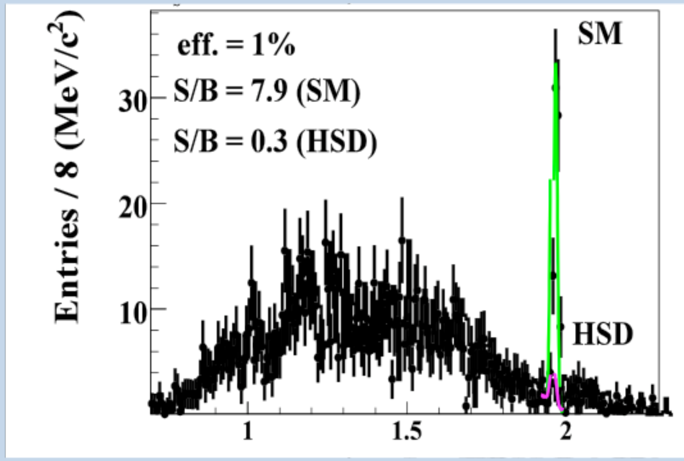
$D^0 \to K^- \pi^+$ + c.c.



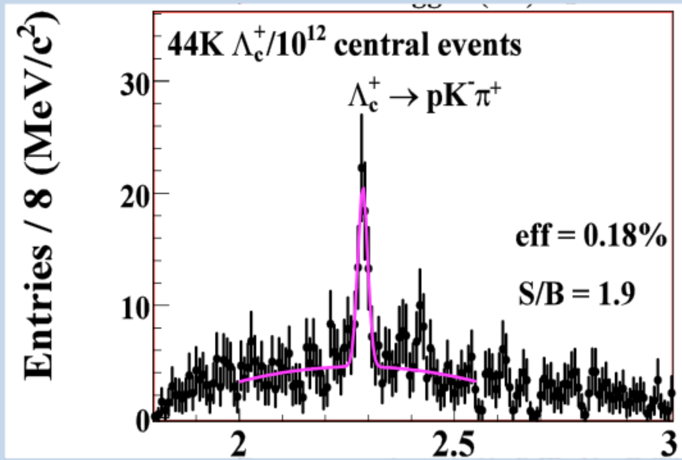
$D^0 \to K^- \pi^- \pi^+ \pi^+$



$D_s^+ \to K^- K^+ \pi^+$



$\Lambda_c^+ \to p K^- \pi^+$



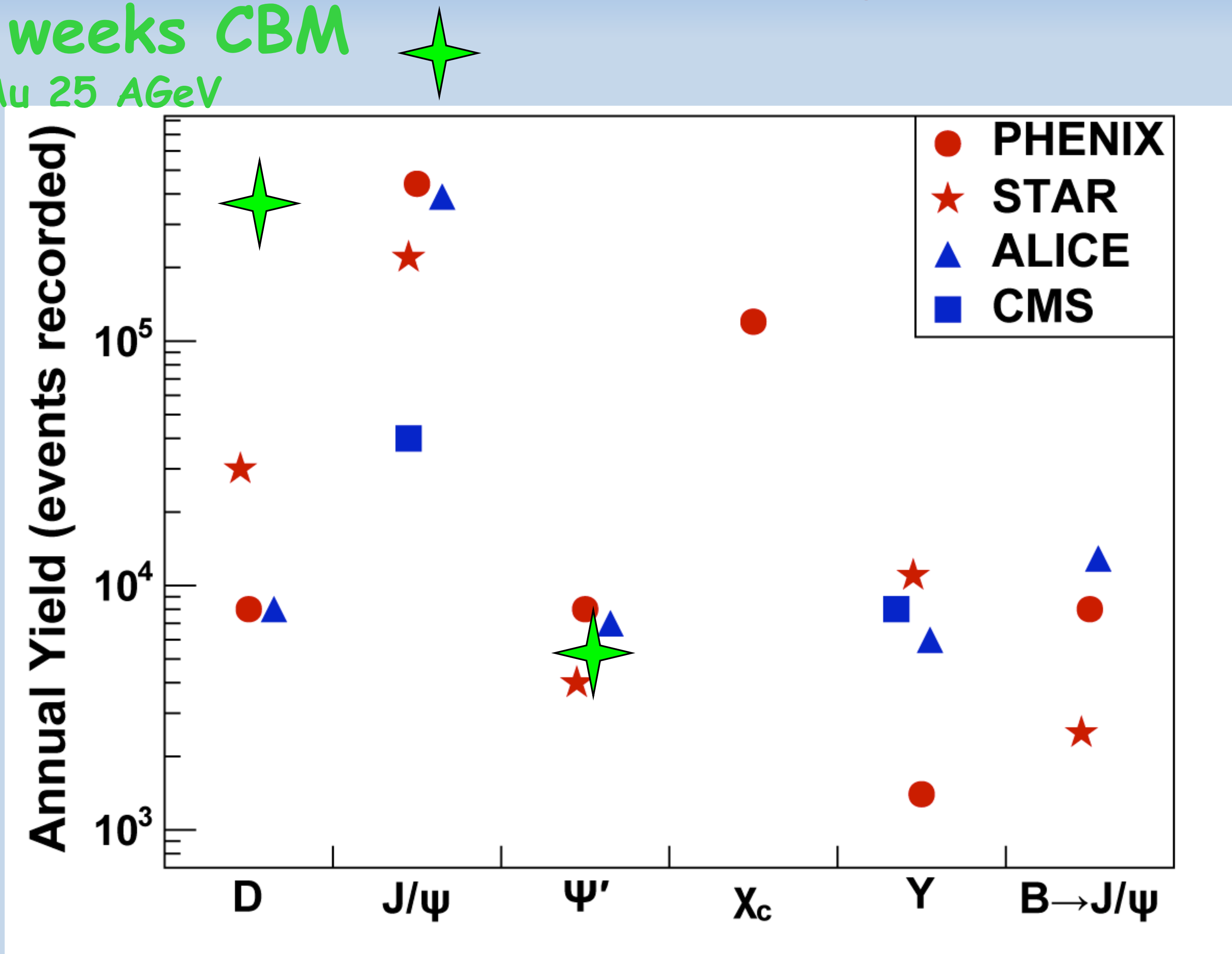
Open charm: summary

	$D^0+\bar{D}^0$	D^0	D^+	D_s^+	Λ_c^+
decay channel	$K^-\pi^+$	$\pi^- K^-\pi^+\pi^+$	$K^-\pi^+\pi^+$	$K^-K^+\pi^+$	$p K^-\pi^+$
M_{HSD}	$1.5\cdot10^{-4}$	$4.0\cdot10^{-5}$	$4.2\cdot10^{-5}$	$5.4\cdot10^{-6}$	
M_{SM}	$8.2\cdot10^{-4}$	$2.0\cdot10^{-4}$	$8.4\cdot10^{-5}$	$1.4\cdot10^{-4}$	$4.9\cdot10^{-4}$
BR(%)	3.8	7.7	9.5	5.3	5.0
geo. acc.(%)	55.7	19.3	39.6	29.6	53.0
s.t. rec. eff.	98	97.7	97.5	97.5	97.6
z-resolution μm	54	82	60	73	70
total eff. (%)	3.25	0.37	4.2	1.0	0.18
σ_m **(MeV/c²)**	11	12	11	12	12
$S/B_{2\sigma}$	4.4	7.1	9.0	0.3(7.9)	0.25
yield(K/10¹¹cen)	5 + 17	1	16	0.3(7.2)	11

CBM Charm in Comparison

10 weeks CBM

Au+Au 25 AGeV



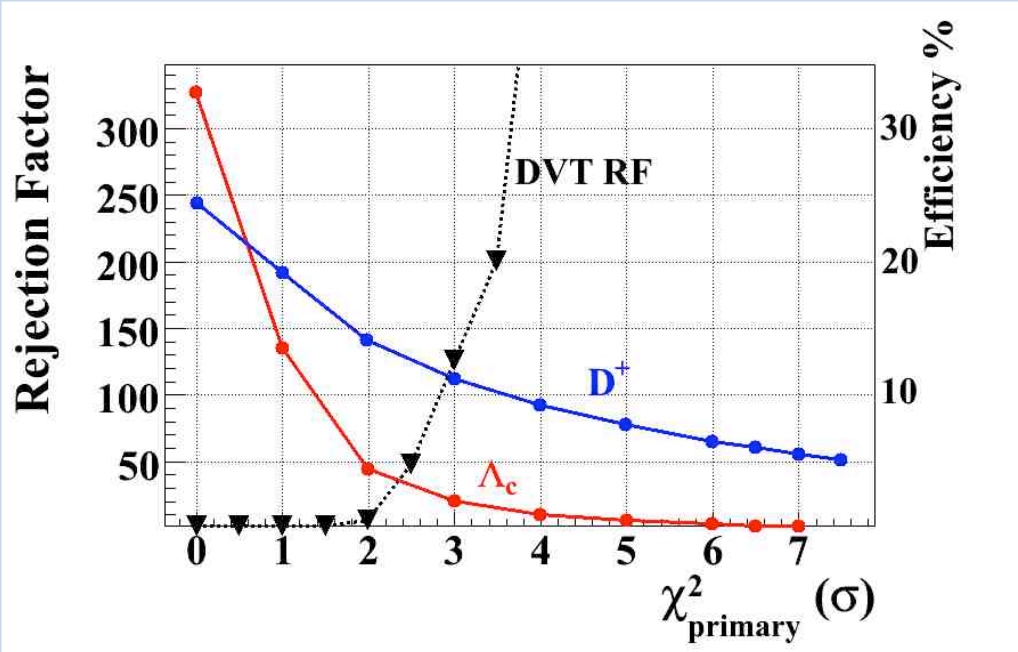
Open charm trigger

Based on:

- impact parameter of daughters
- geometrical and topological vertex cuts

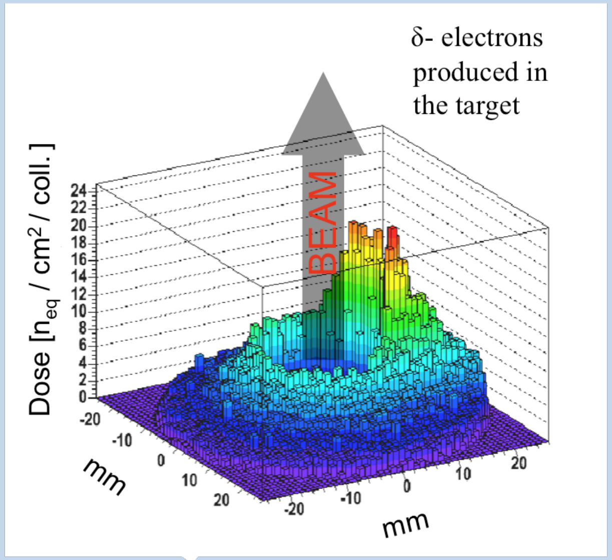
Rejection factors > 100 in reach

To be implemented in FLES



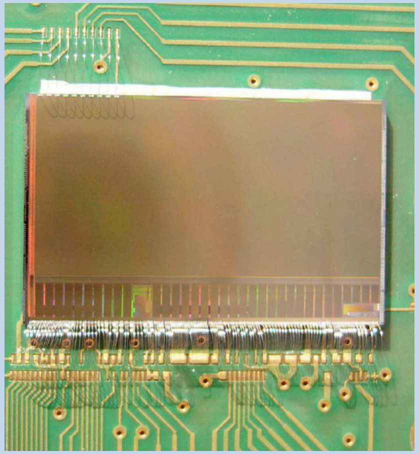
Open charm: challenges

- High event rates (10^5 – 10^6) indispensable
- Requires:
  - Online trigger reduction by factor > 100
    - Online track reconstruction and SV detection
  - Fast micro-vertex detector
    - MAPS: Limited by readout, 10 µs frame rate possible
    - Simulations: Event pile-up of 10 – 20 tolerable
  - Radiation-hard detector: up to 10^{14} n_{eq}/cm^2/year
    - R&D on MAPS radiation tolerance ongoing
    - Regular replacement of MAPS stations feasible

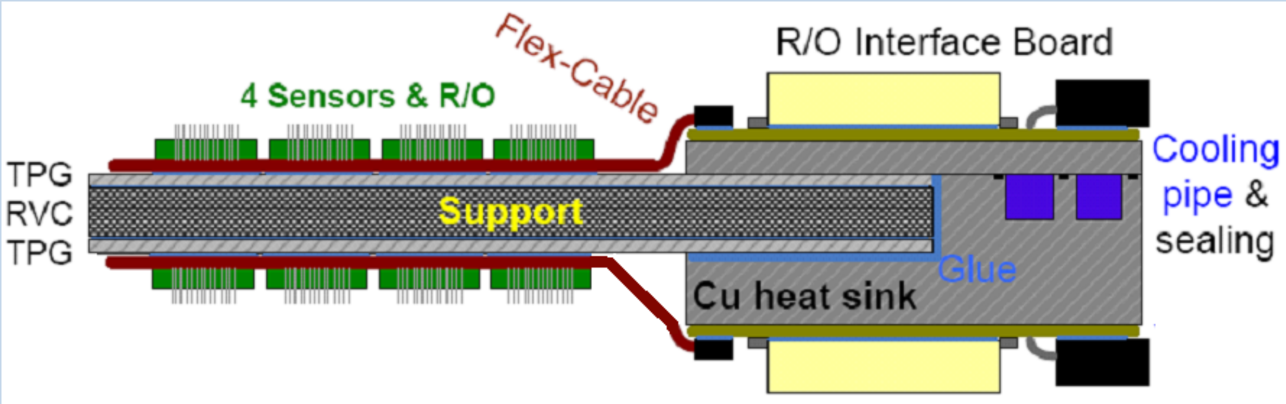


MVD: R&D on MAPS

MIMOSA-26 sensor



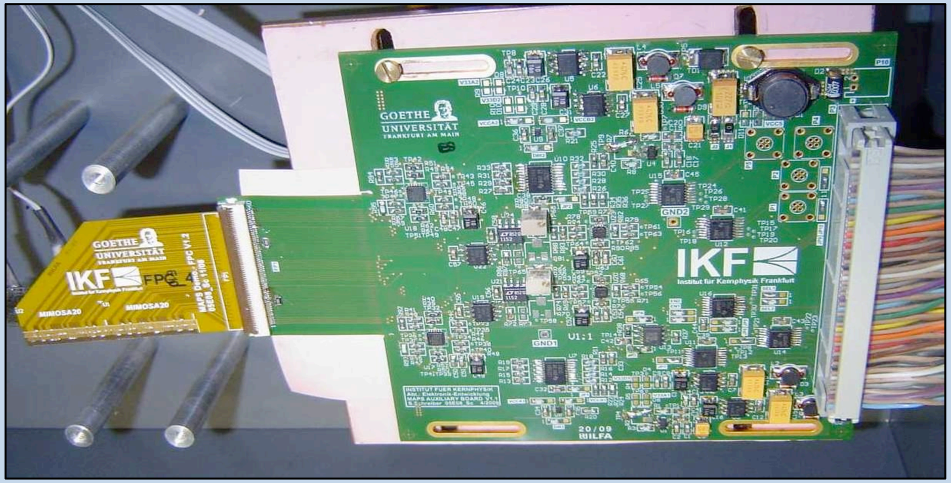
Ladder design



R&D punchlines:

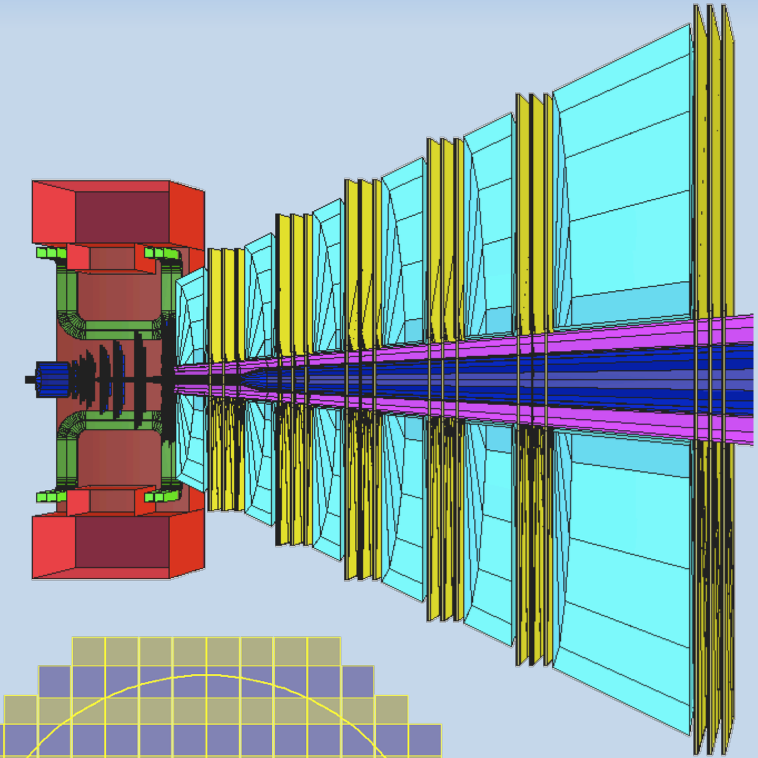
readout speed
radiation hardness

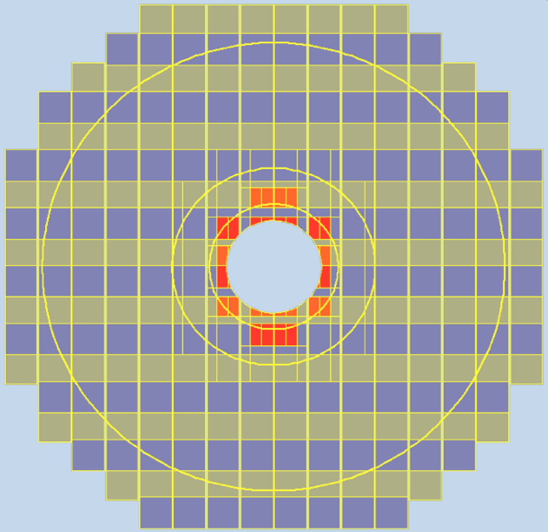
Readout frames of 30 μs in reach
(10 μs with 3-d integration)



MVD demonstrator at IKF

MUCH – No Hadrons Allowed



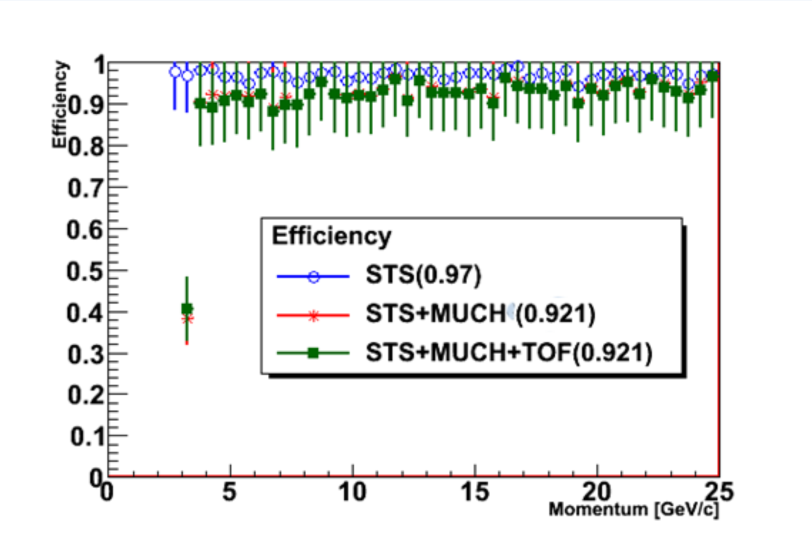


Muon detection system with „active“ absorber (alternating Fe absorber and detector layers)

Enables efficient suppression of hadrons while tracking through the setup still possible

Modular pad layout according to track density

Reconstruction of Muon Pairs



Tracking algorithm (track following from STS) developed

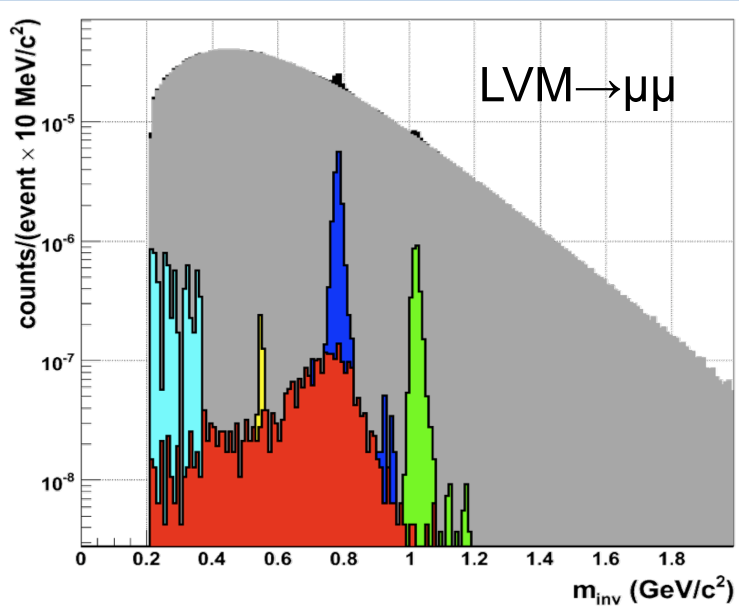
Satisfactory efficiency for muons

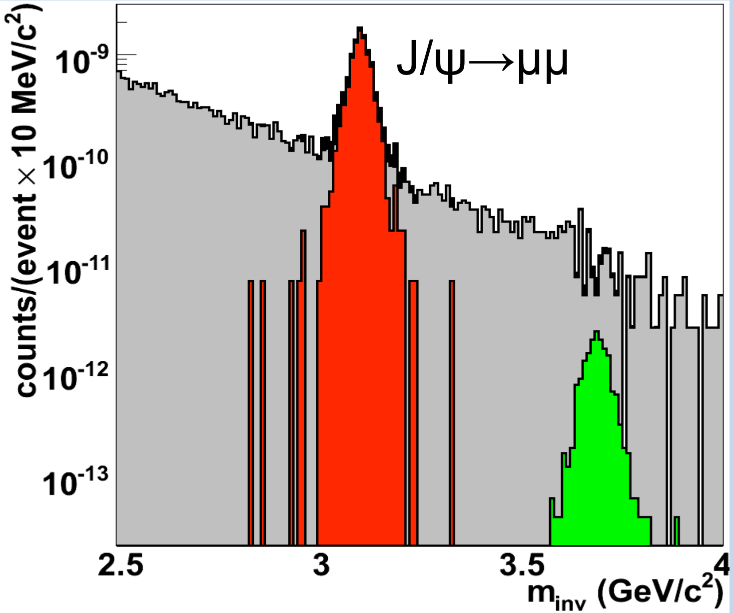
Background:

- muons from weak decays (π, K)
- track mismatches

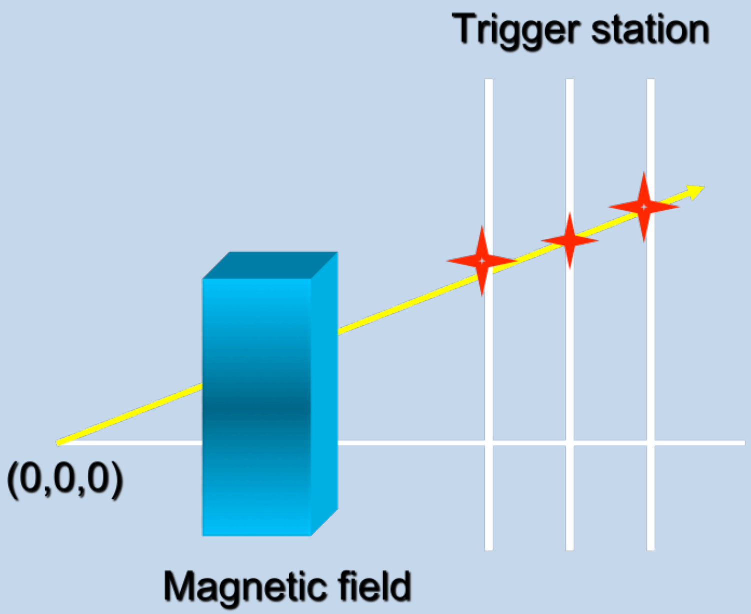
J/ψ signal well observable

Low-mass vector mesons feasible





Charmonium Trigger



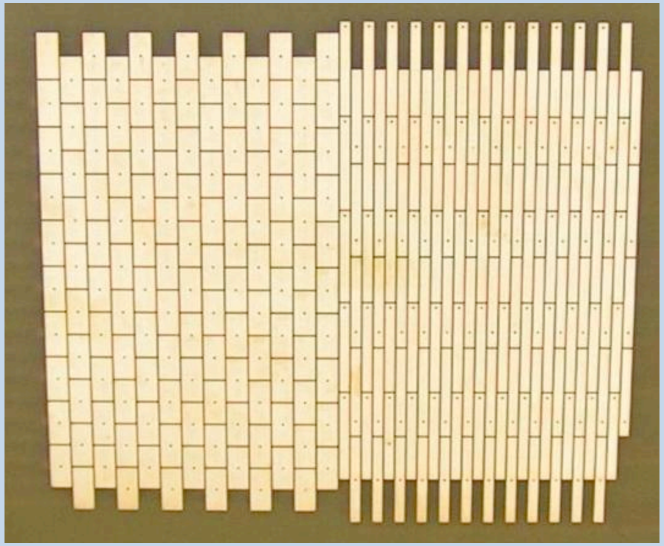
Highest interaction rates (10 MHz) required for charmonium measurement

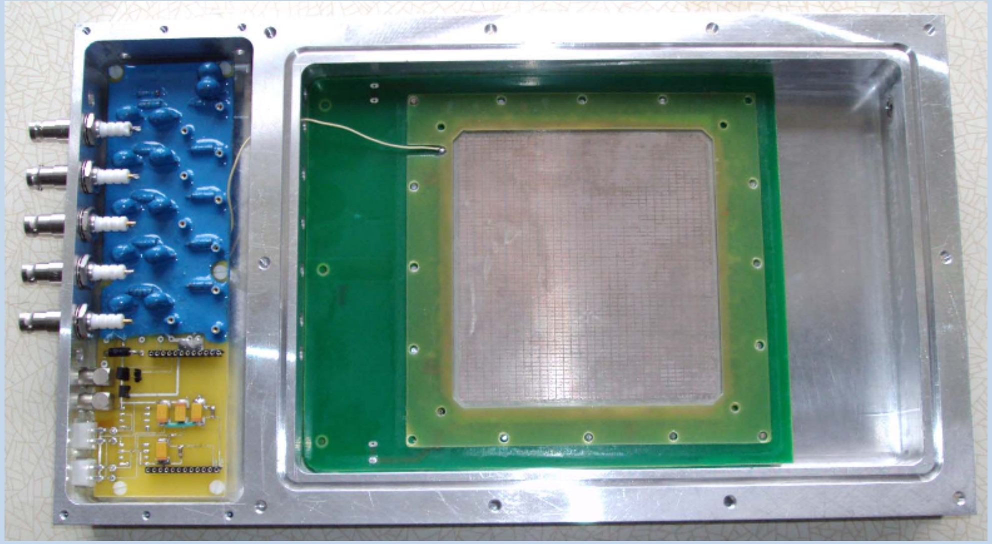
Online event suppression > 1,000 needed

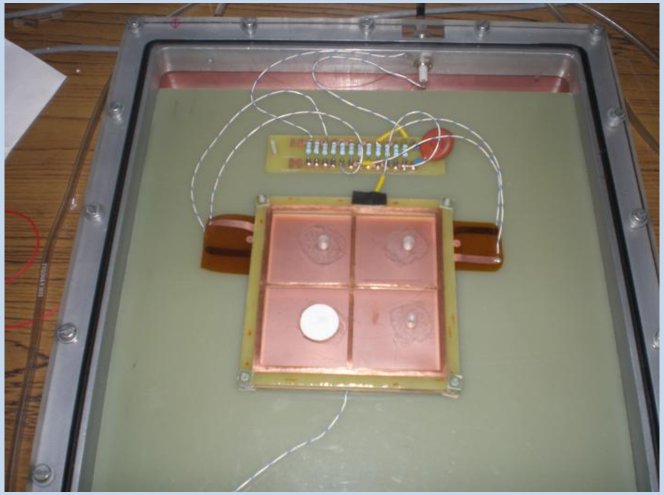
Simple trigger algorithm (two oppositely charged vertex tracks after absorber) feasible and sufficient

	J/ψ reconstruction efficiency	event suppression factor
without trigger	29.3 %	1
after trigger	15.3 %	~1430

MUCH – R&D on GEM and Micromega





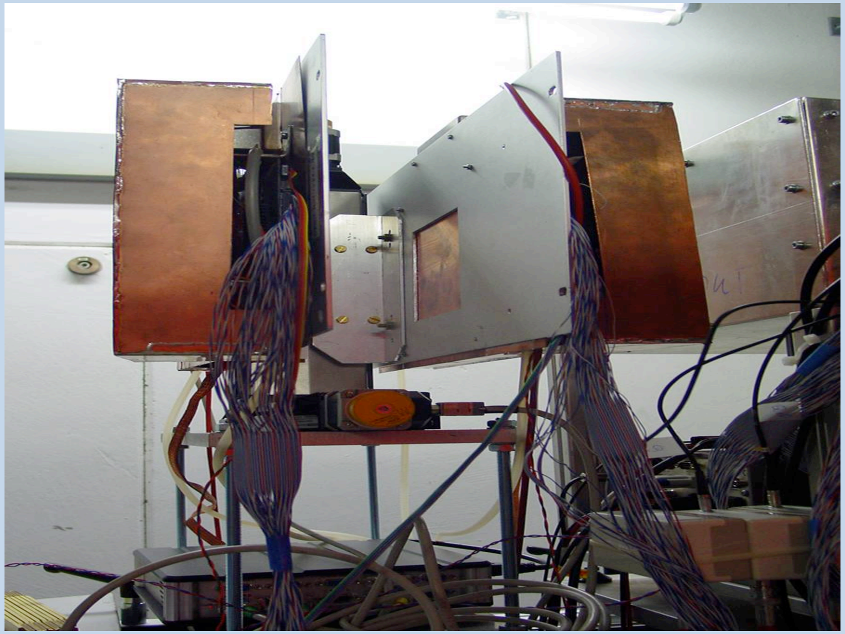


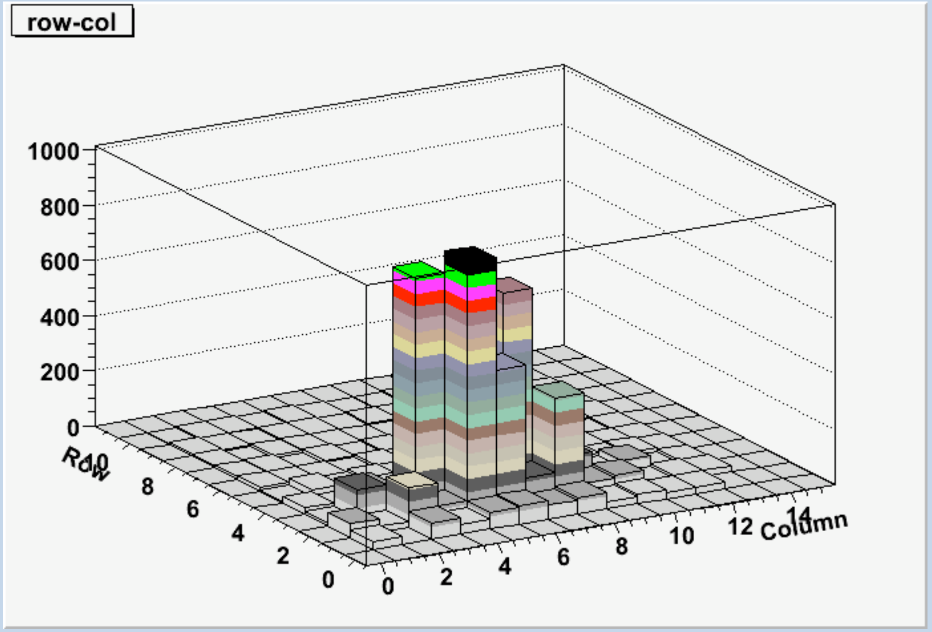
Detector developments at VECC Kolkate and PNPI St. Petersburg

Design choices: GEM / Micromega for high density regions

MWPC / Straw Tubes for outer regions

GEM – In-beam Test August 2009 @ GSI

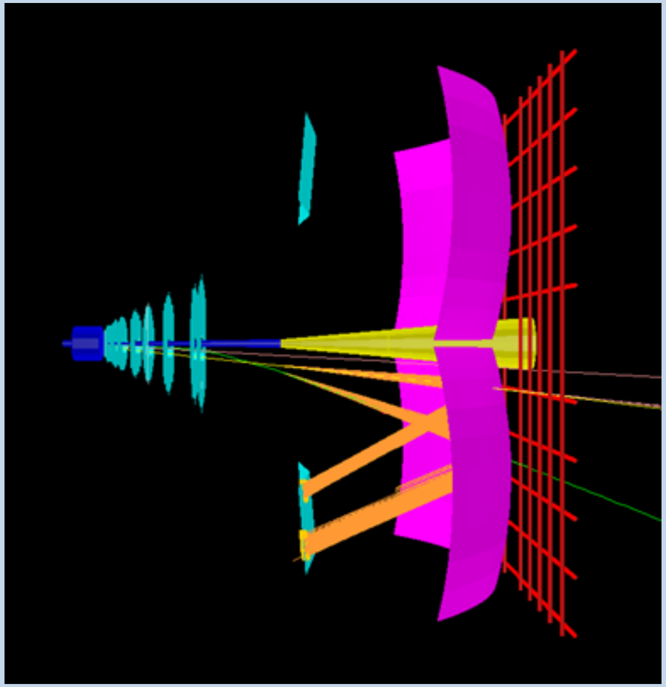


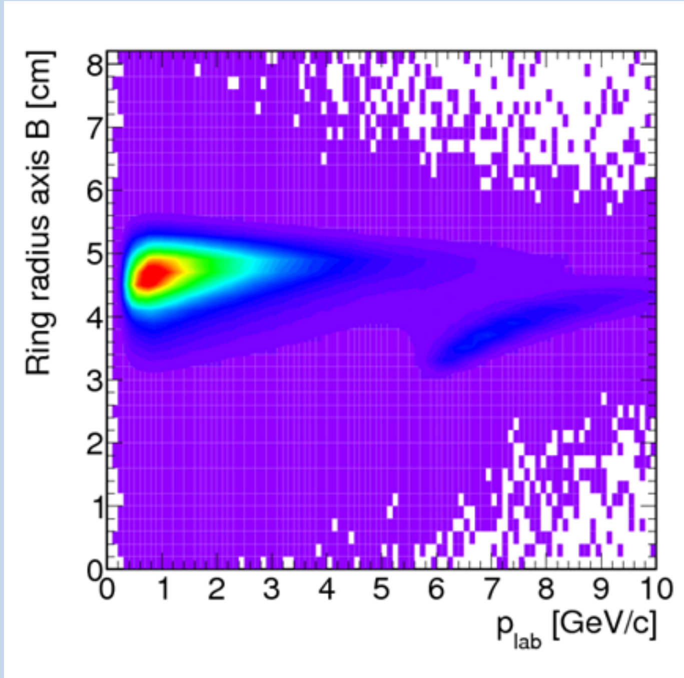


Successful operation of two GEM detectors in proton beam

Beam spot nicely observed

Electrons Only – RICH and TRD

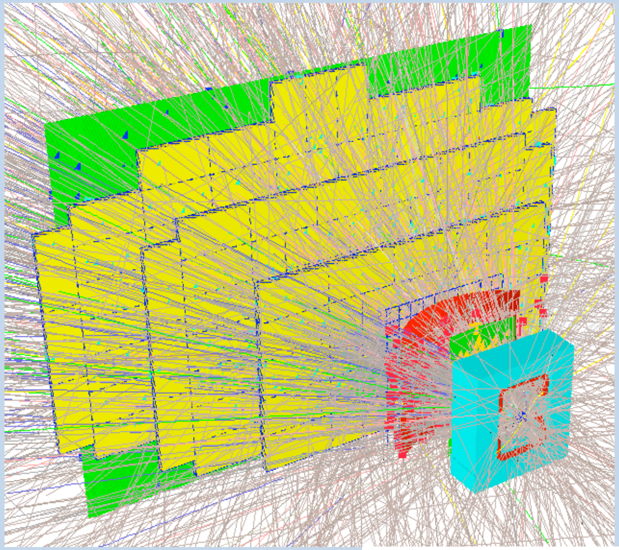




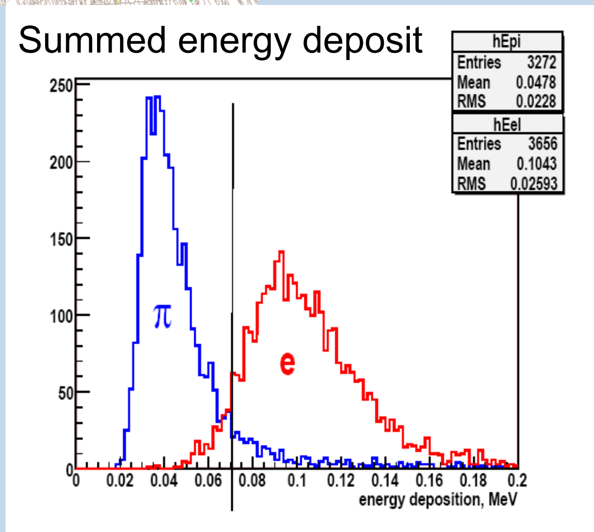
Identification of electrons by Cherenkov radiation in RICH and Transition Radiation in TRD

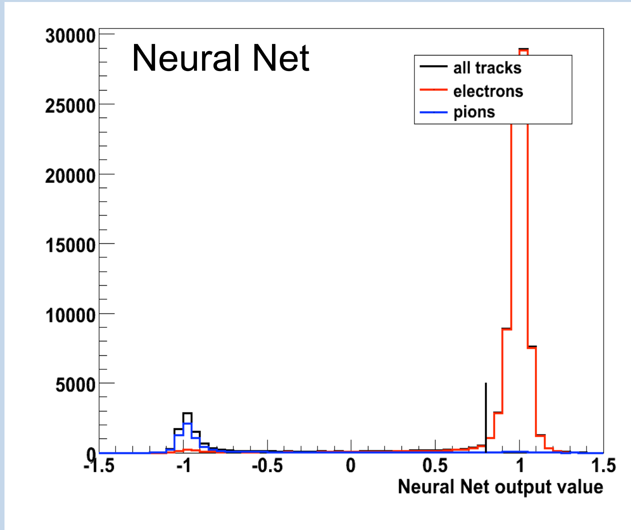
RICH: Gas Radiator (pion threshold 4,6 GeV)
TRD: 10 – 12 stations, readout with MWPC

Electron identification in TRD

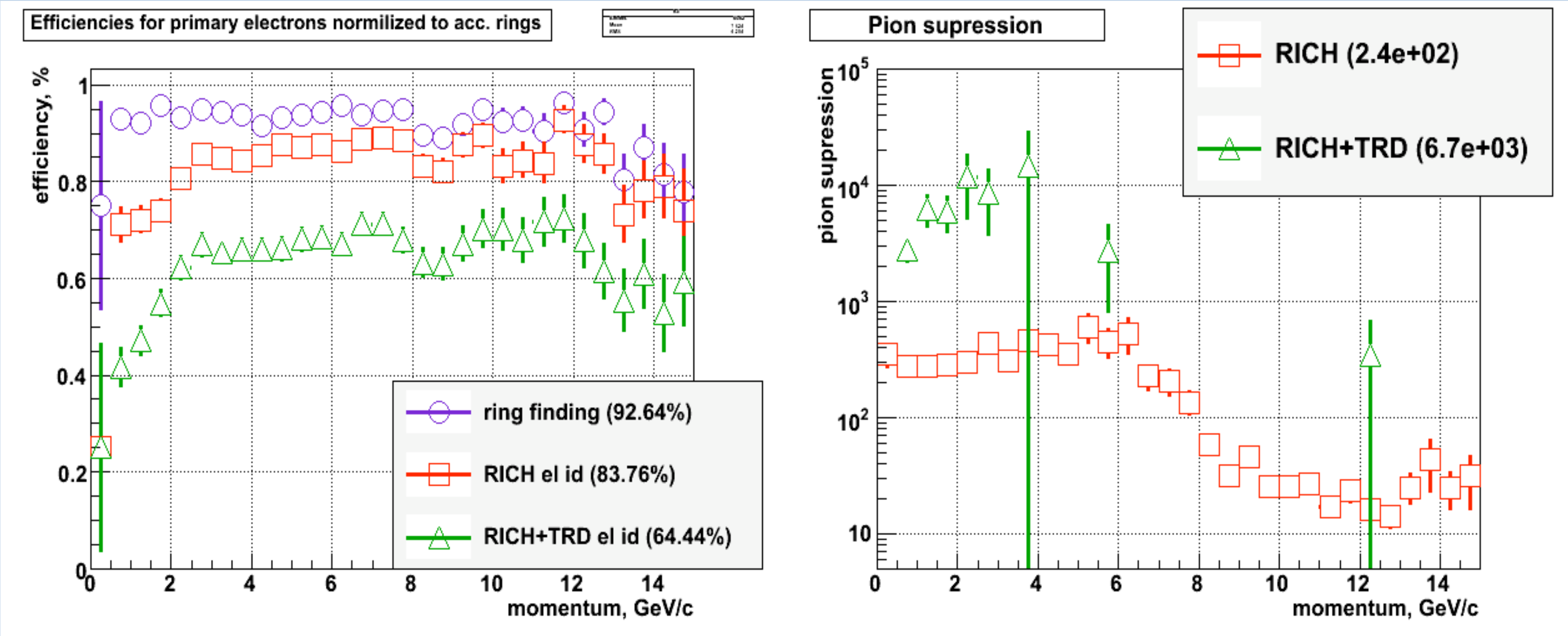


- 10 – 12 independent measurements of energy deposit (dE/dx + transition radiation (for $e^{\pm}$))
- Identification by
  - summed en energy deposit
  - neural net
  - statistical methods (ω^k_n, likelihood, ...)
- Pion suppression > 200 achievable



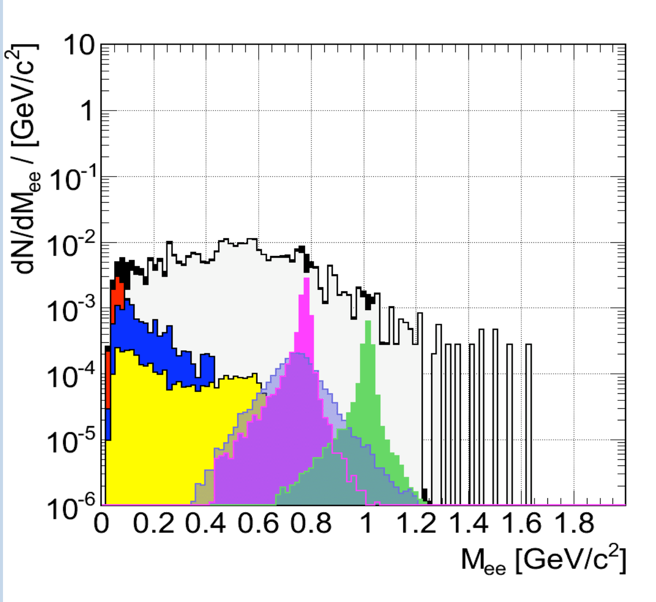


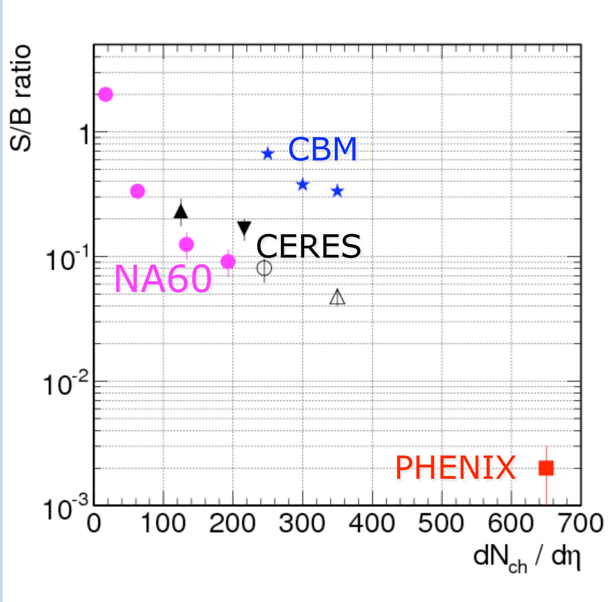
Combined electron identification

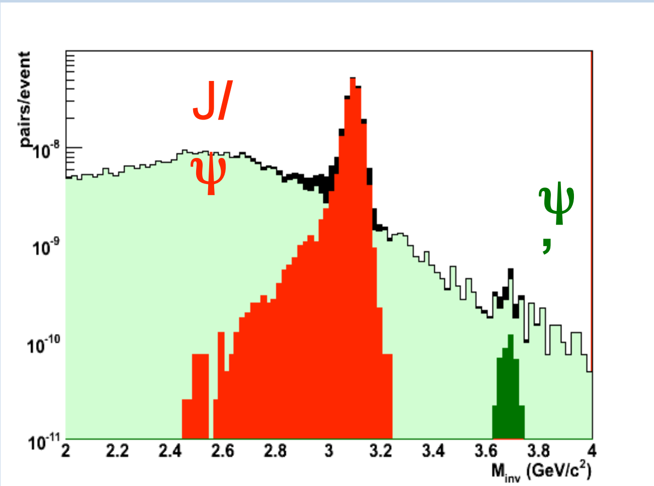


- The combined RICH+TRD pion suppression is > 1000 at an electron efficiency of ≈70 %
- This satisfies the requirements posed by low-mass vector meson and charmonium measurements
- Improvement at low momenta with TOF, at high momenta with ECAL under investigation

Performance for di-electrons



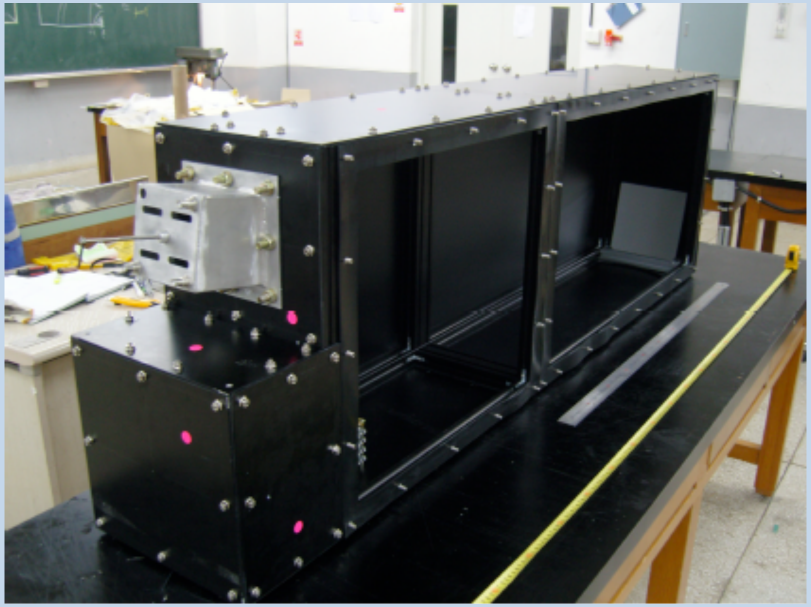




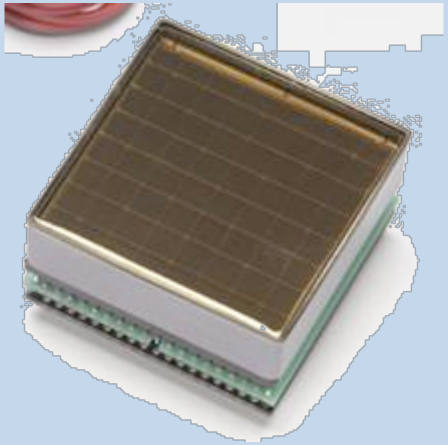
Charmonium well visible above background

Good S/B for low-mass vector mesons

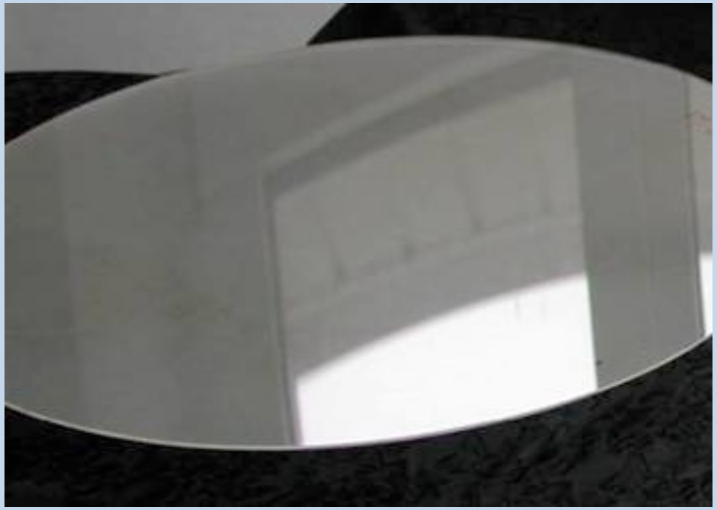
R&D on RICH Components



RICH prototype in Pusan

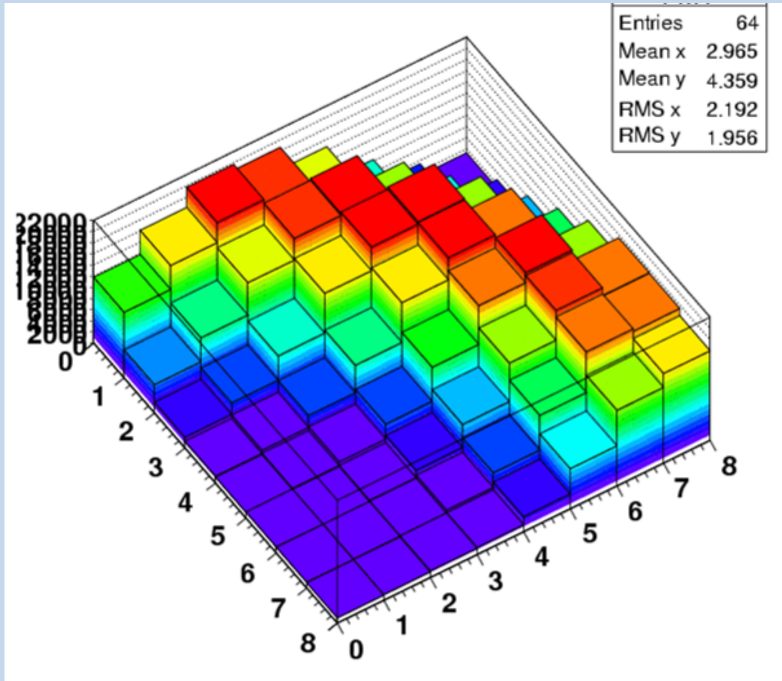


Hamamatsu MAPD



Mirror development

MAPDs in Beam Test @ GSI



Successful operation in self triggered readout chain

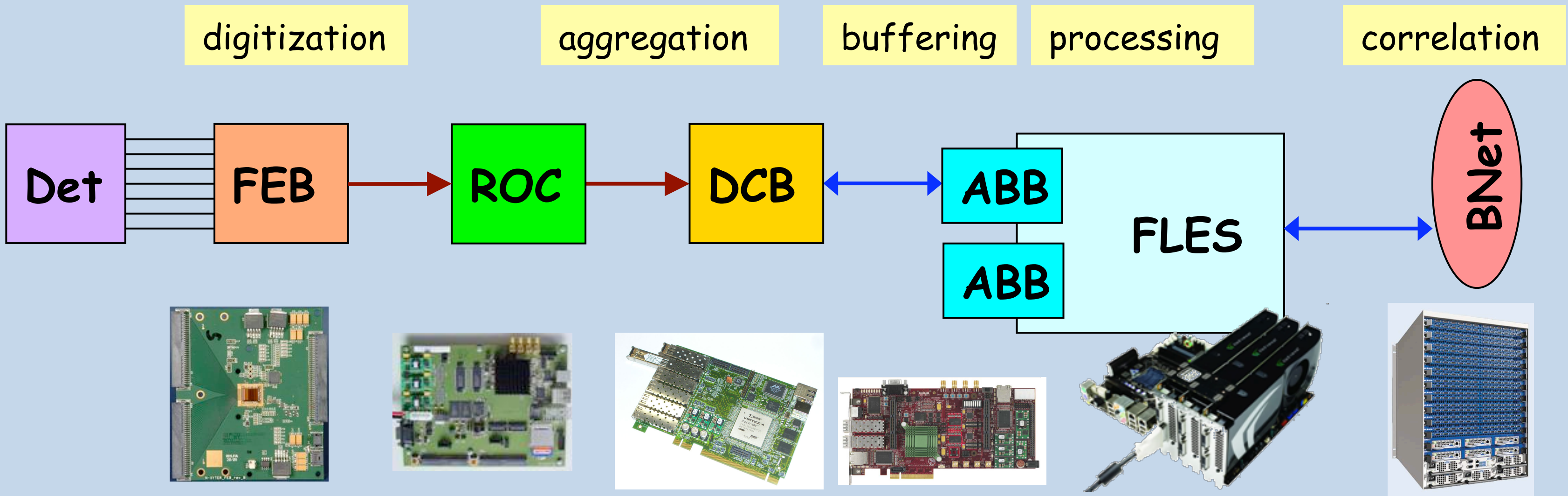
¼ cherenkov ring clearly visible

New DAQ concept

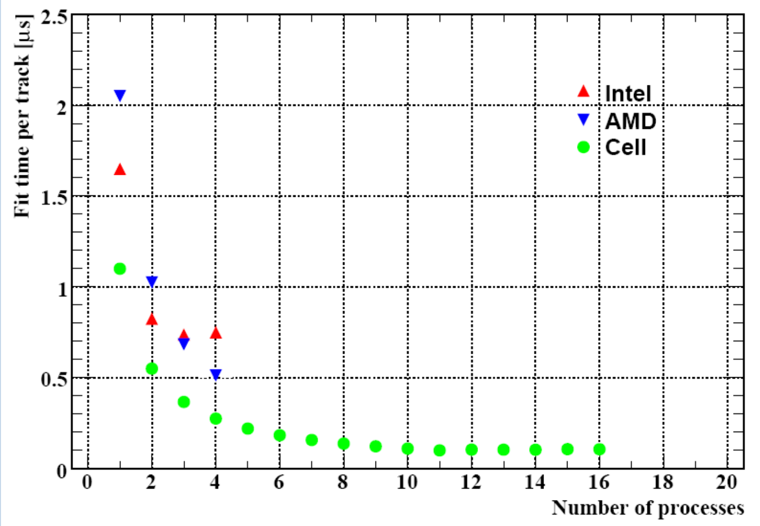
Extreme event and data rates (up to 1 TB/s from FEE) require new DAQ and FLES strategies

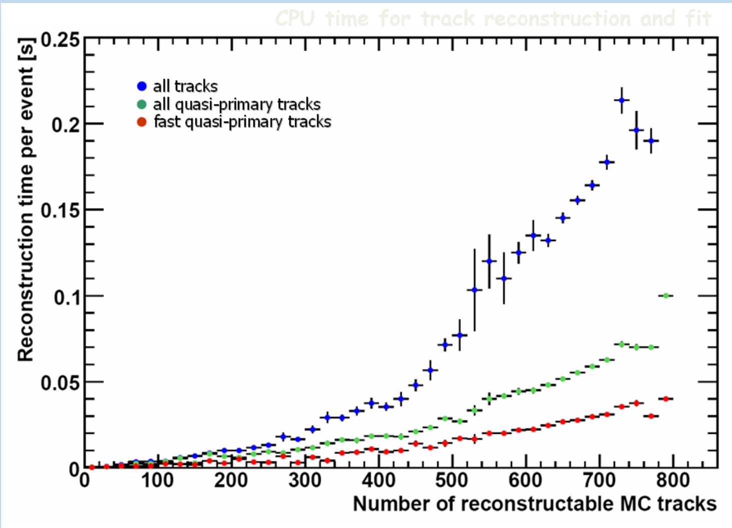
No convential trigger mode, but self-triggered, free-streaming FEE with time tags

FEE and DAQ components under development and testing at GSI; first successful test of free-streaming R/O chain in 2008



Fast event reconstruction





FLES has to reduce the raw data rate (1 TB/s) to the recordable rate (1 GB/s)

Necessity of (partial) event reconstruction online at MHz rates

Novel algorithms and implementations to exploit modern / future computer architectures

Paradigmata: vectorisation and parallelisation

Current event reconstruction time in STS: 50 ms

Stage	Description	Time/track	Speedup
	Initial scalar version	12 ms	–
1	Approximation of the magnetic field	240 μs	50
2	Optimization of the algorithm	7.2 μs	35
3	Vectorization	1.6 μs	4.5
4	Porting to SPE	1.1 μs	1.5
5	Parallelization on 16 SPEs	0.1 μs	10
	Final simdized version	0.1 μs	120000