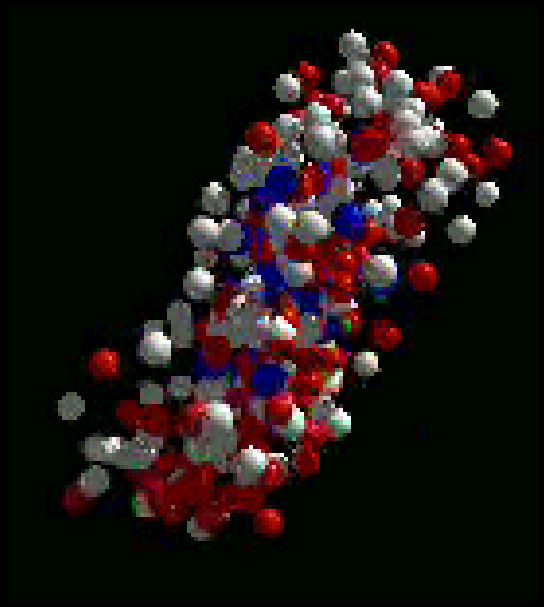
Experiment CBM at FAIR
(Compressed Baryonic Matter)



Yuri Zaitsev (ITEP)

CBM Collaboration

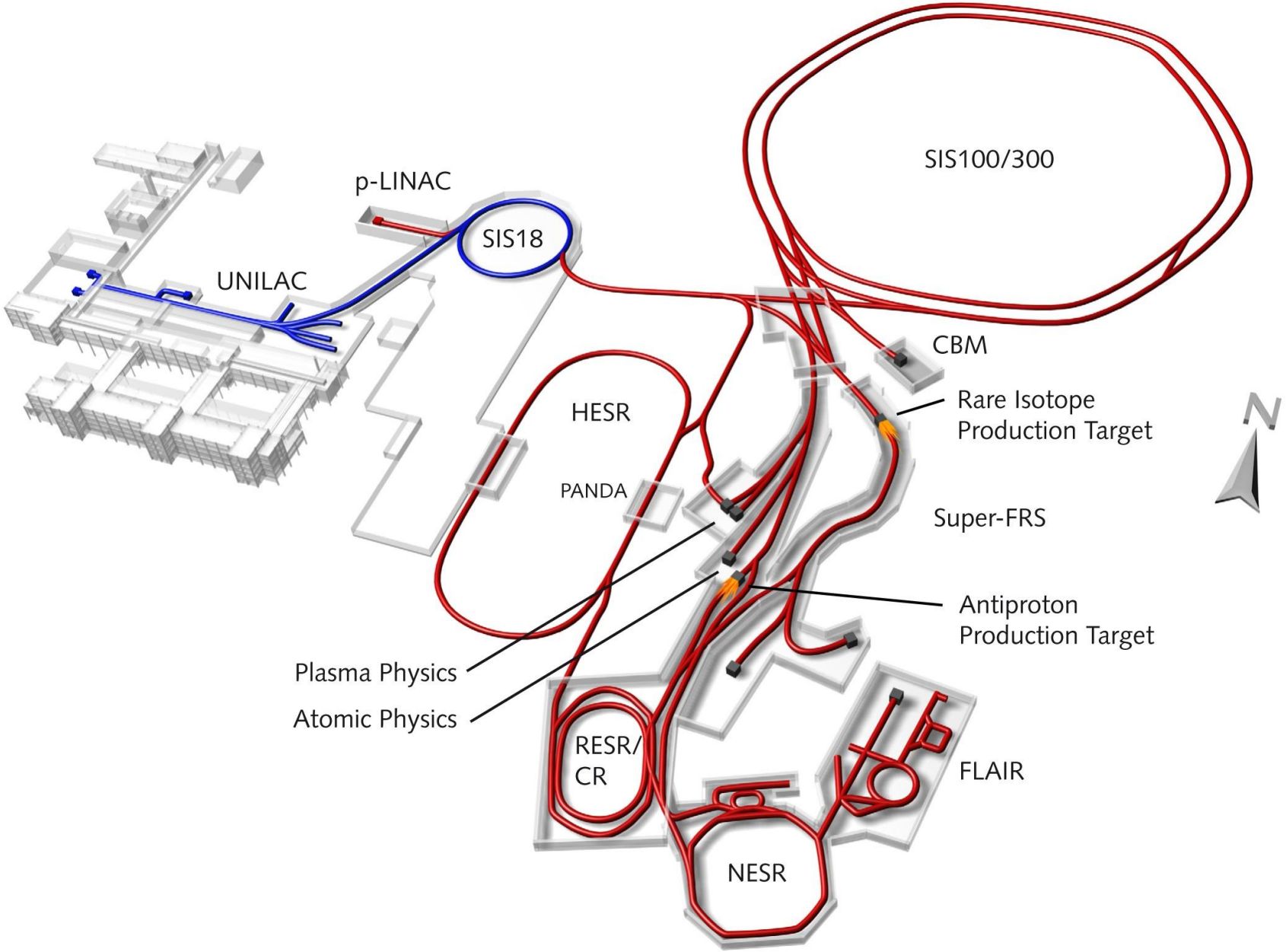
14 countries

59 institutes

~450 physicists

21 February 2012,Bekasovo

The goal: realization of the full FAIR version

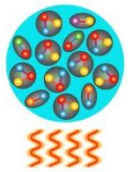


Goal of high energy heavy-ion physics

Study of in-medium properties of hadrons and nuclear matter equation of state including a search for possible signs of deconfinement and/or chiral symmetry restoration phase transitions and QCD critical end-point

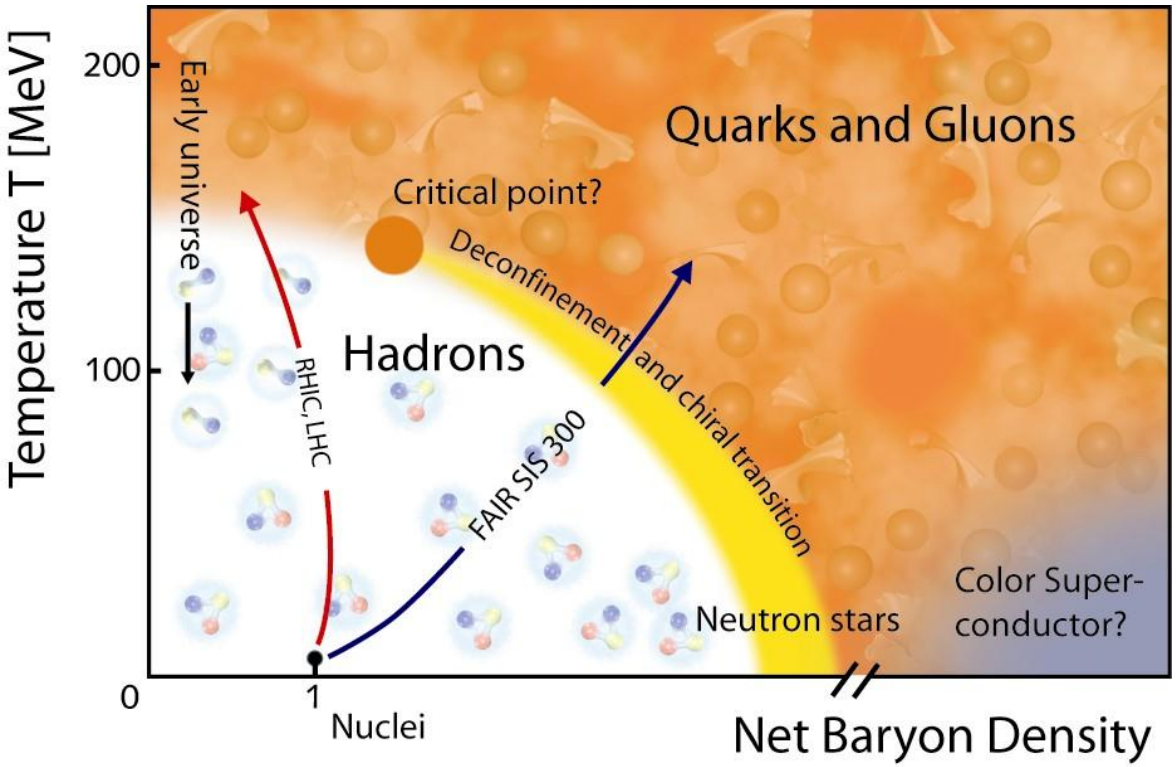
- **C**ompressed **B**aryonic **M**atter experiment (**CBM**)
- SIS 300 → U^{92+} 15-35 GeV/nucleon with beam intensities up to 10^9/s

  Z/A = 0.5 nuclei up to 45 GeV/nucleon



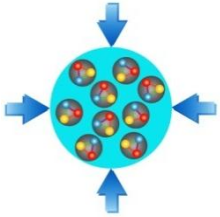
→ **exploration of the QCD phase diagram with heavy-ion collisions!**

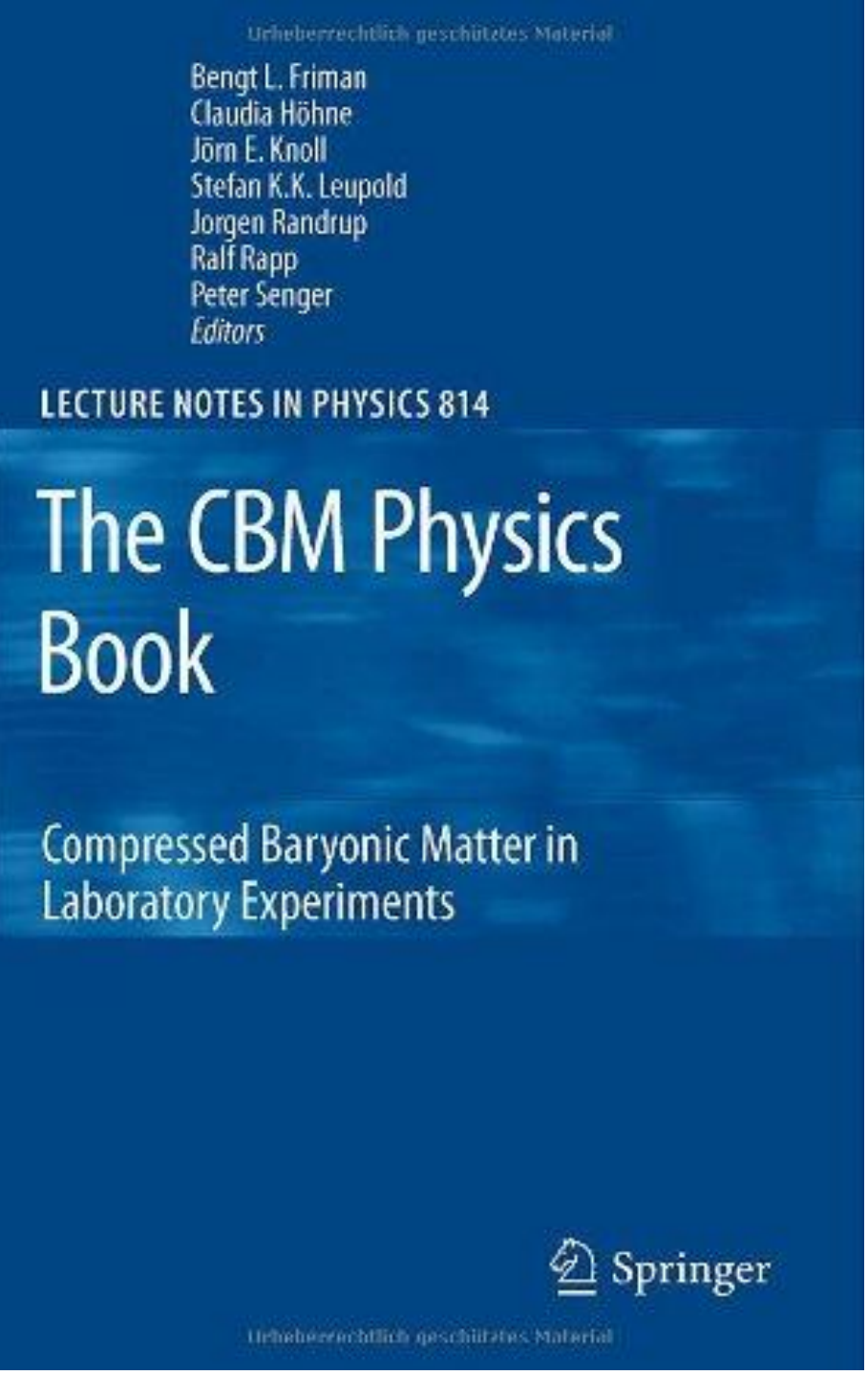
→ **investigation of nuclear matter at highest baryon densities but still moderate temperatures in A+A collisions**



The chemical potential of a thermodynamic system is the amount by which the energy of the system would change if an additional particle introduced, with the entropy and volume held fixed.

If a system contains more then one species of particle, there is a separate chemical potential associated with each species, defined is a change in energy when the number of particles of that species is increased by one.





The CBM Physics book is available now:
Springer Series:
Lecture Notes in Physics, Vol. 814
1st Edition., 2011, 960 p., Hardcover
ISBN: 978-3-642-13292-6

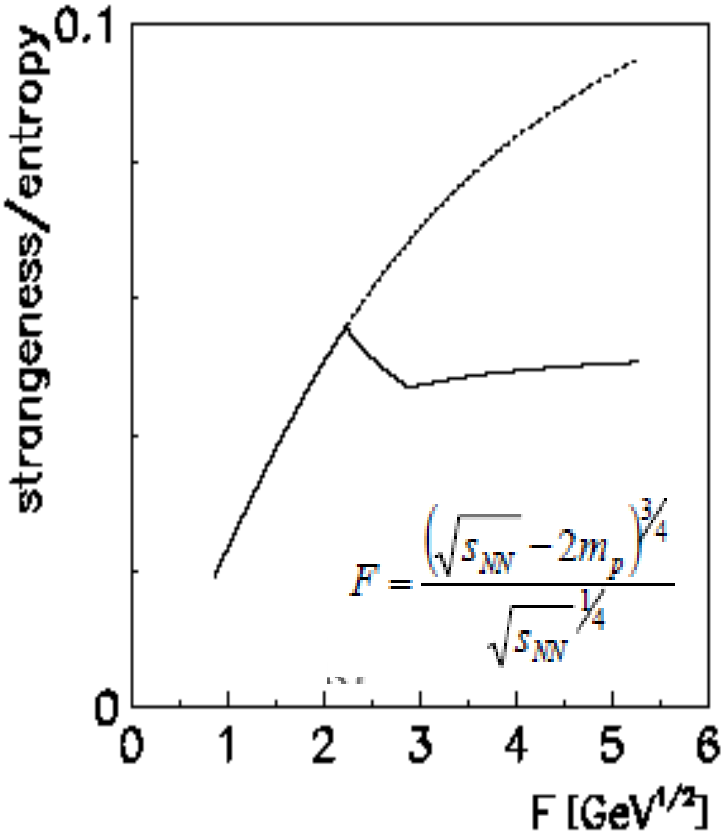
Physics case & observables

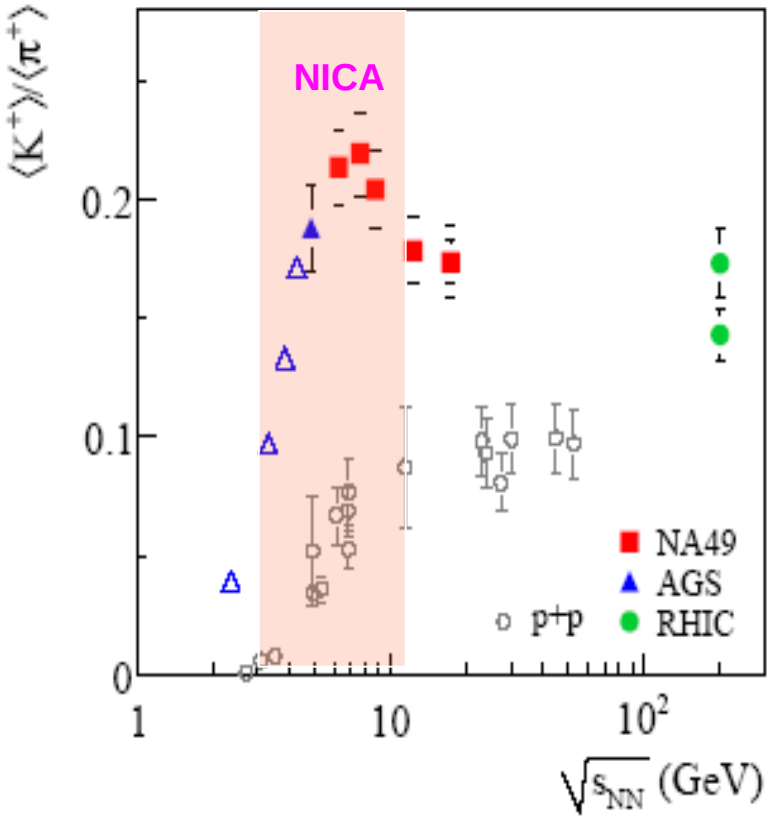
- Anti-proton to proton ratio
- Baryon to meson ratios
- Charged particle directed flow
- Charged particle elliptic flow
- Elliptic flow for identified hadrons & photons
- Femtoscopy of identical particles
- Femtoscopy of Kπ, Ξπ, Ωπ , etc
- Fluctuations of particle ratios, esp. K/π, p/π
- Fluctuations of $\langle p_T \rangle$, $\langle v_2 \rangle$, photon multiplicity, etc
- Hyperons and light hypernuclei
- Invariant mass and p_T distributions of leptons
- Longe-range forward-backward correlations

Physics case & observables, cont.

- Rapidity and p_T spectra of identified hadrons
- Production of light nuclei and antinuclei
- Strange to non-strange ratios for mesons and baryons
- Triggered azimuthal correlations
- Untriggered pair correlation in $\Delta\varphi$ and $\Delta\eta$
- Yields of strange particles
- Multistrange hyperons
- In-medium properties of vector mesons
- Production of charmonium states at threshold: J/ψ, χ_{c1}, χ_{c2}, ψ'
- Open charm production & propagation in nuclear matter
- Shockwaves
- etc ...

Strange to non-strange particle ratio, «horn»

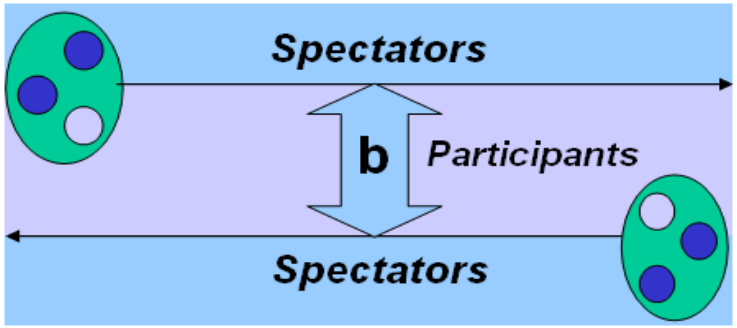




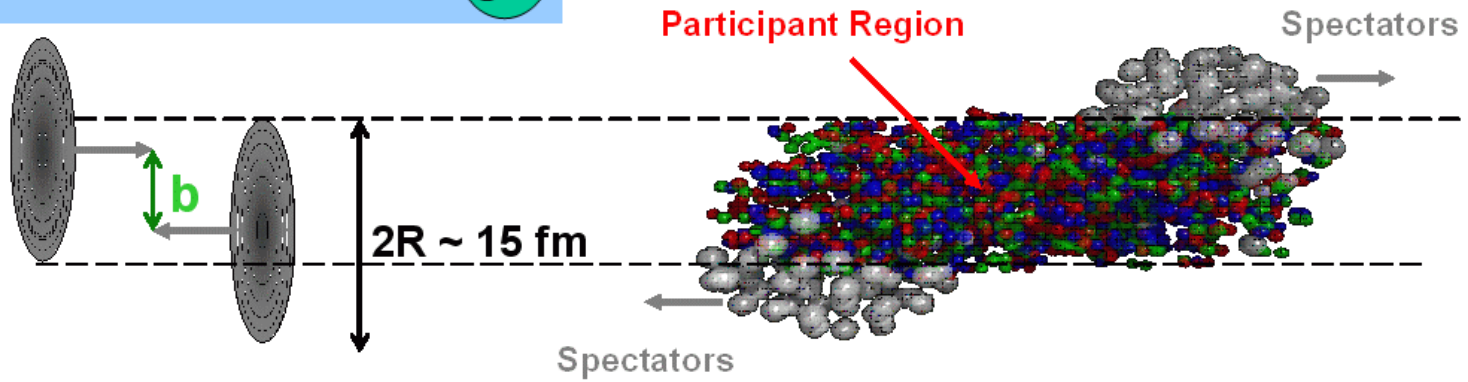
M.Gazdzicki, M.I.Gorenstein,
Acta Phys. Pol. **B30** (1999) 2705

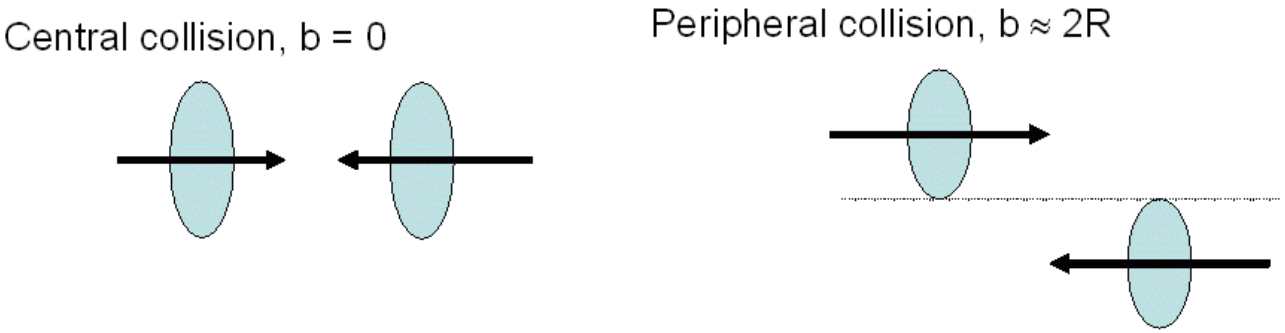
M.Gazdzicki, arXiv:0712.3001

The centrality determination – the observables:

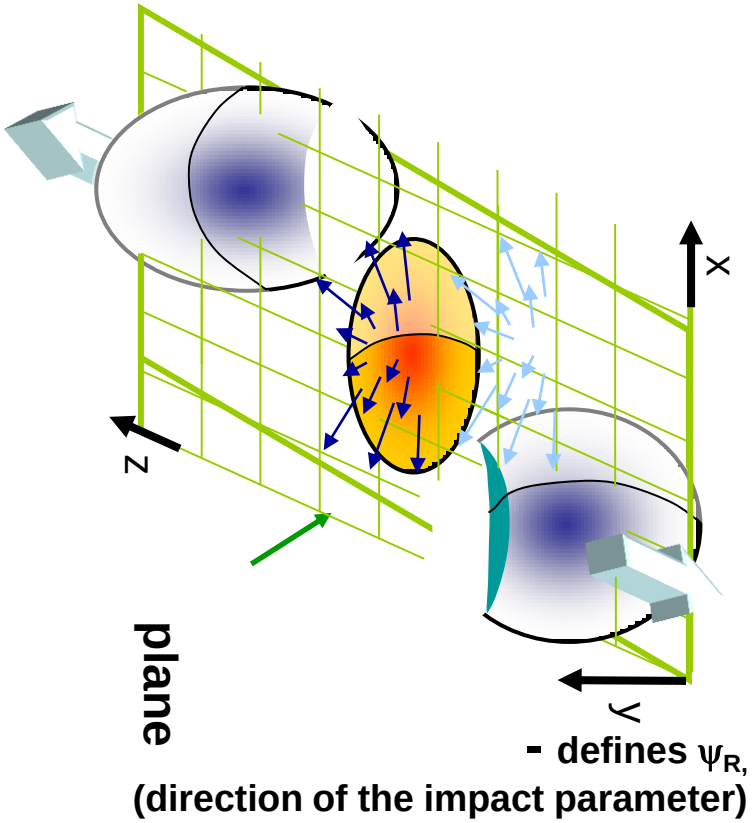


- **The number of particles produced in the region of rapidity close to zero**
- **The total energy of spectators**





remarks on AC



- defines ψ_R,
(direction of the impact parameter)

centrality is (not directly measurable) event variable common to most of tasks

its value is correlated to impact parameter of a collision

for task on Azimuthal Correlation the centrality determination has to be then followed Reaction Plane evaluation

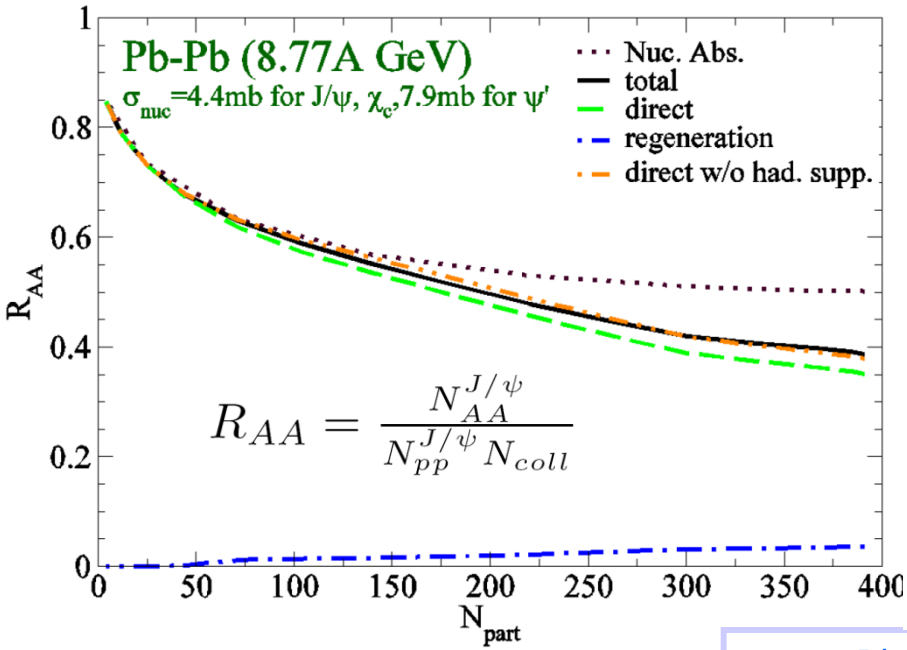
$$dN/d(\phi-\phi_{RP}) \sim \Sigma\, v_n \cos [\, n\,(\phi - \phi_{RP})\,]$$

$v_1 = \langle \cos[\phi - \phi_{RP}] \rangle$ directed flow

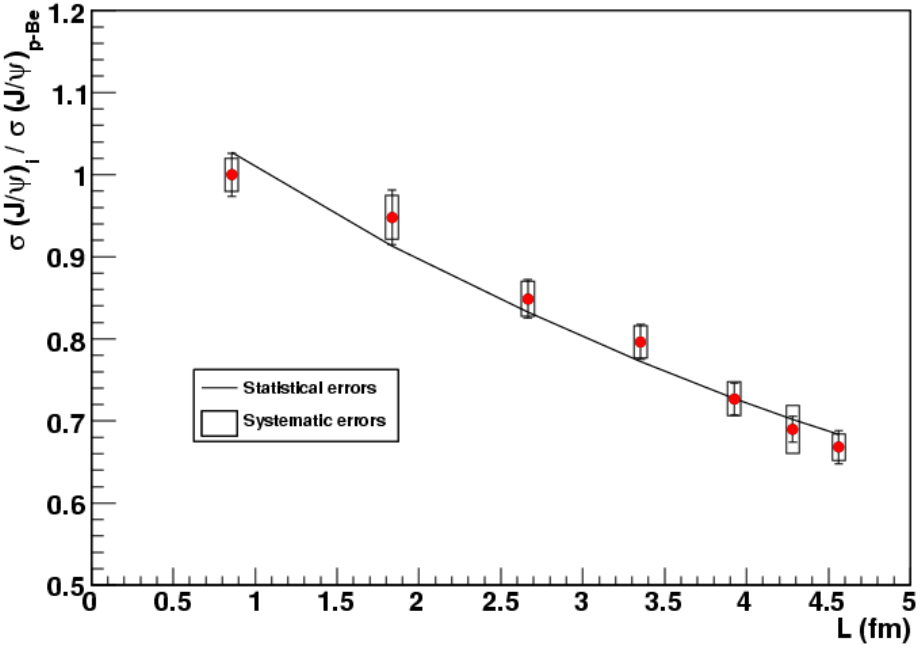
$v_2 = \langle \cos[2(\phi - \phi_{RP})] \rangle$ elliptic flow

Heavy flavor physics: Charmonium propagation in nuclear matter

J/ψ suppression at FAIR energies dominated by nuclear absorption (Xingbo Zhao and Ralf Rapp)



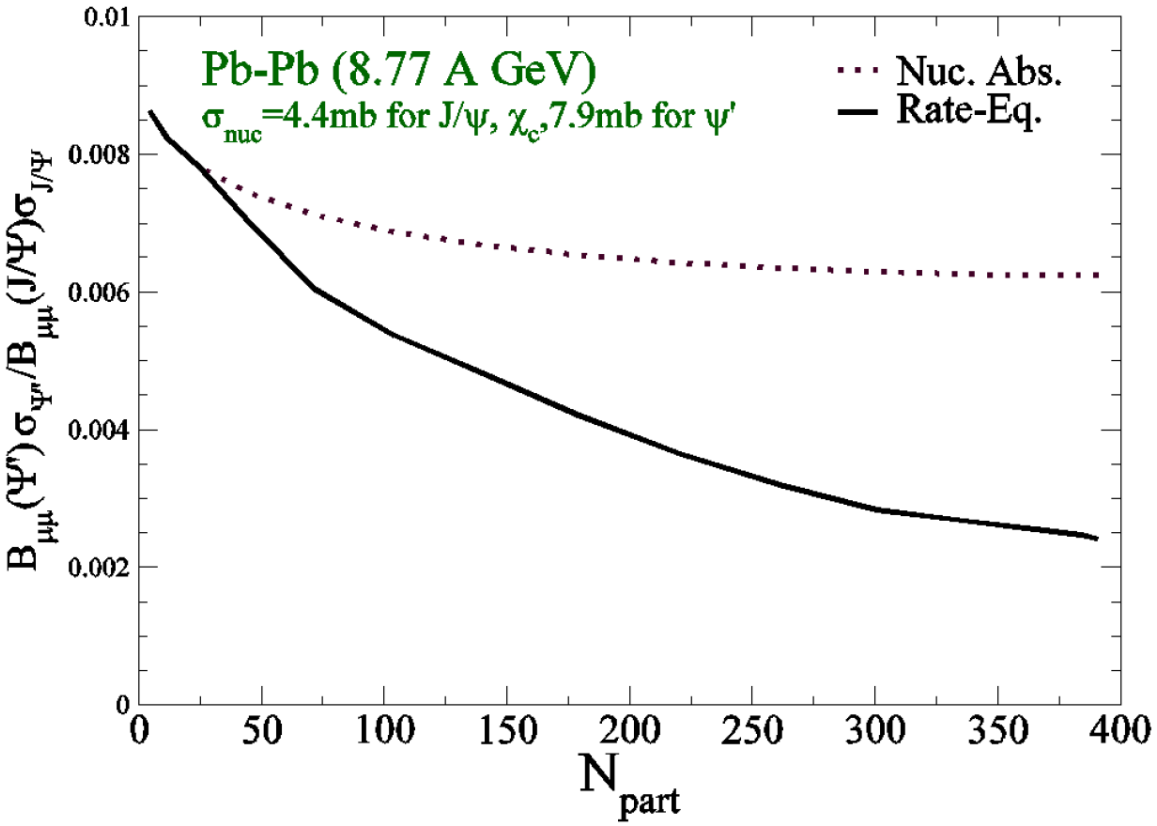
NA60 data: 158 GeV p+A
E. Scomparin, QM2009



$\sigma_{abs}^{J/\psi}$ (158 GeV) = 7.6 ± 0.7 ± 0.6 mb
$\sigma_{abs}^{J/\psi}$ (400 GeV) = 4.3 ± 0.8 ± 0.6 mb

Measure: p + C (..... Au) → J/ψ + X

Heavy flavor physics: In-medium properties of D-mesons



Xingbo Zhao and Ralf Rapp

D meson mass modification affects the ψ'/(J/ψ) ratio

New absorption mechanism in nuclear medium if D meson mass reduced: $\psi' \rightarrow D^+D^-$

Not possible in vacuum: ψ'(3686 MeV) < D^+D^-(3738 MeV)

Measure: p + C (..... Au) → J/ψ, ψ'

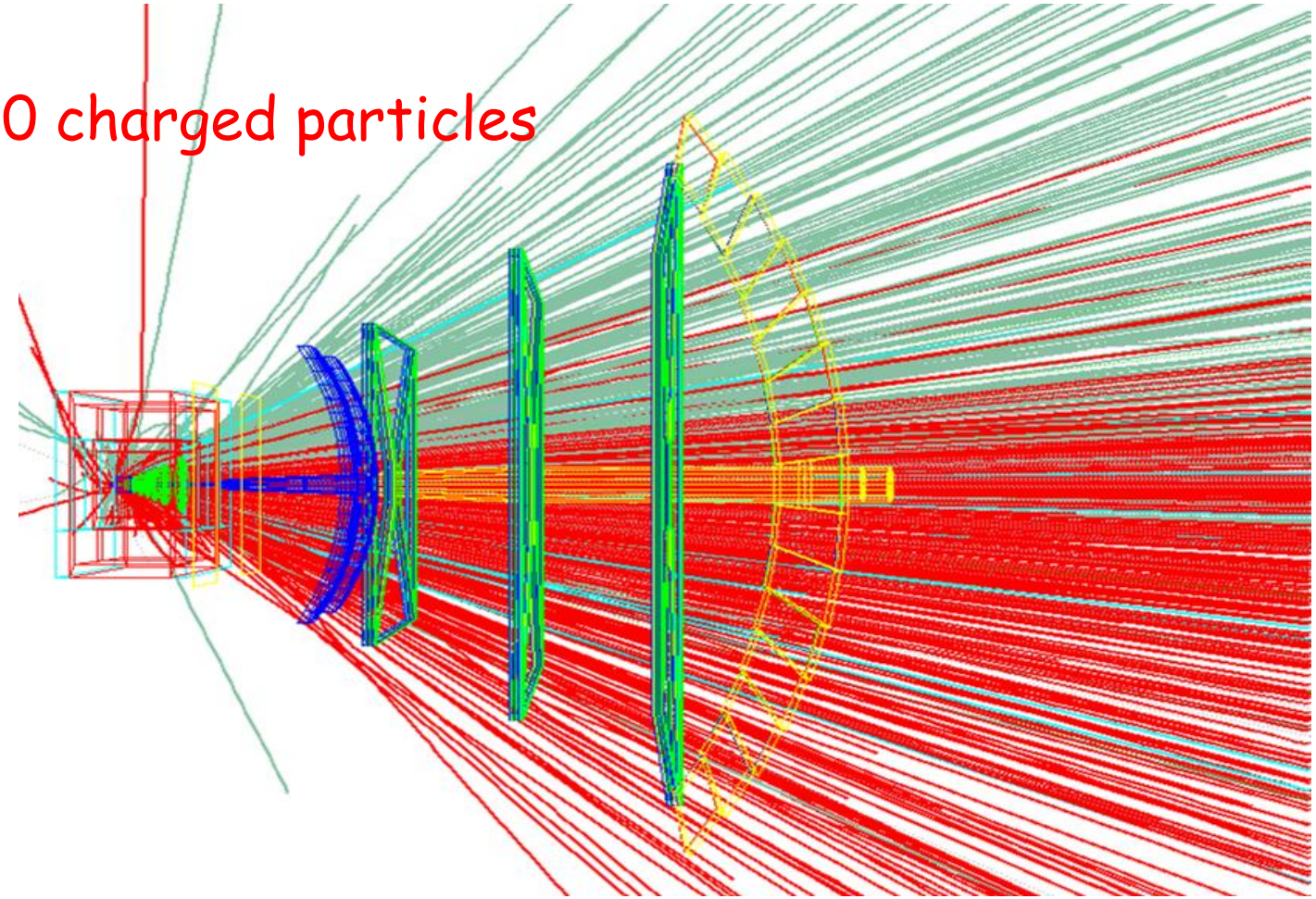
Experimental challenges

Central Au+Au collision at 25 AGeV:
URQMD + GEANT4

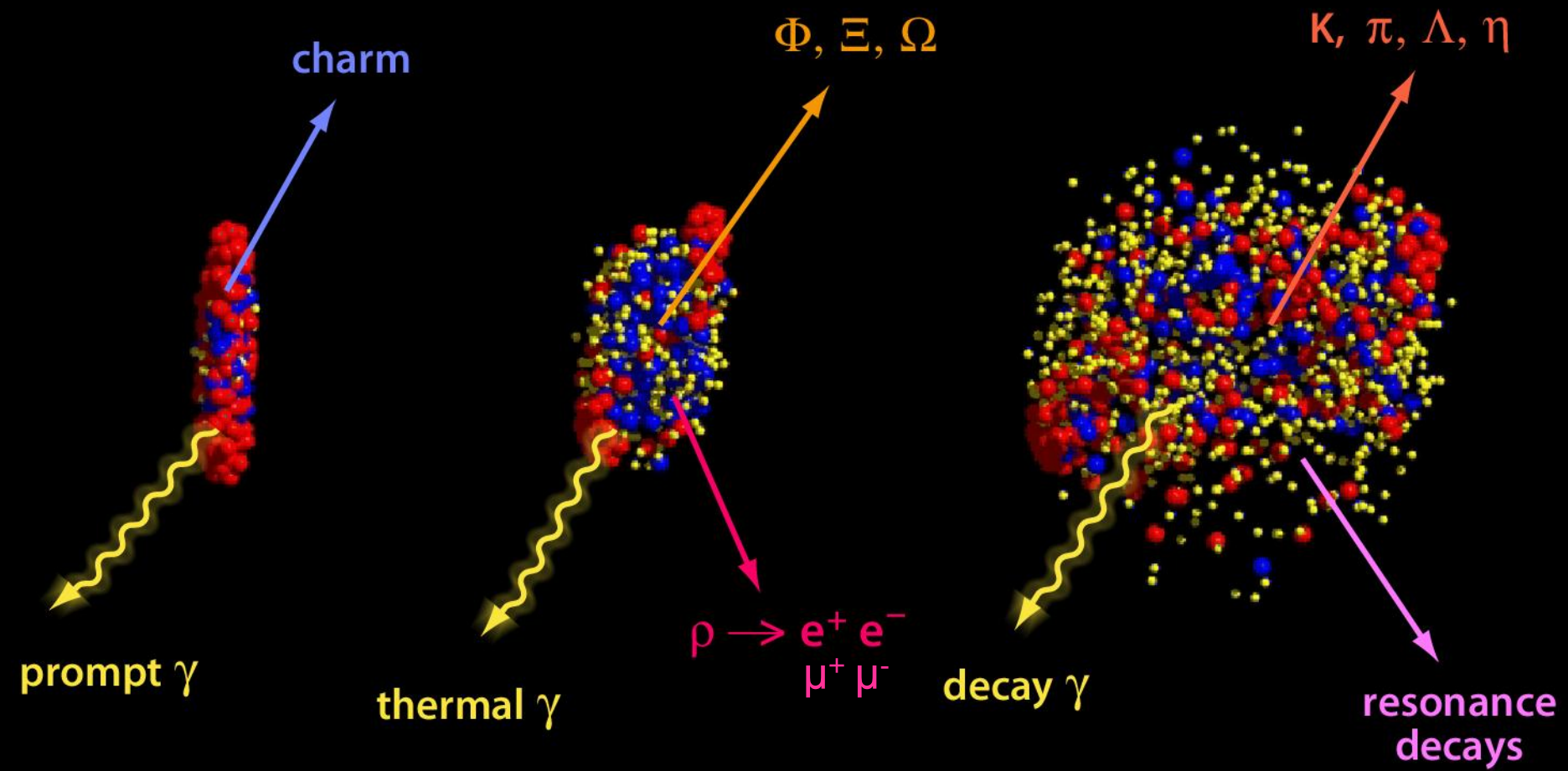
More then 1000 charged particles

160 p
400 π^-
400 π^+
44 K^+
13 K^-

and Photons
Electrons
Muons



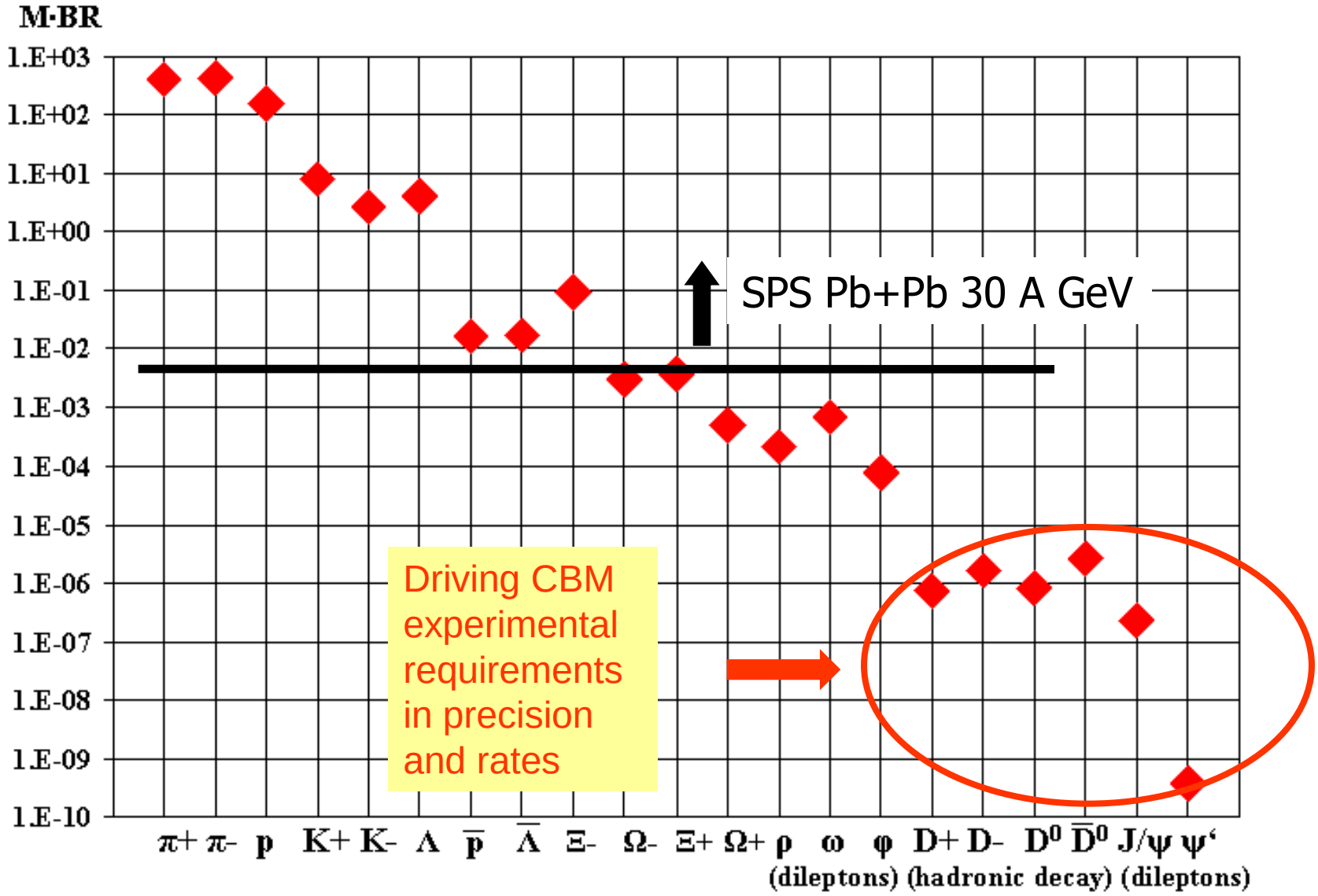
CBM strategy: measure messengers from the dense fireball



Up to date only freeze-out probes have been measured in A+A collisions at 2 - 40 AGeV

CBM experimental challenges

(example: min. bias Au+Au collisions at 25 GeV)



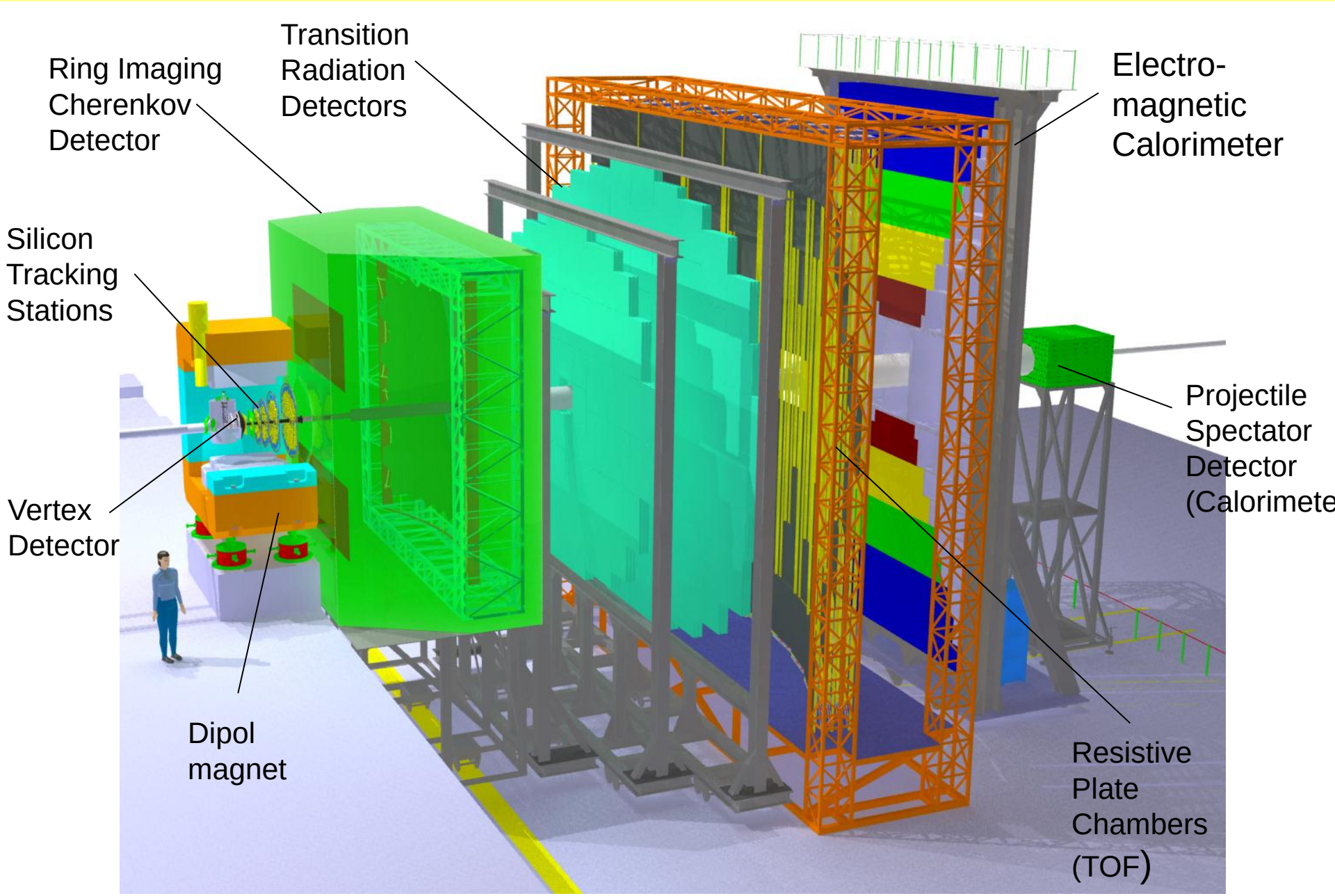
Experimental challenges II

- 10^5 - 10^7 Au+Au reactions/sec
- determination of (displaced) vertices with high resolution ($\approx$ 50 μm)
- identification of leptons and hadrons
- fast and radiation hard detectors
- self-triggered readout electronics
- high performance computer farm for online event selection
- 4 D track reconstruction

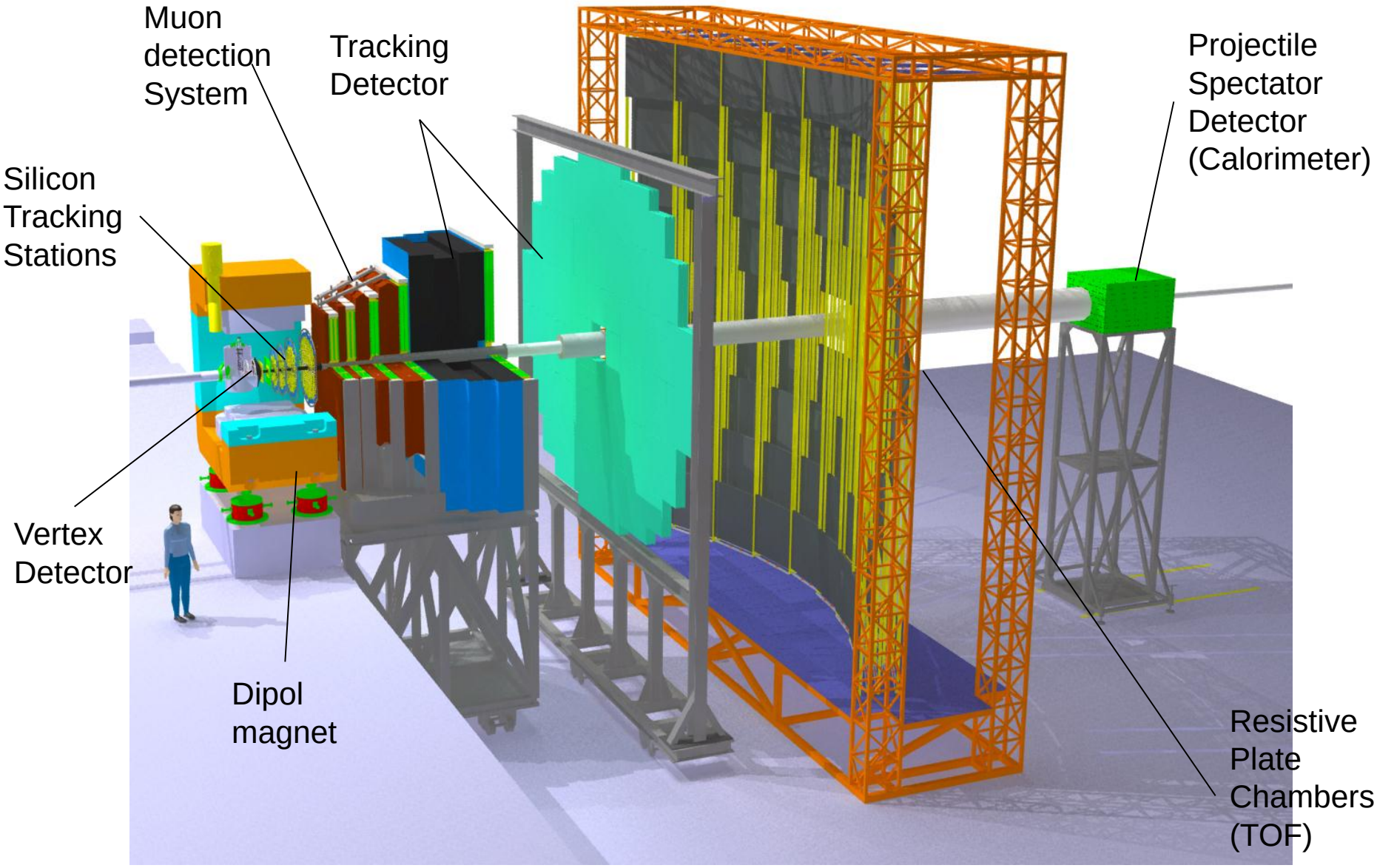
Experimental challenges III

Momentum measurement	– very high granularity silicon strip detectors in the magnetic field (STS)
Vertex measurement	– micro vertex pad detector (MPD + STS)
Hadrons identification	– fast (<100 ps), high granularity time-of-flight system (TOF)
Electron identification	- ring imaging cherenkov counters (RICH), transition radiation detectors (TRD), electromagnetic calorimeter
Muon identification	- special muon detector (MUCH)
Photon measurement	- electromagnetic calorimeter (ECAL)

The Compressed Baryonic Matter Detector (CBM)

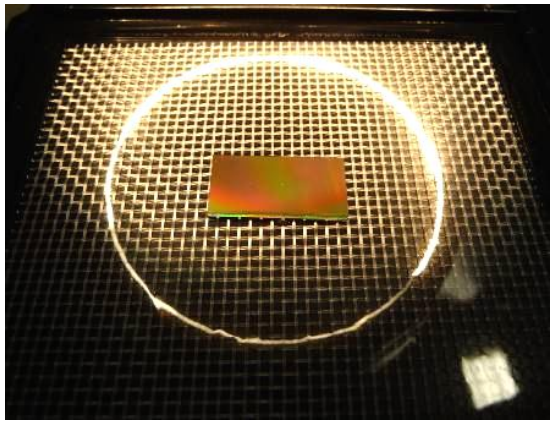


The CBM muon option



The CBM Micro-Vertex Detector (MVD)

Monolithic Active Pixel Sensors (MAPS)



Single point resolution 1.5 – 2.5 µm

Pixel-pitch 10 -40 µm

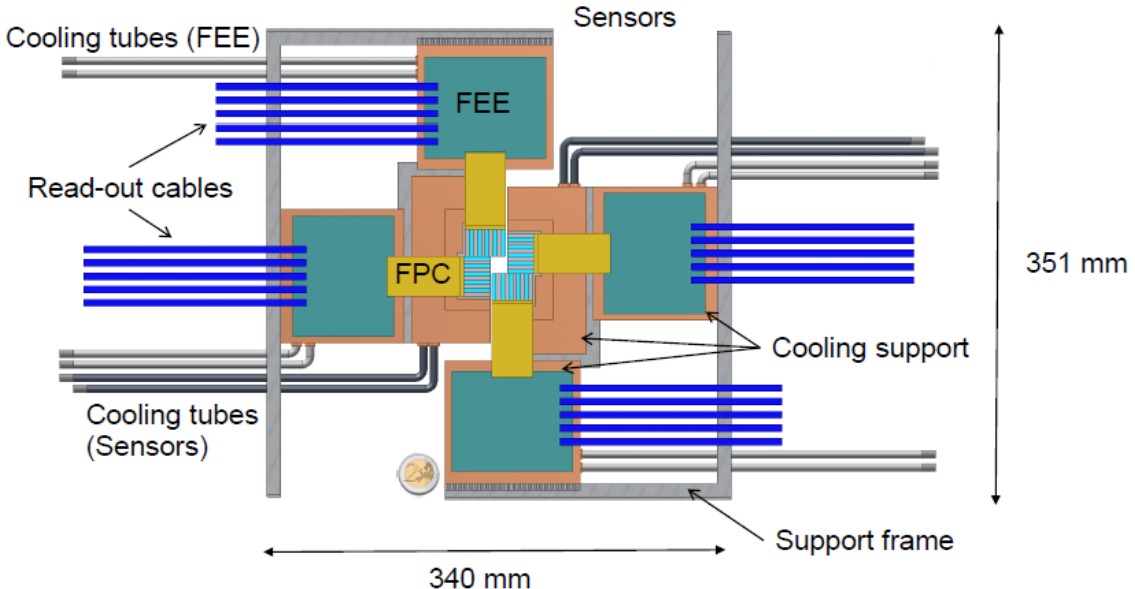
Thinning achieved 50 – 120 µm

S/N for MIPs 20 – 40

Radiation hardness: 1 MRad; 1 x 10^{13} n_{eq}/cm^2

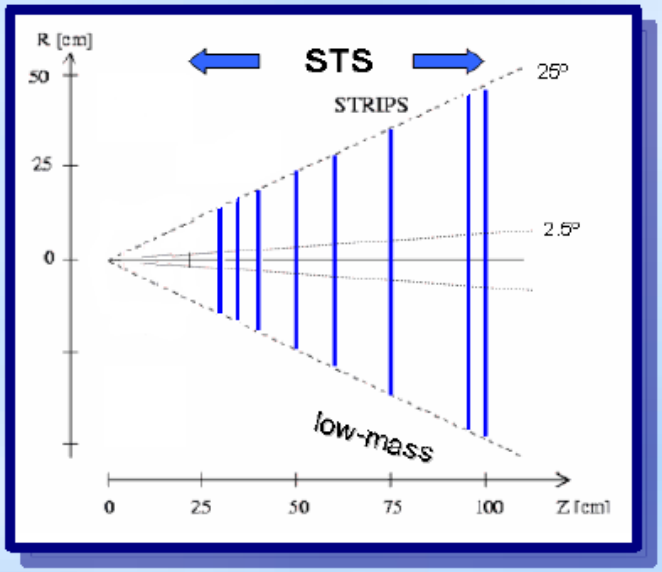
Time resolution ~ 20 µs (massive parallel readout)

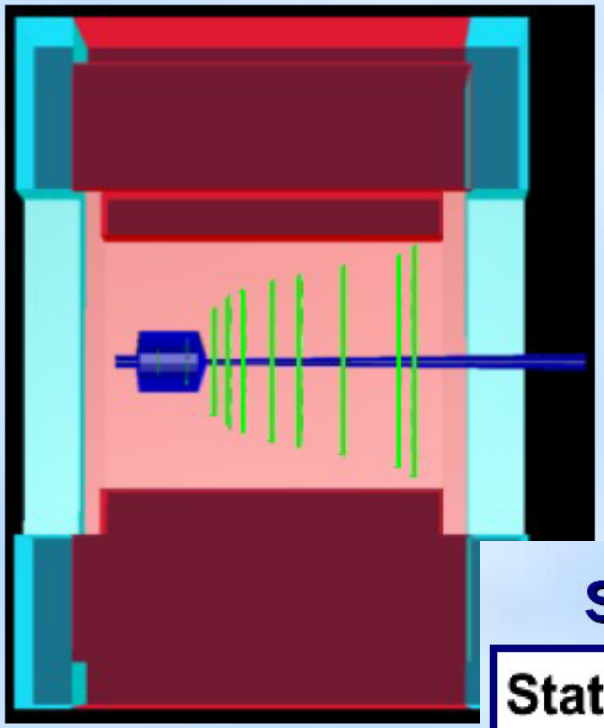
Detector design



Towards a realistic STS in the simulations

STS Detector setup



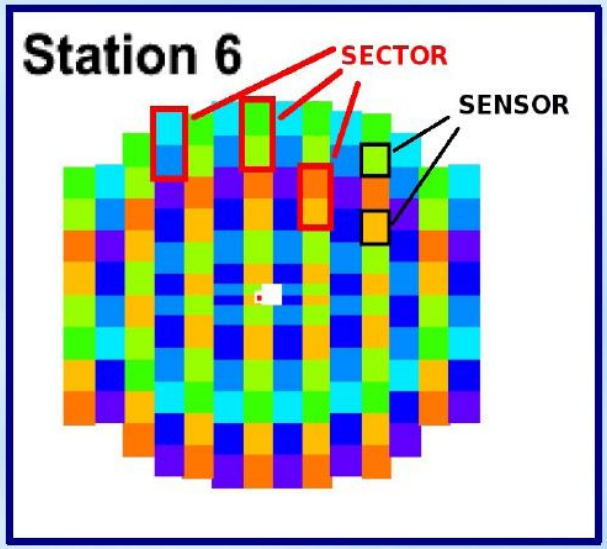


8 stations

fully based on micro-strip detectors

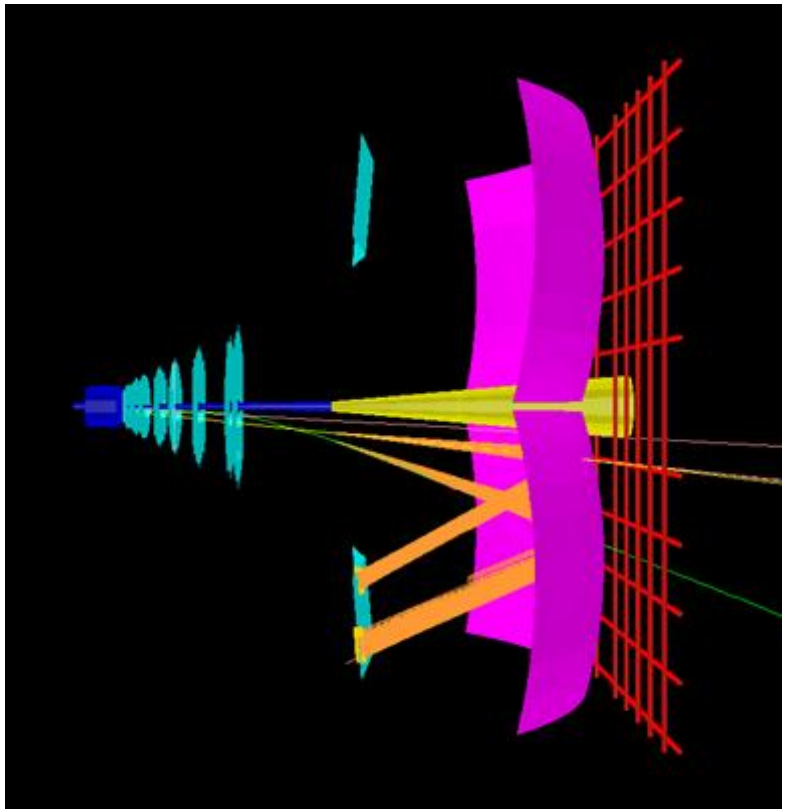
Anna Kotynia

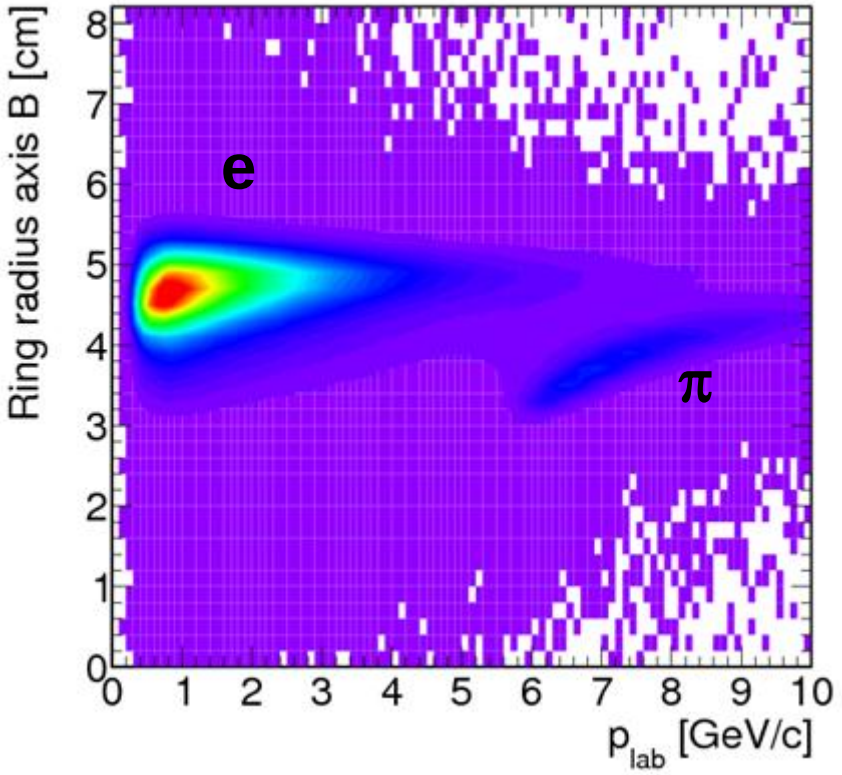
Sectors & sensors



RICH detector for CBM

- **electrons:** Cherenkov radiation, projected into rings
- **pions:** Cherenkov threshold p_{th} = 4.65 GeV/c

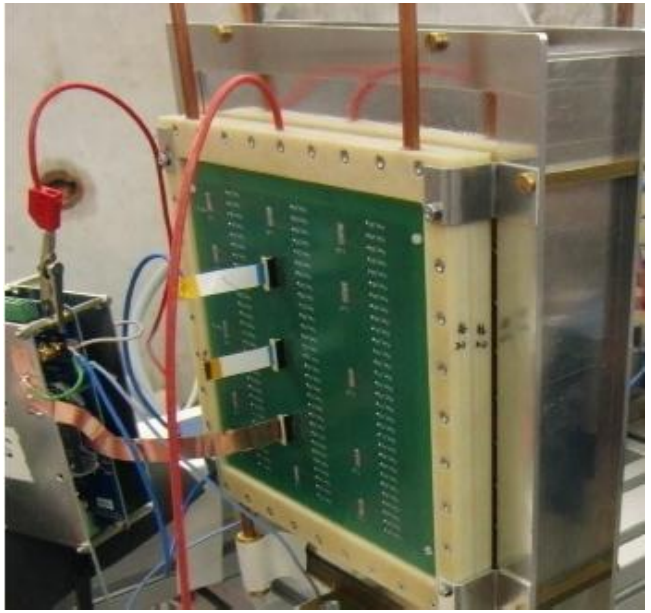




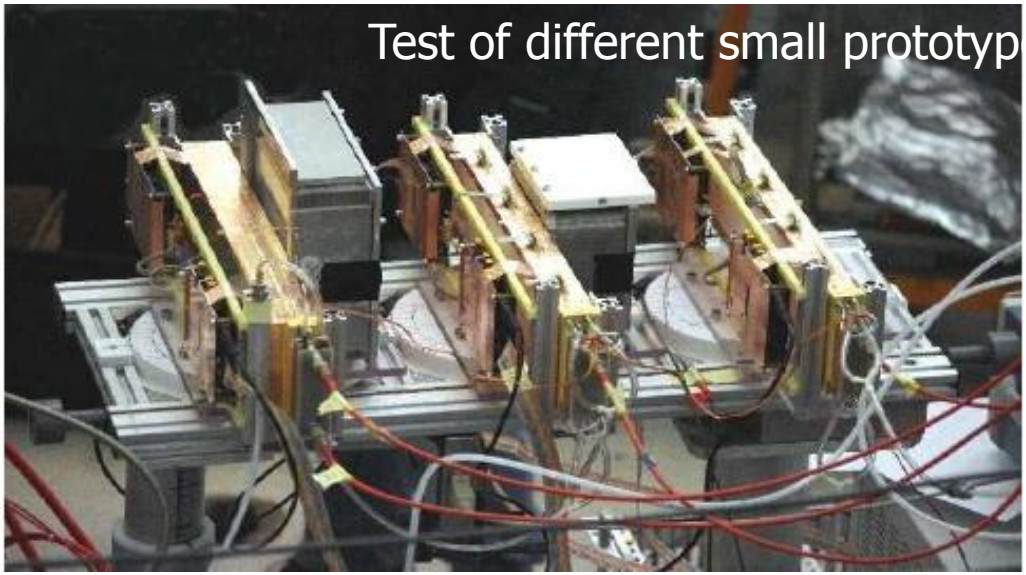
T. Galatyuk, Univ. Frankfurt

The CBM TRD

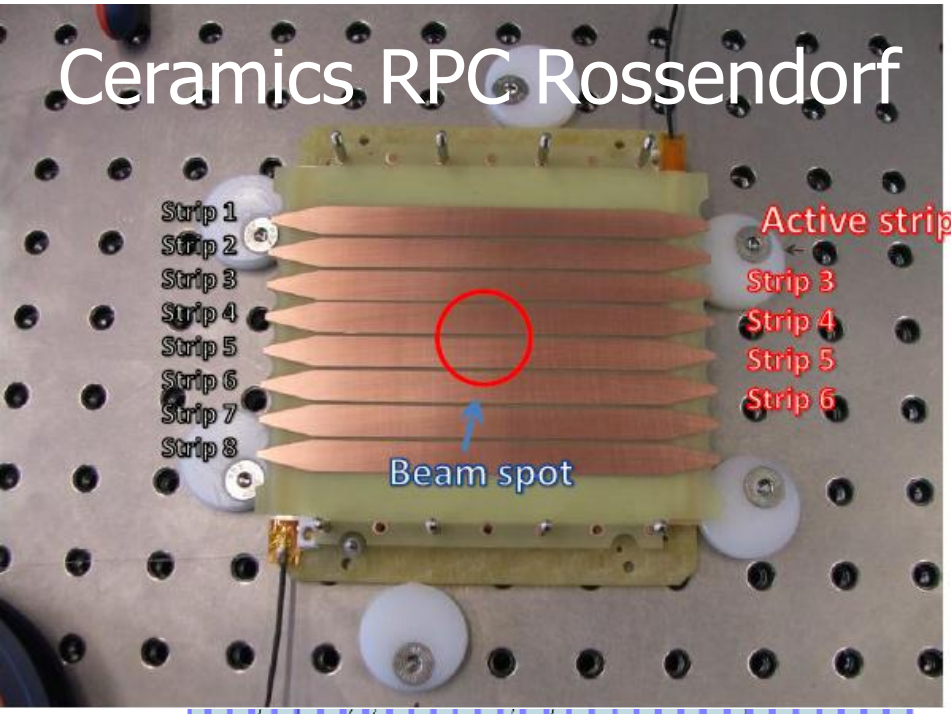
Requirements:
- e/π discrimination of > 100 (p > 1.0 GeV/c)
- active area ~1000 m^2 (12 stations)
- rate capability up to 100 kHz/cm^2
- position resolution about 200 µm

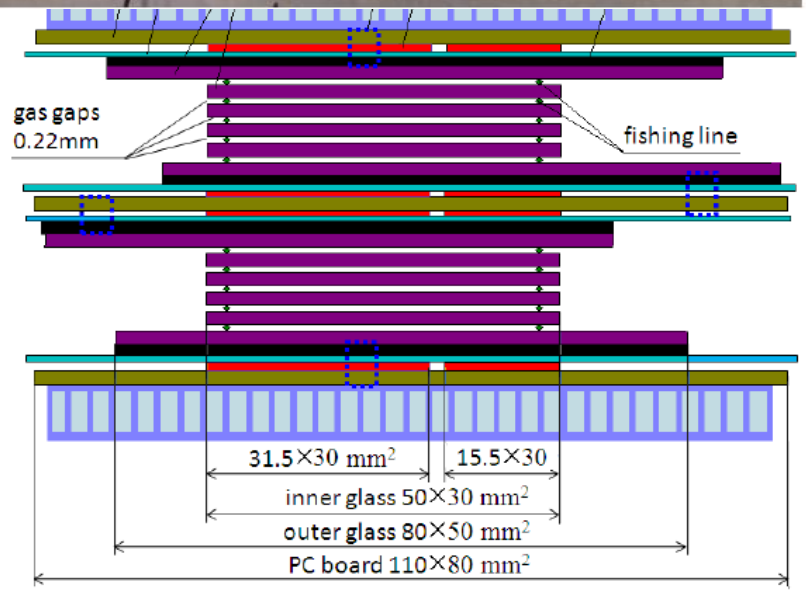


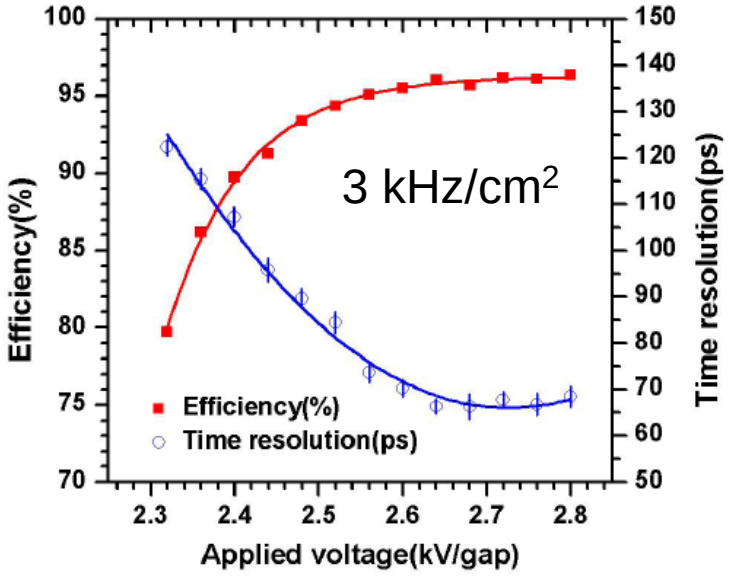
Prototype detectors:
- no drift region
- thickness of gas volume ~1 cm

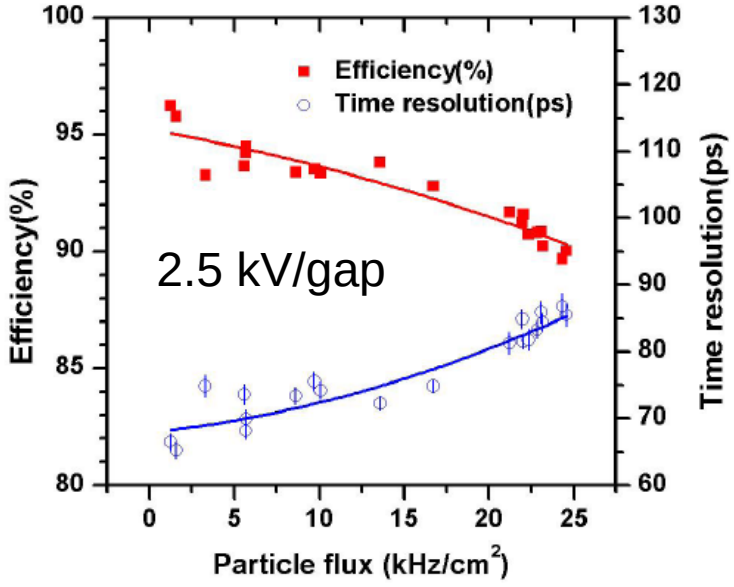


High-rate MRPCs for the CBM TOF detector





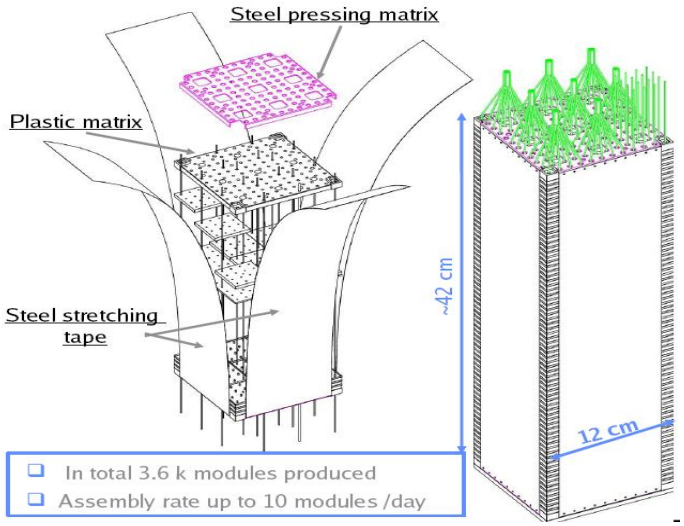


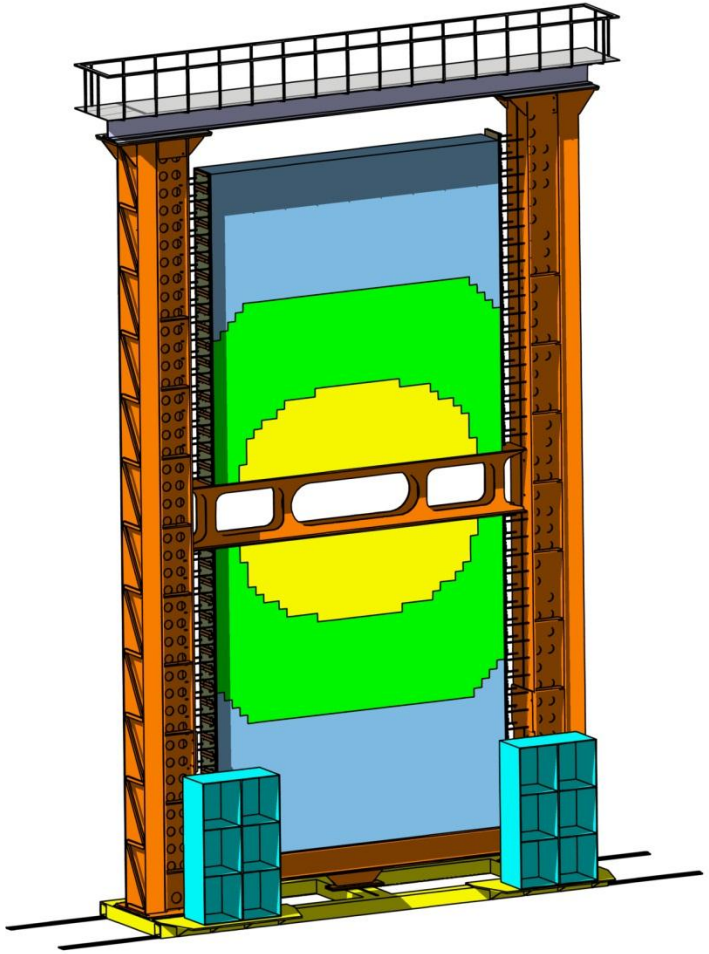


Optimized calorimeter (price)

Main features

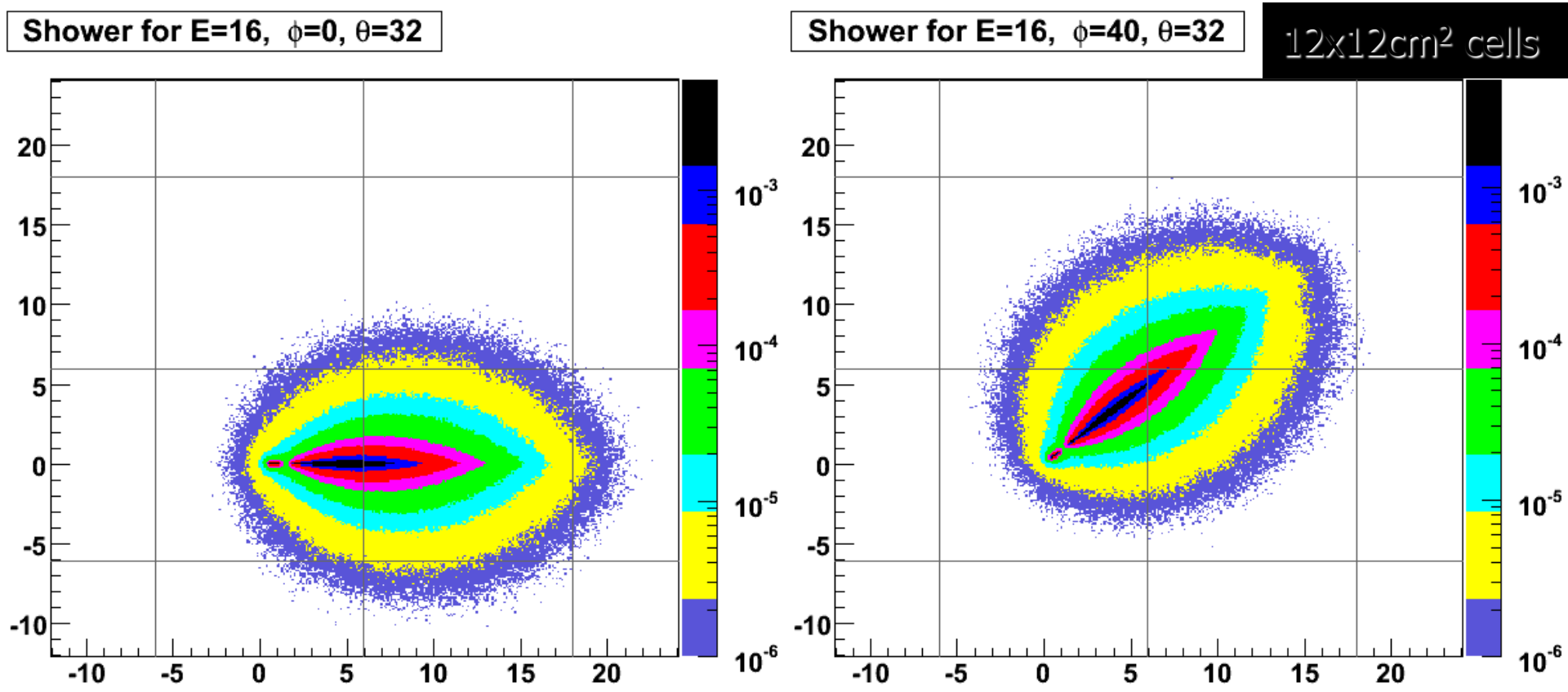
- ~14K channels
- Efficient γ, π^0, η reconstruction
- Electron identification
- Movable design (no central region-???)





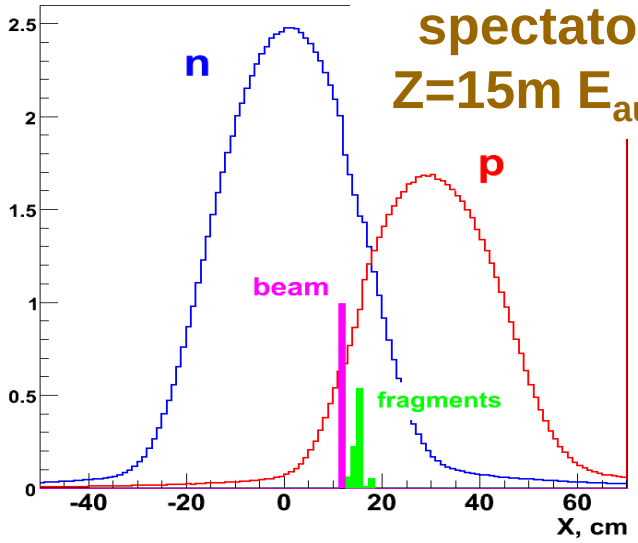
Proposal based on the technology of scintillator sampling calorimeter type of "Shashlyk" developed in Russia

Shower library

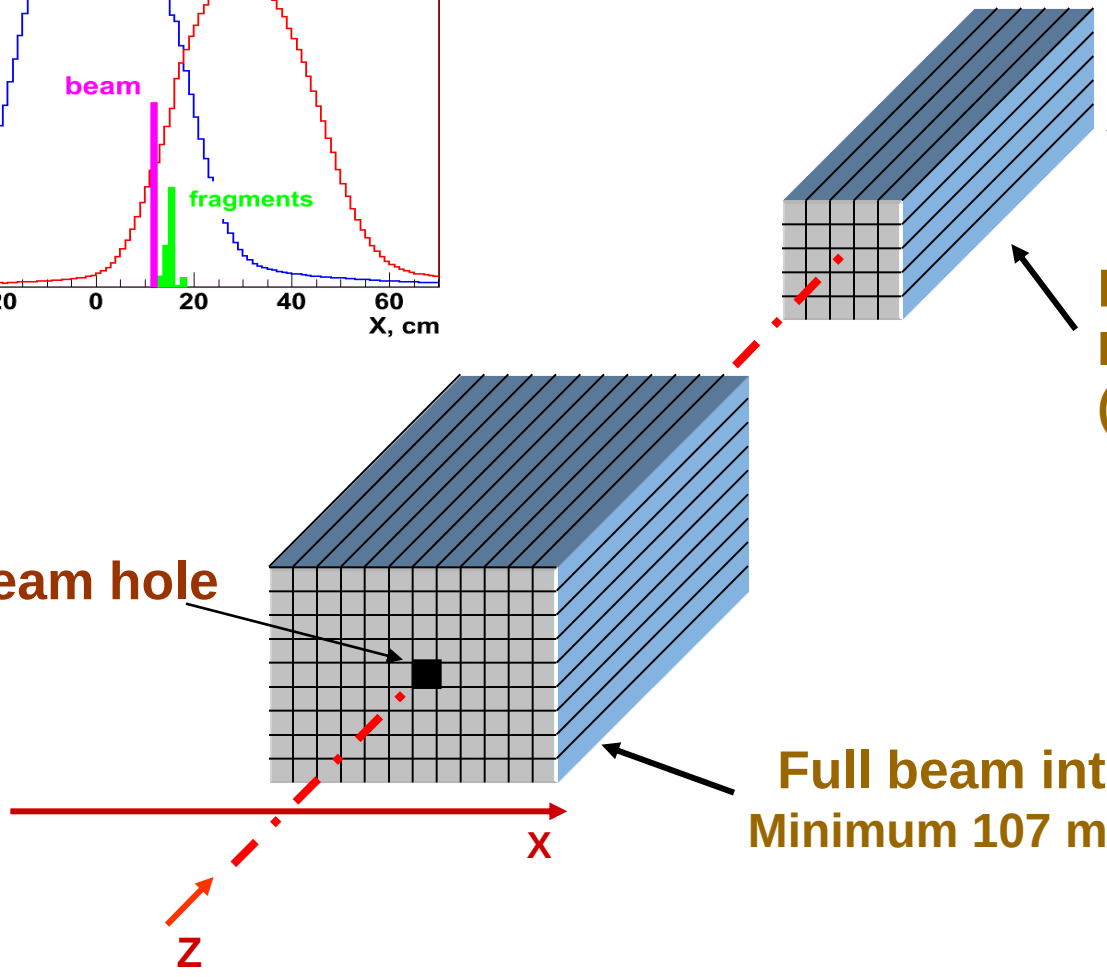


- Shower rotating on fly?
  - classical trade CPU vs. memory

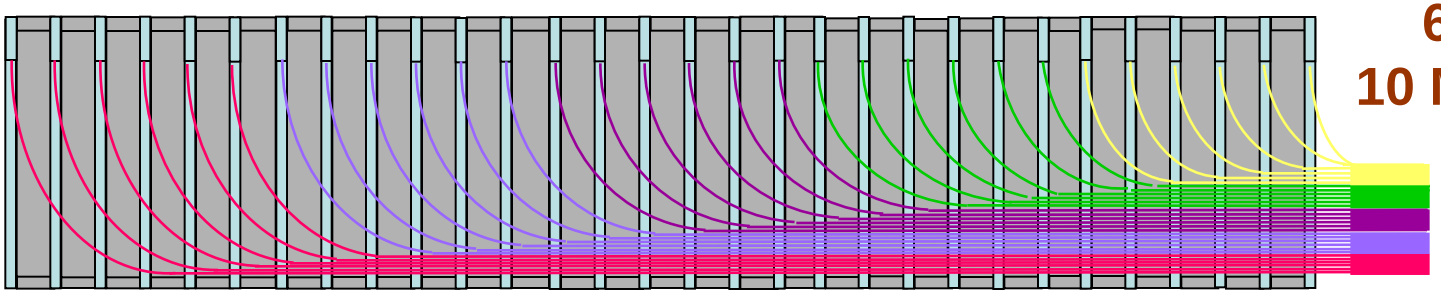
Schematic view of PSD configuration.



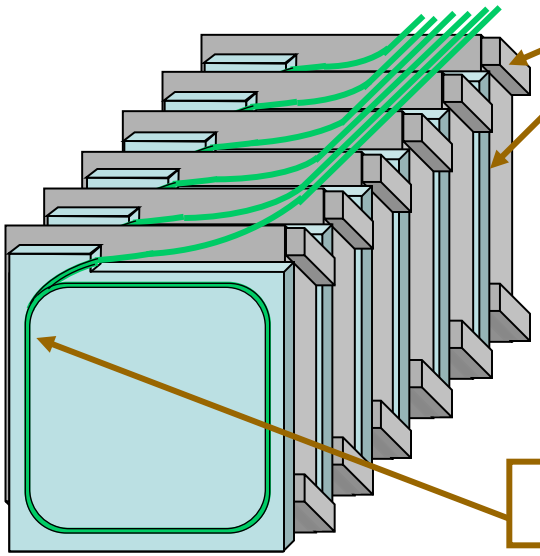
spectator spots at
Z=15m E_{au}=15 AGeV



Light readout from scintillators.



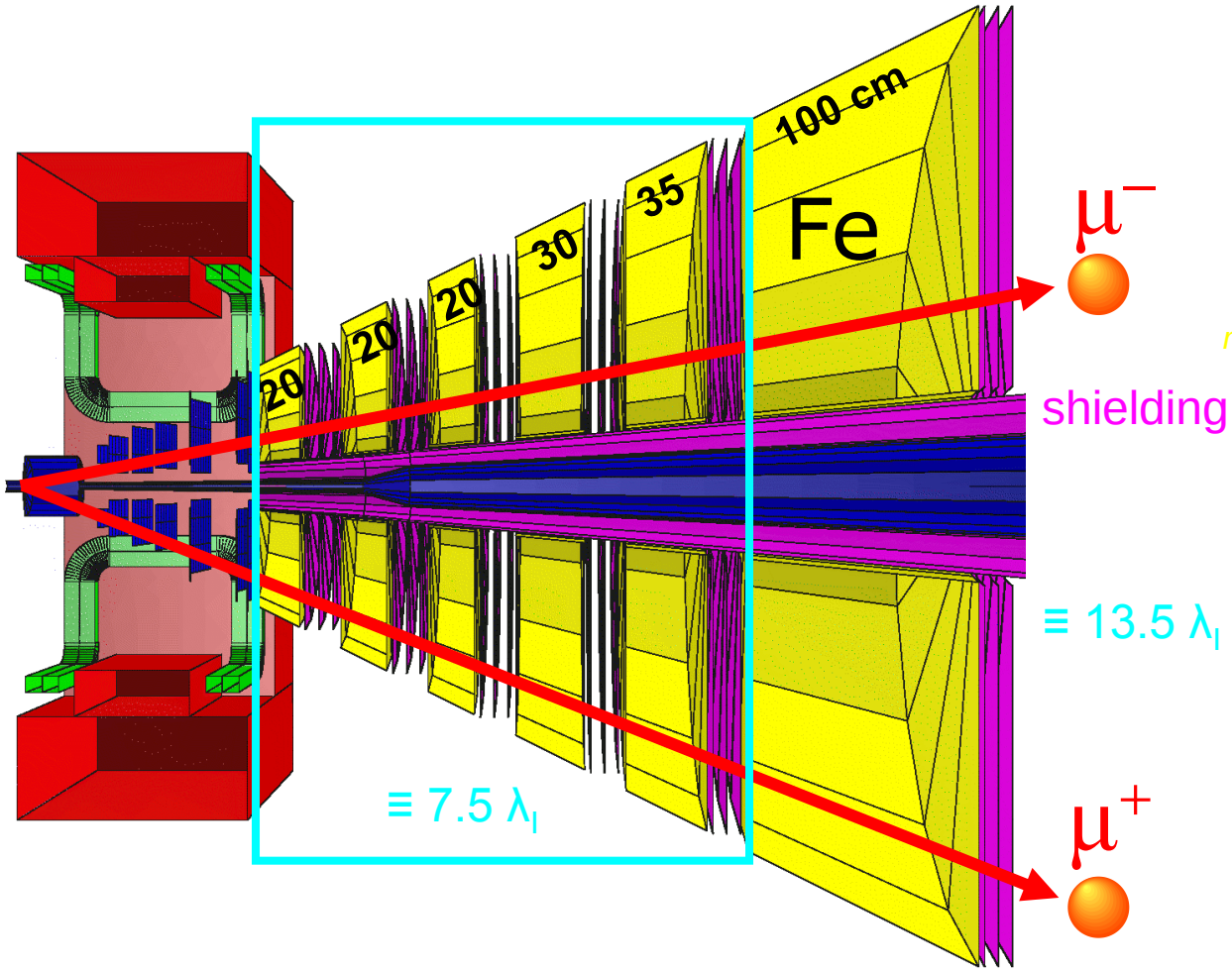
6 fiber/MAPD
10 MAPDs/module



60 lead/scintillator sandwiches.

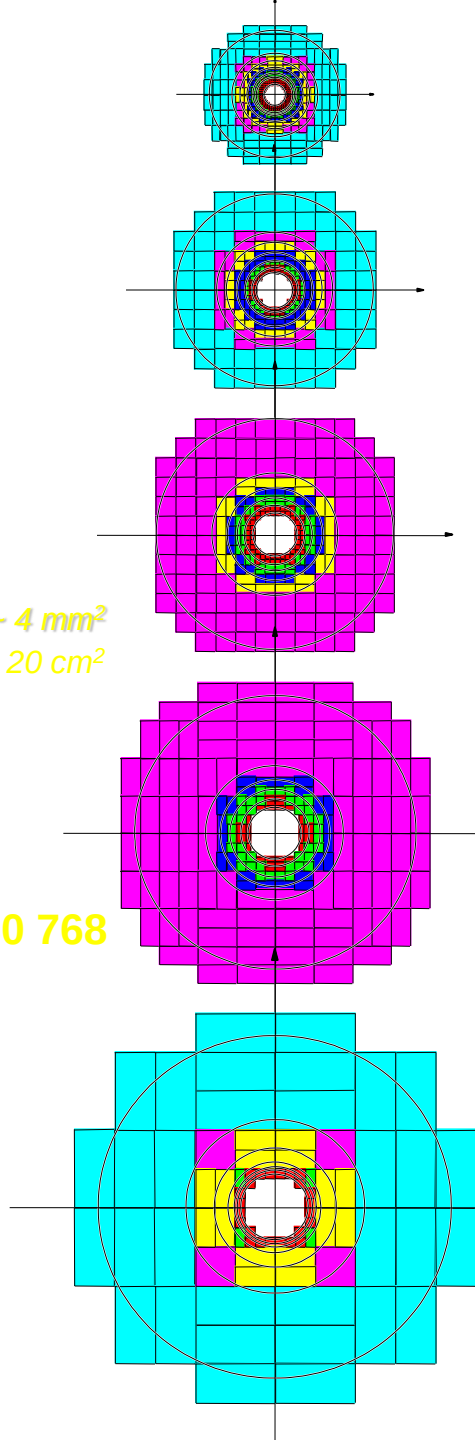
groove with WLS-fiber

Muon Chamber System (MUCH)

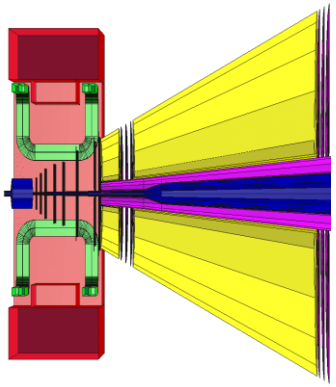


min pad ~ 4 mm²
max pad ~ 20 cm²

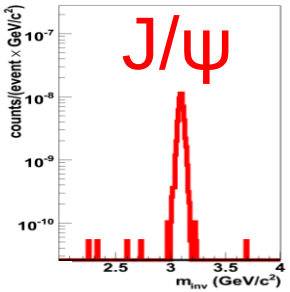
480 768

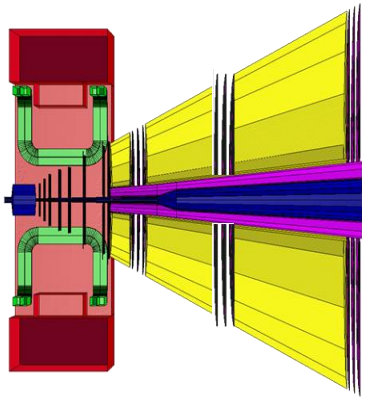


Example for upgrade scenario: Muon detector

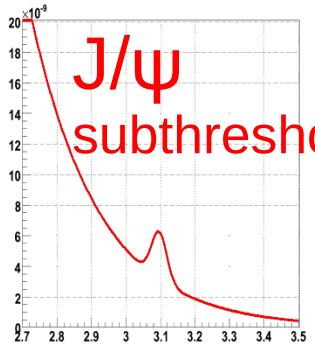


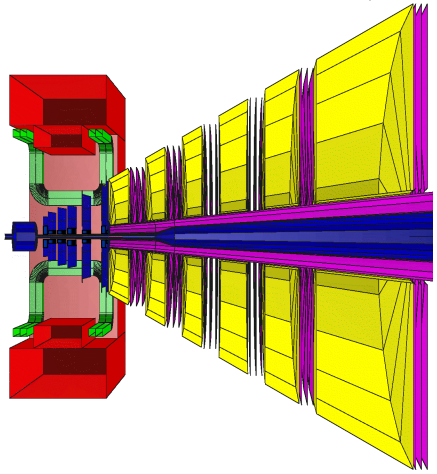
Start version I
25 GeV p+A → J/ψ
Iron absorber: 20+205 cm
2 detector triplets:
GEM + straw tubes



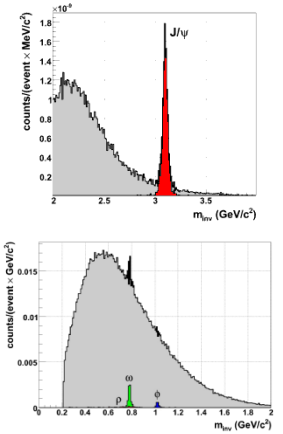


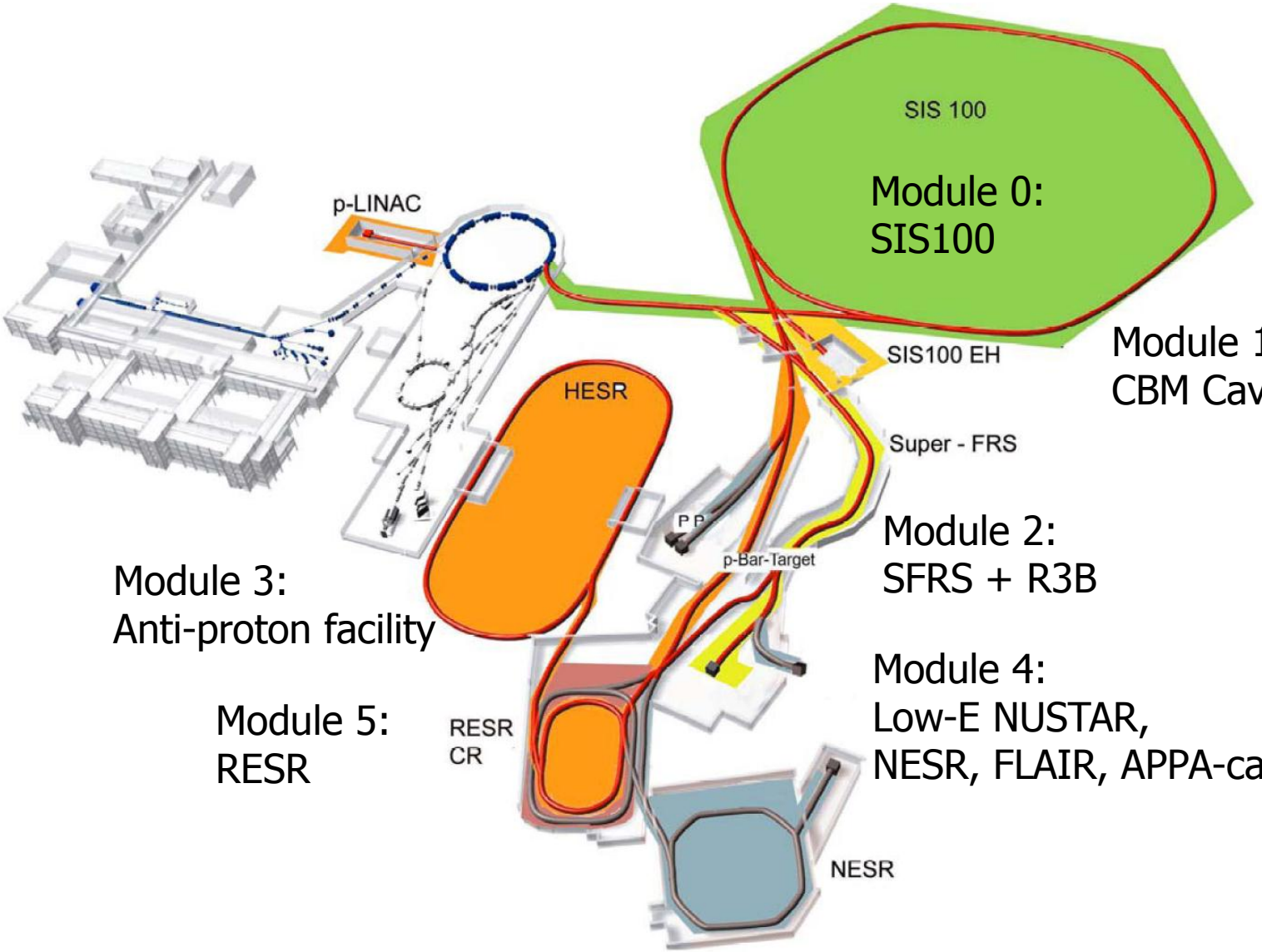
Start version II
10 A GeV Au+Au → J/ψ
Iron absorber: 20+70+135 cm
3 detector triplets:
GEM + micromegas + straw tubes





Full version
25 A GeV Au+Au → ρ,ω,φ,J/ψ
Iron absorber: 3x20+30+35+100 cm
6 detector triplets:
2 GEM+2 micromegas+2 straw tubes

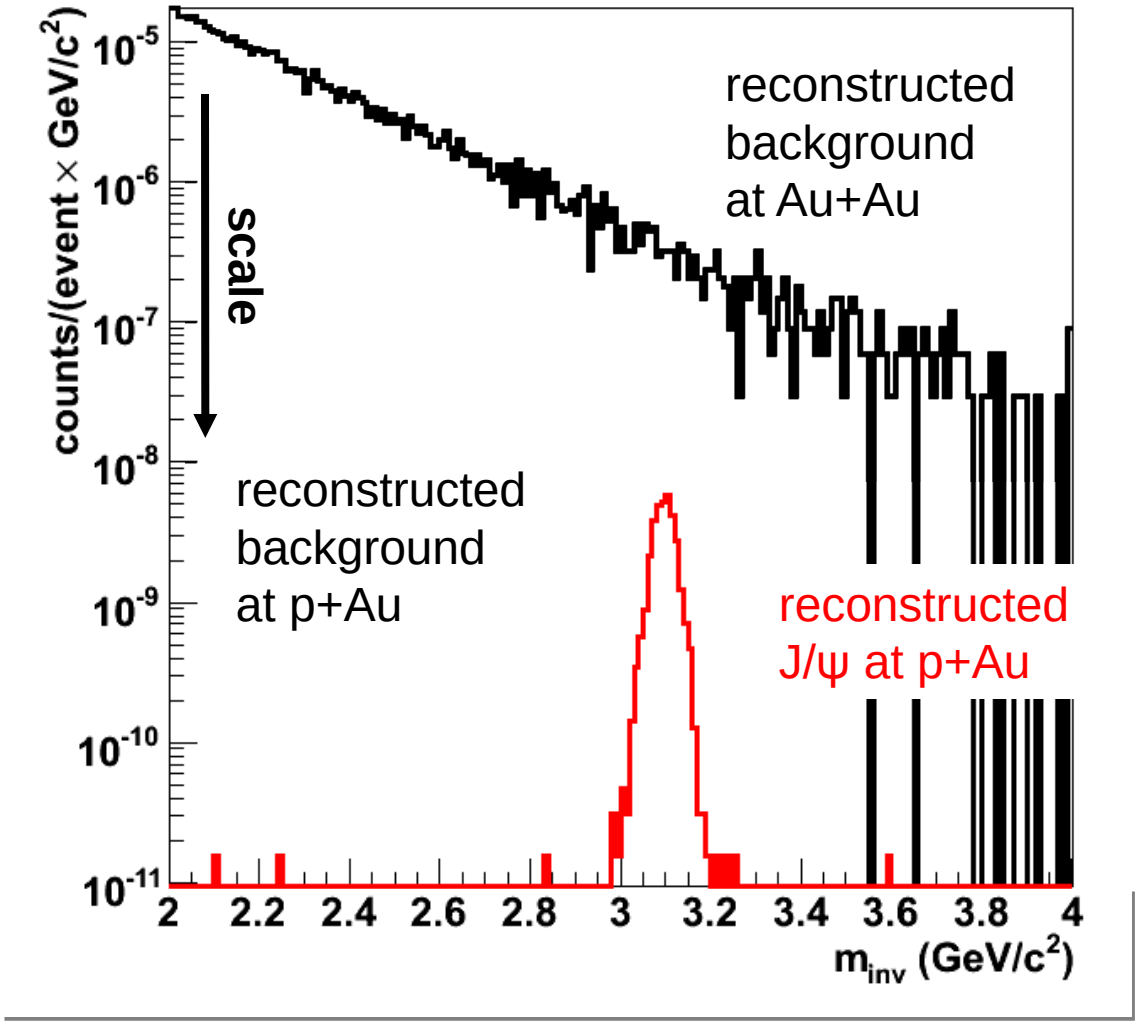




Evaluation of the scientific program with modules 0-3 on Oct. 16, 2009

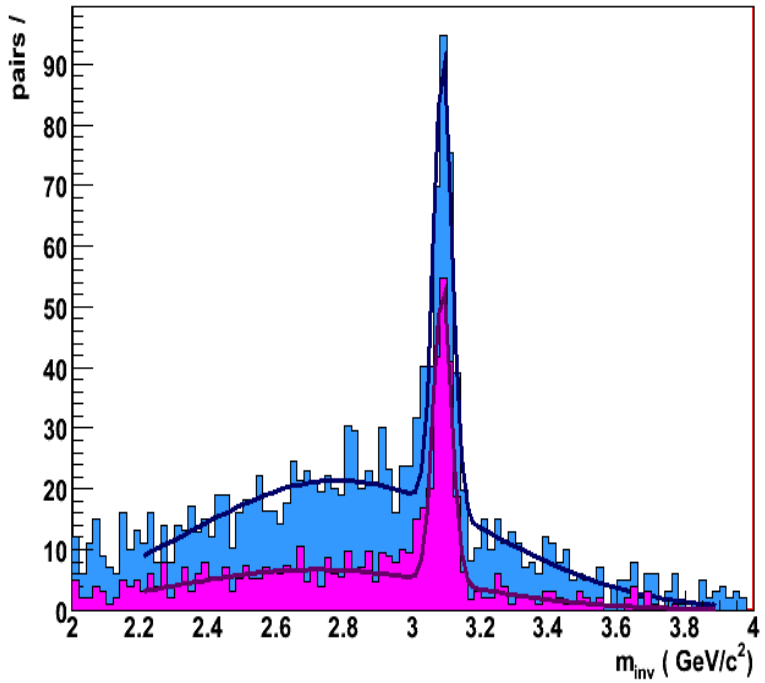
S/B ratio calculation for p+A

$$\text{scale} = \frac{N_{p+Au}}{N_{Au+Au}}$$



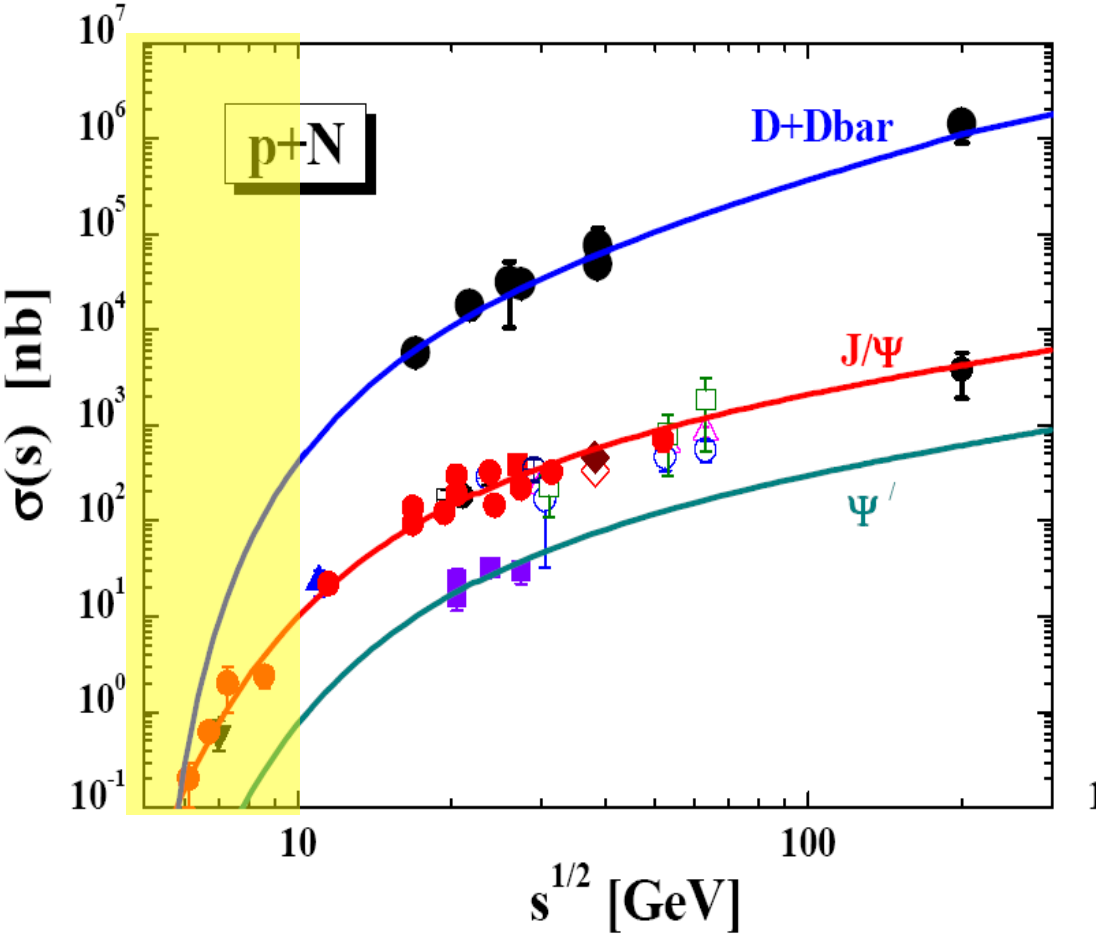
Invariant mass spectra of J/ψ→ e^+e^- + combinatorial background

(330 J/ψ + superevent 10^{12} pC@30GeV UrQMD events)



	RICH & TRD	RICH & TRD & ECAL
S/B	3	7.2
$\frac{S}{\sqrt{S+B}}$	1.95	1.7
$N_{J/\psi}$	330	210
Eff (%)	11.8	7.39

Charm production at threshold energies (motivation)



Input to hadronic transport models (HSD):
Parameterization of measured cross sections
O. Linnyk et al., Nucl. Phys. A786 (2007) 183

No data:

X-sections,

flow(s),

p_t, y;

D^0/D^+, D^0/D_s, D^0/Λ_c ratios

HADES/CBM start version at SIS-100