

The PANDA@HADES physics program for SIS 18

Jacek Biernat

for the HADES collaboration and UU Hyperon group



UPPSALA
UNIVERSITET



Presentation plan:

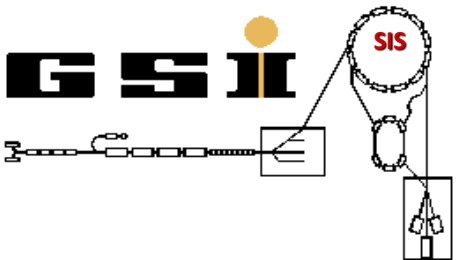
- HADES experiment (History, physics program, old setup, results)
- Phase0 – FAIR / PANDA@HADES
- Upgrades
- Planed measurements

The HADES collaboration

- Started in 1995
- First measurement on SIS 18: 2003

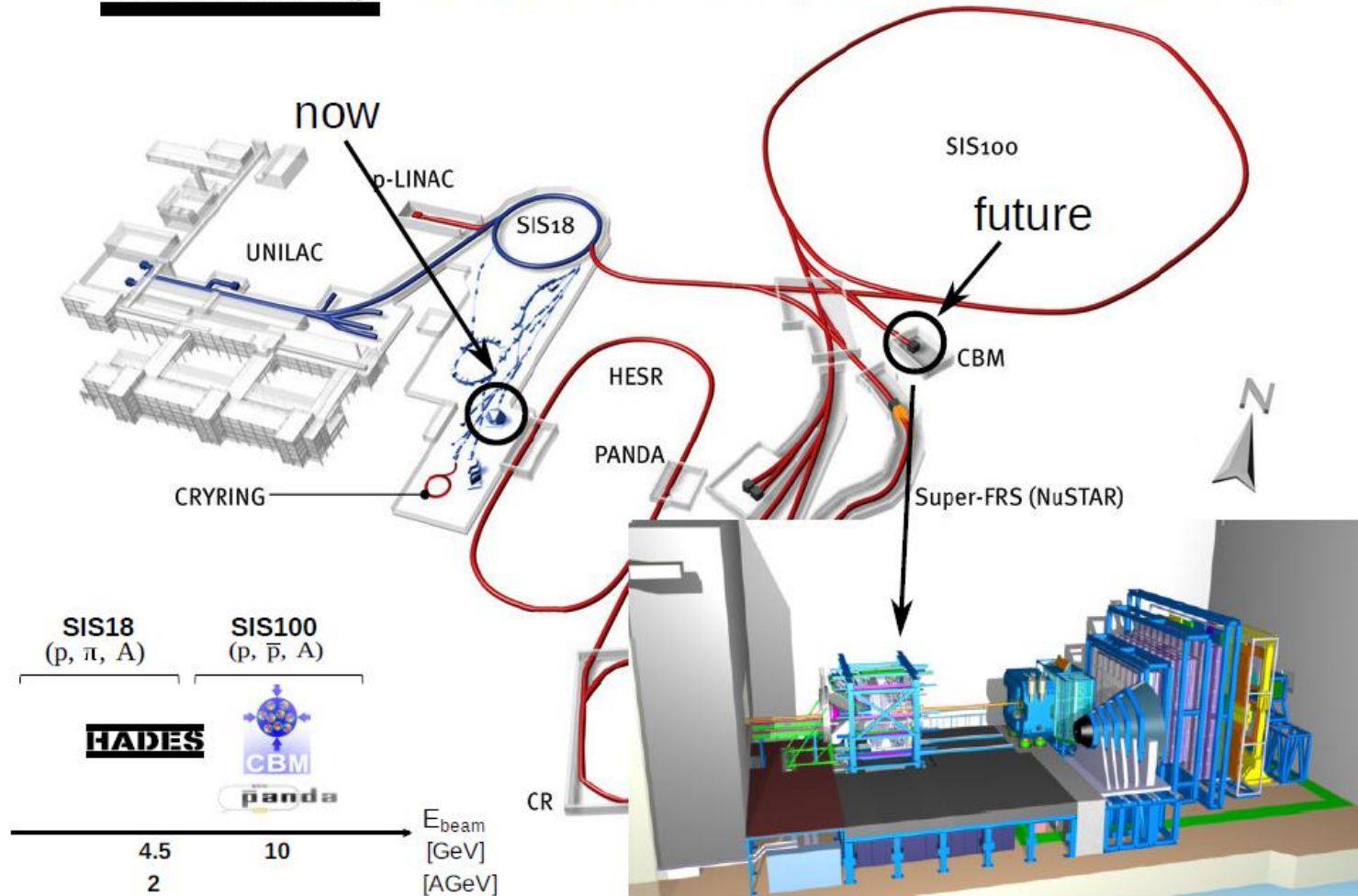


- Cracow (Univ.), Poland
- Darmstadt (GSI), Germany
- Dresden (FZD), Germany
- Dubna (JINR), Russia
- Frankfurt (Univ.), Germany
- Giessen (Univ.), Germany
- Jülich (FZJ), Germany
- München (TUM), Germany
- Moscow (ITEP,MEPhI,RAS), Russia
- Nicosia (Univ.), Cyprus
- Orsay (IPN), France
- Rez (CAS, NPI), Czech Rep.
- Sant. de Compostela (Univ.), Spain
- Wuppertal (BUG), Germany
- Coimbra (Univ.), LIP, Portugal



HADES @ FAIR

HADES - first detector of FAIR Phase0 (2018-2020)



The HADES spectrometer

- **Detector geometry**

full azimuthal range covered, 6 sectors
polar angle: $16^\circ < \theta < 84^\circ$

- **Tracking**

Superconducting coils, toroidal field
24 Mini Drift Chambers

- **Particle identification (e, p, K, π)**

RICH, MDC, TOF, TOFINO, Shower (RPC)

- **Resolutions**

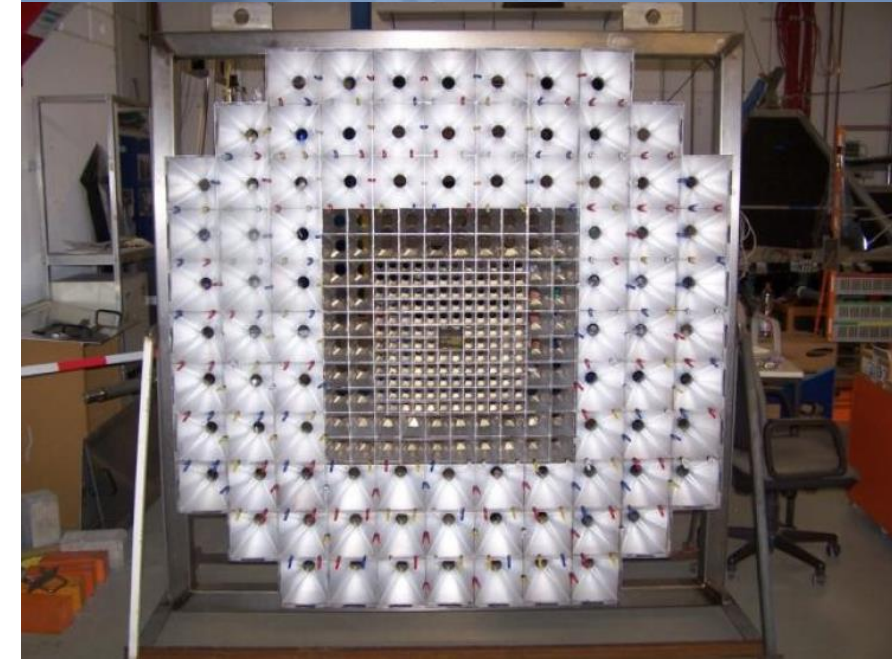
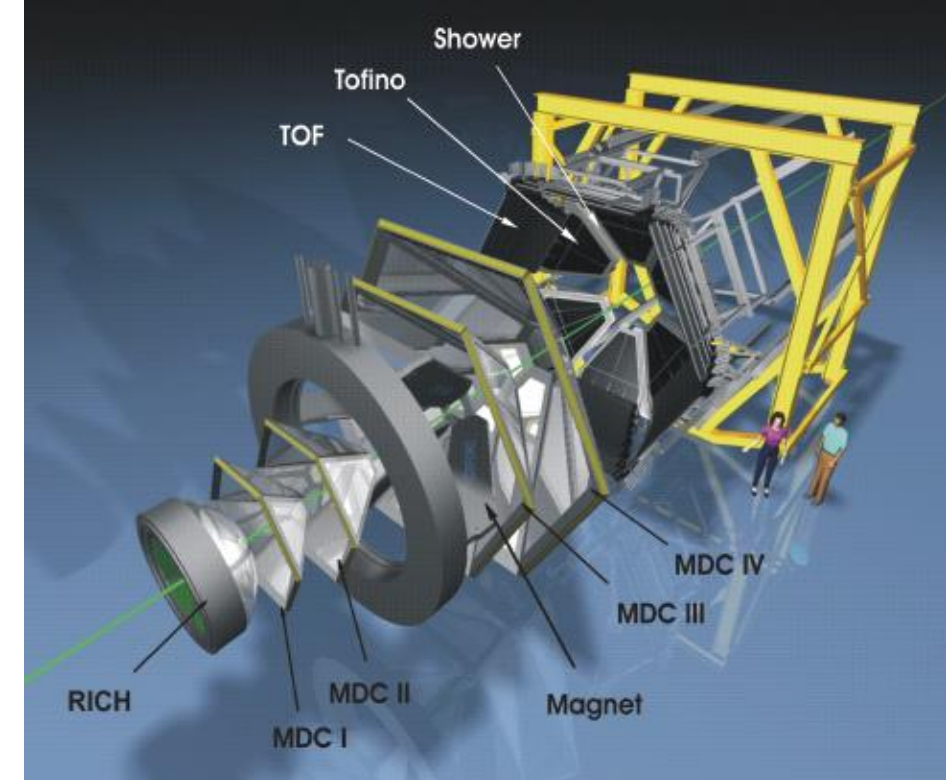
$\Delta M\omega/M\omega \sim 2.1\%$ at ω peak
 $\Delta p/p \sim 2\text{-}3\%$ for proton and π

- **Forward Wall:**

Plastic scintillators covering θ angles up to 7°
Detector dedicated to tag proton spectator

- **Cells in FW:**

140 small 4x4cm	$\rightarrow (0^\circ < \theta < 2^\circ)$
64 middle 8x8cm	$\rightarrow (2^\circ < \theta < 3.3^\circ)$
84 large 16x16cm	$\rightarrow (3.3^\circ < \theta < 7.2^\circ)$



The physics program of HADES

- ❑ Studies of dense and hot matter:
 - C + C for 1 and 2 GeV/n, Ar + KCl @ 1.75 GeV/n , Au + Au @ 1.25 GeV/n

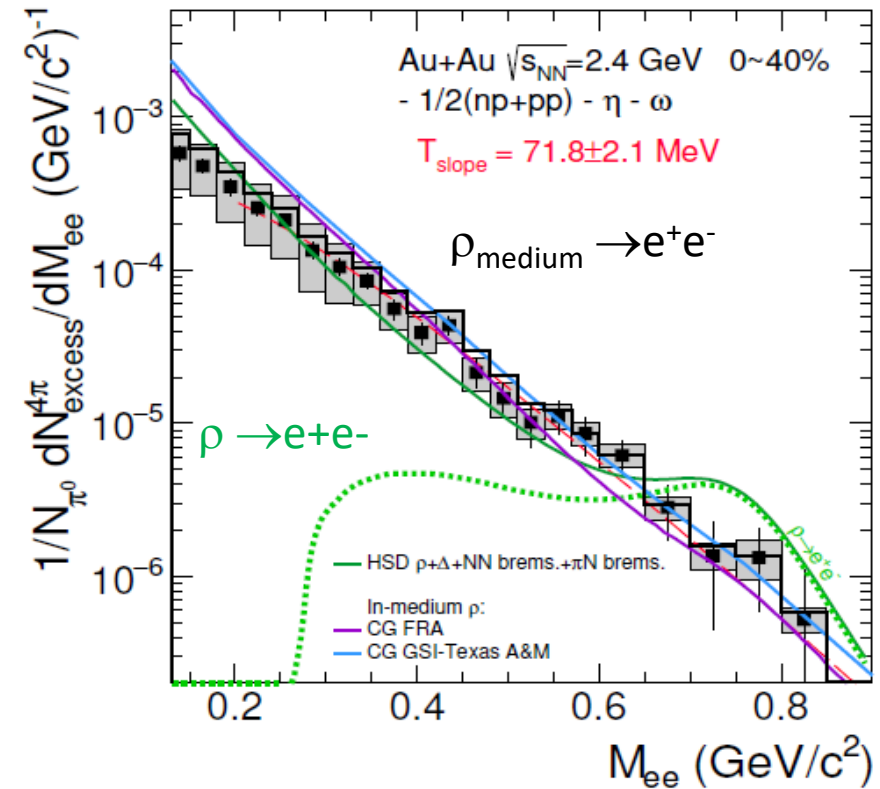
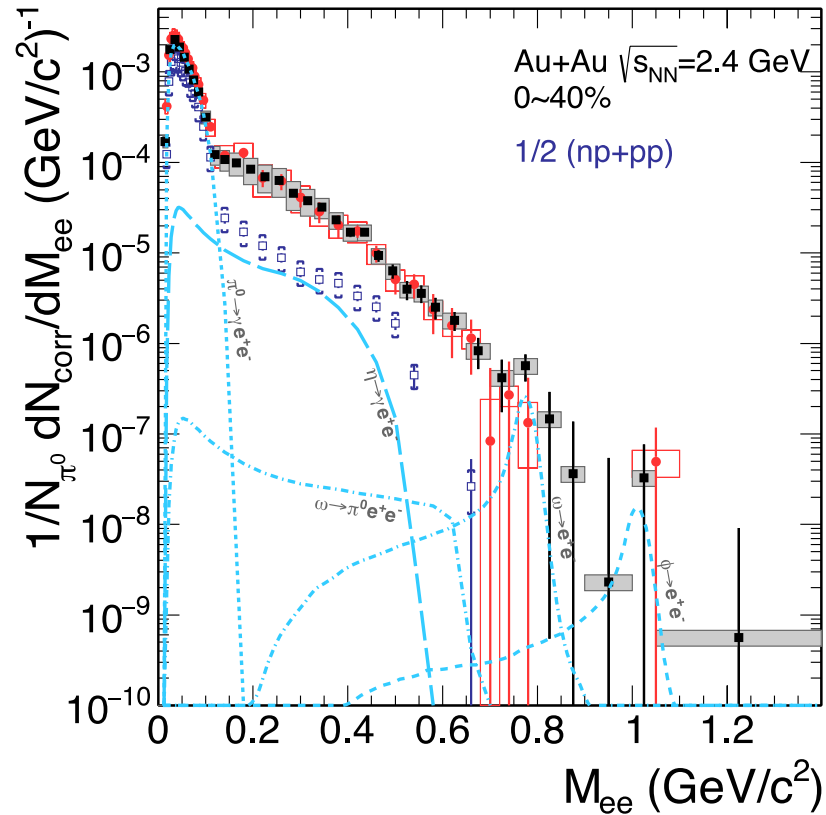
- ❑ Cold matter at normal nuclear densities: p + Nb @ 3.5 GeV/c and $\pi^- + W/C$ 1.7 GeV/c

- ❑ Dilepton emission in elementary collisions pp, dp and π^-p
 - As a reference to HI measurements
 - Dalitz decays of baryon resonances

- ❑ Simultaneous measurements of hadronic channels (inclusive and exclusive meson production $1\pi, 2\pi, \eta, \rho, \omega, \dots$)

- ❑ strangeness measurement program: $K^-, K^0, \phi, \Sigma(1385), \Lambda(1405), \Lambda p$ correlations

Au + Au @ 1.25 GeV/n

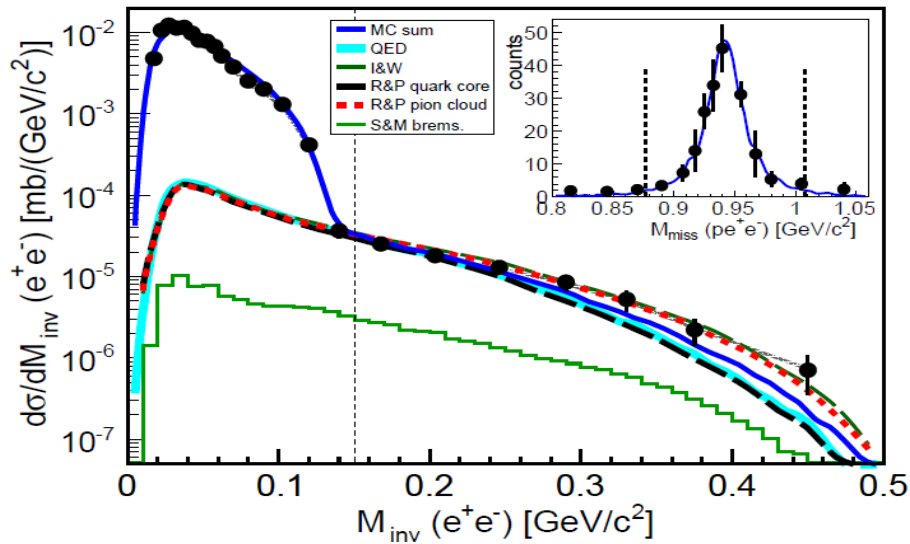


- In medium effects, the Au + Au spectrum not described by a superposition of elementary reactions (1/2 np + pp)
- ρ meson spectrum width modification

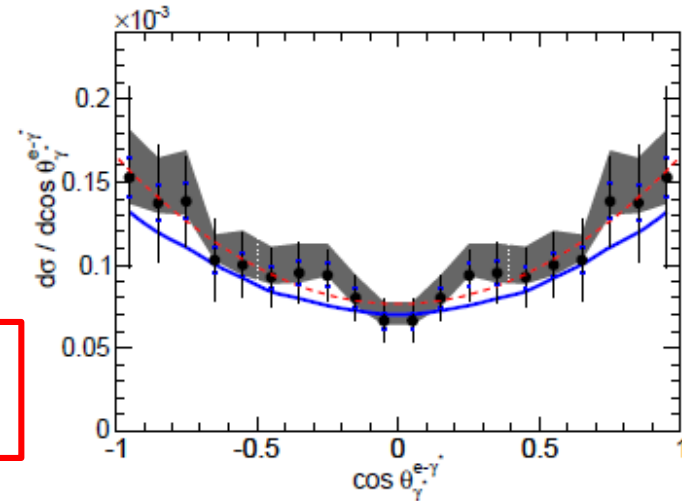
Elementary reactions pp and np @ 1.25 GeV/c

Δ and π^0 production cross section deduced from PWA of one pion production channels

HADES, *Eur. Phys. J. A* 51 (2015) 137



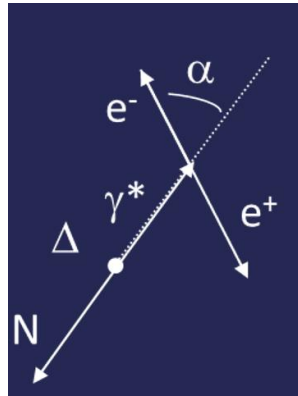
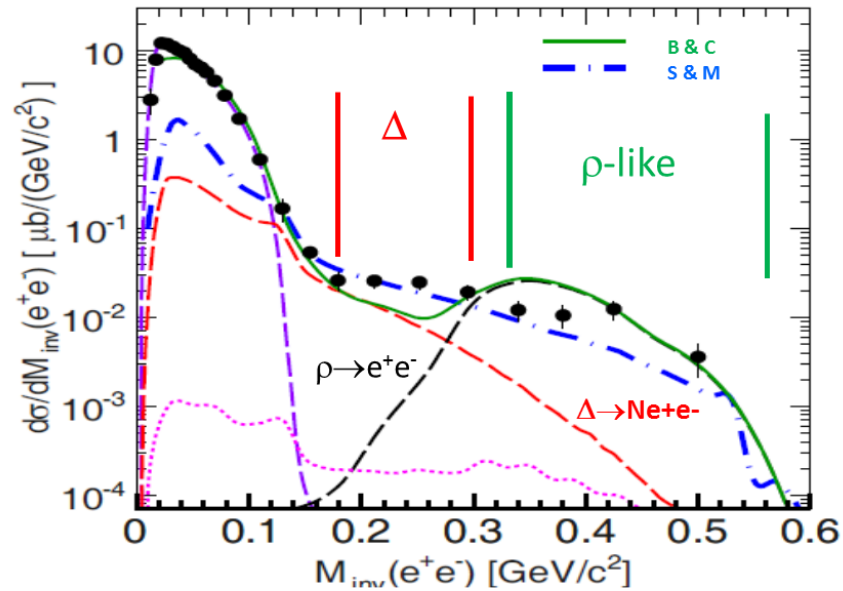
- Δ Dalitz $\Delta \rightarrow \pi e^+ e^-$
- « photon-point » $G_M=3, G_E=G_C=0$
- Ramalho/Pena model *Phys.Rev. D*85 (2012) 113014
- meson cloud
- - quark core
- - Iachello, Wan model *Int. J Mod. Phys. A*20 (2005) 1846
- pp Bremsstrahlung *Shyam and Mosel, PRC*82 (2010)062201



first measurement of $\Delta(1232)$ Dalitz decay branching ratio
 $BR(\Delta \rightarrow \pi e^+ e^-) = 4.19 \pm 0.42$ (model) ± 0.46 (syst.) ± 0.34 (stat.) 10^{-5} .

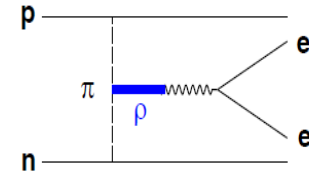
Elementary reactions pp and np @ 1.25 GeV/c

HADES EPJA 7, 149 (2017)

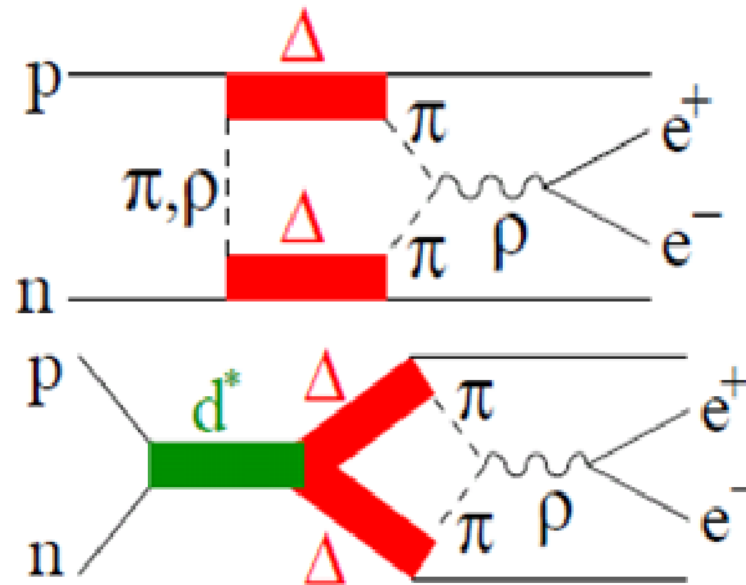
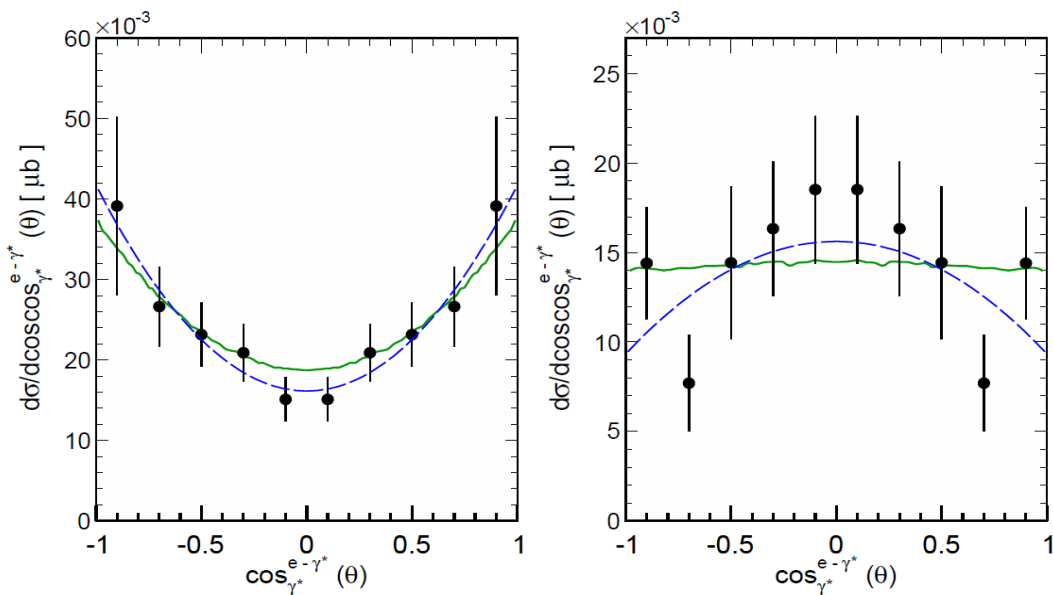


Significantly larger production at large M_{ee} than in pp

S&M: *Shyam & Mosel Phys. Rev. C 82:062201, 2010*



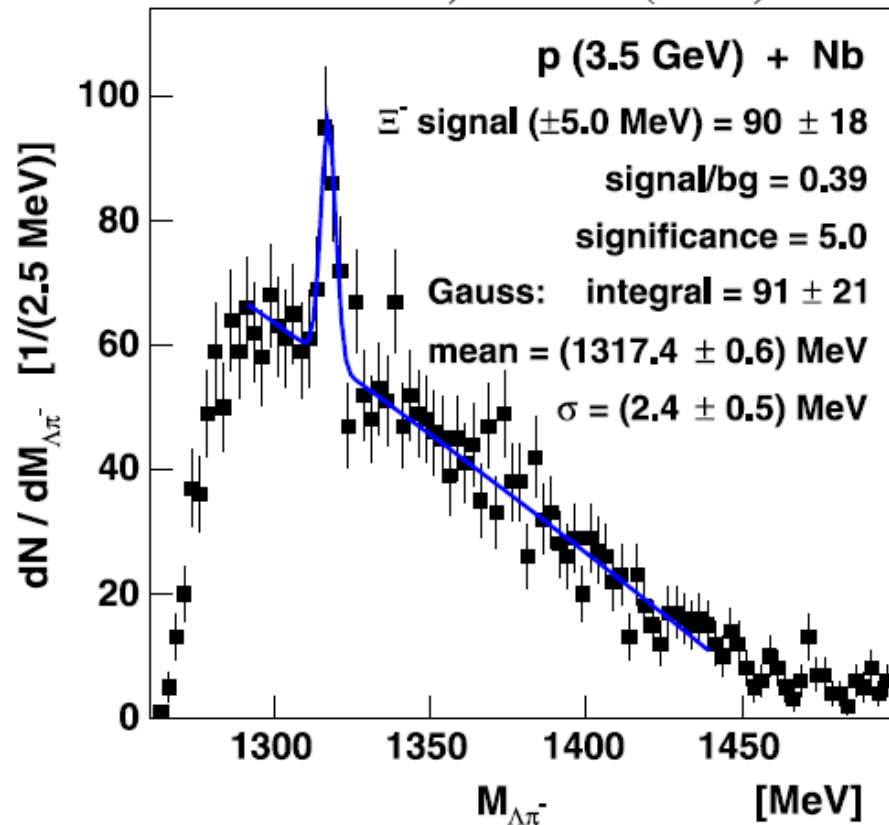
B&C *Bashkanov & Clement Eur. Phys. J. A 50, 107 (2014)*



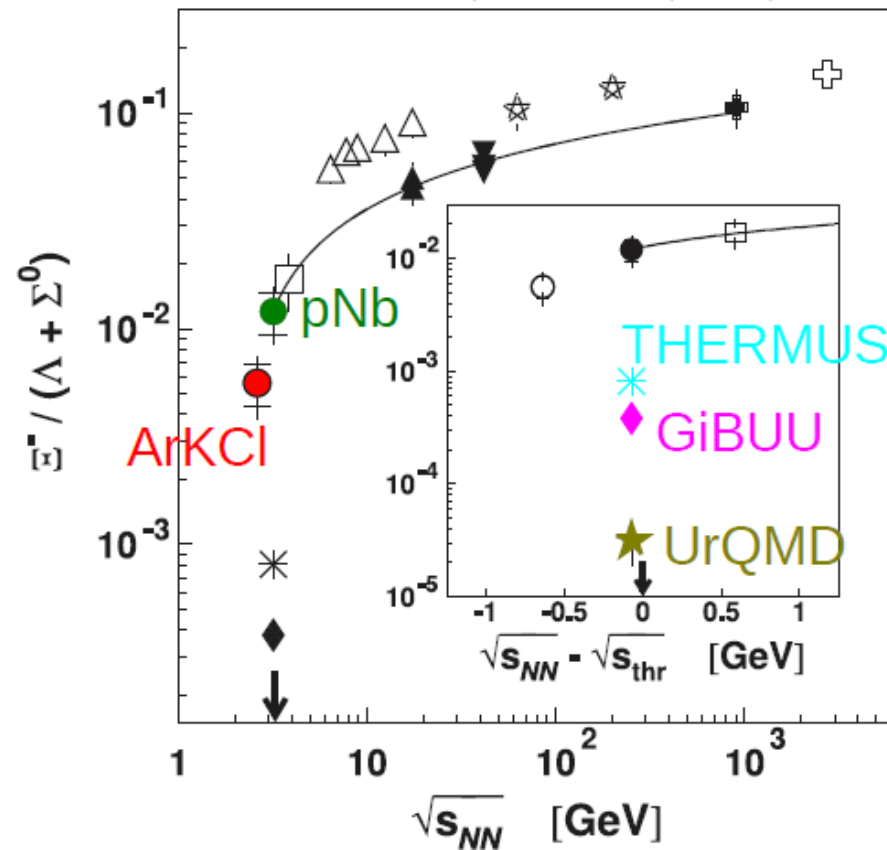
HADES Puzzle: $\Xi(1321)$ production

- ✓ strong enhancement in respect to existing models (UrQMD, GiBUU) for Ar + KCl @ 1.76 GeV sub-threshold production
- ✓ No data close to threshold in NN interactions

PRL 114, 212301 (2015)



PRL 114, 212301 (2015)



PANDA@HADES detector upgrades

The Forward detector

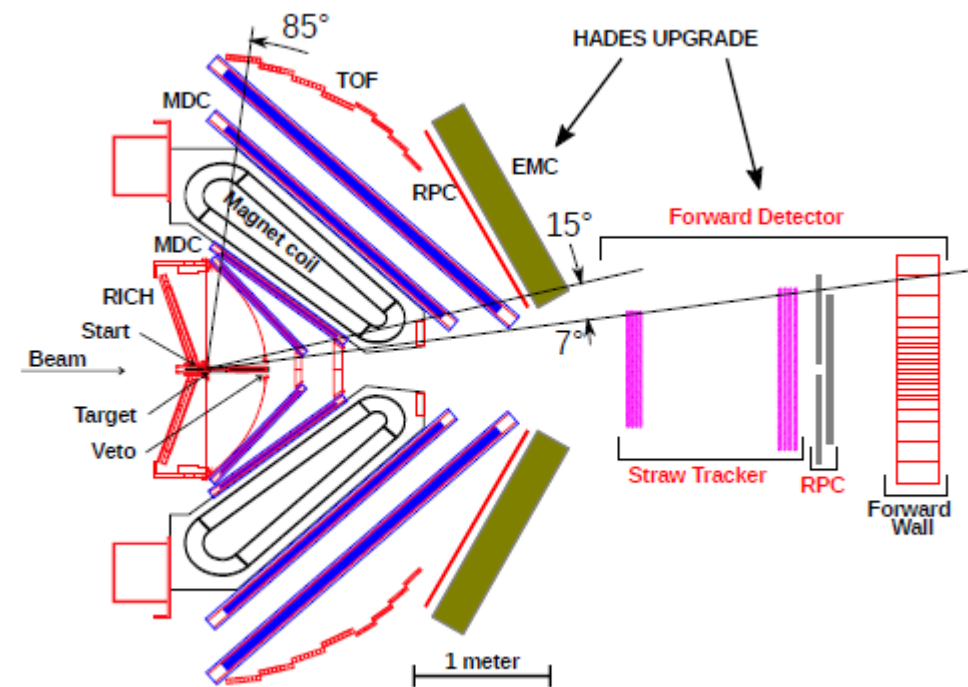
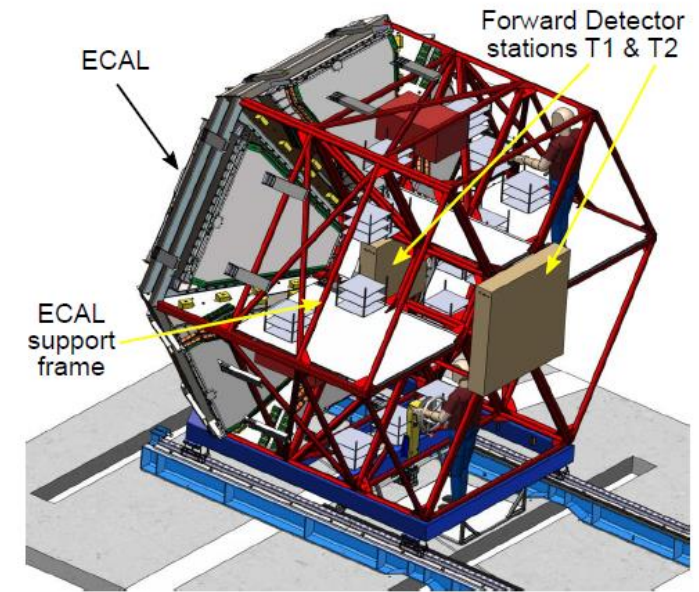
- Enable the possibility of track reconstruction originating from charged particles at $\theta < 7$ deg
- No magnetic field
- Time of flight from RPC

STS1 (FZ Jülich):

- 640 straws in 4 layers
- length 766 mm, $\Phi = 10:05$ mm
- Compatible with PANDA FT 3,4
- Active area: 766mm by 800mm

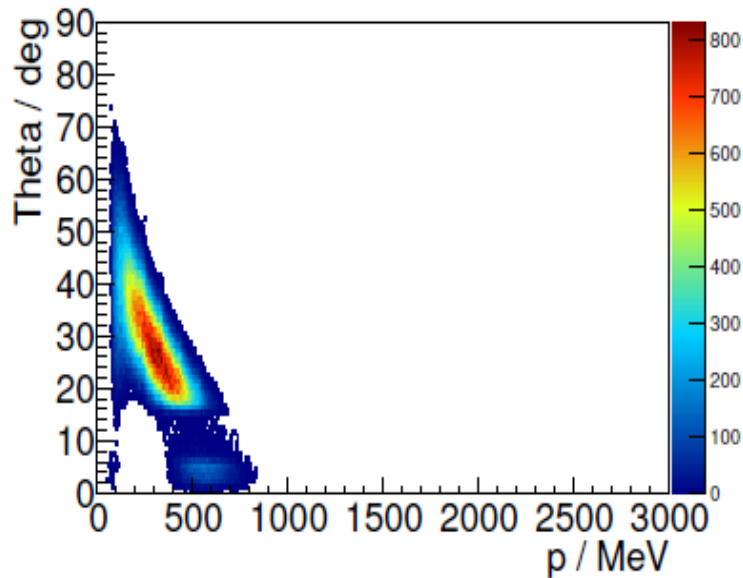
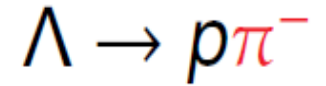
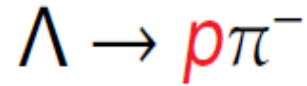
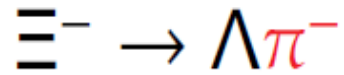
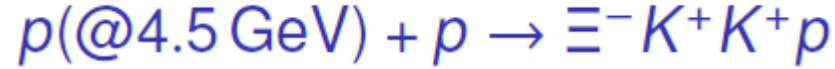
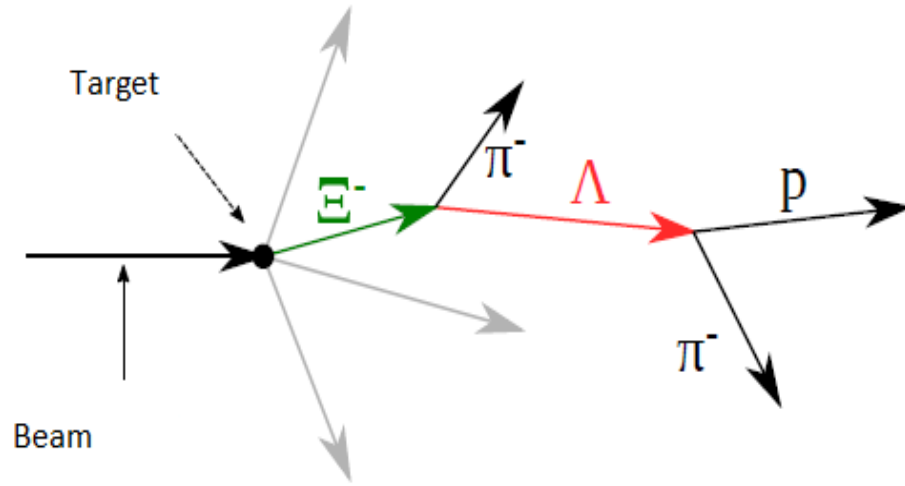
STS2 (UJ Kraków/IPN Orsay):

- 1024 straws in 4 layers
- Length: 1250 mm, $\Phi = 10:05$ mm
- Compatible with FT 5,6
- Active area: 1131mm by 1280mm
- Gas system (IFJ-PAN Kraków)
- Fastening system (INP Orsay)

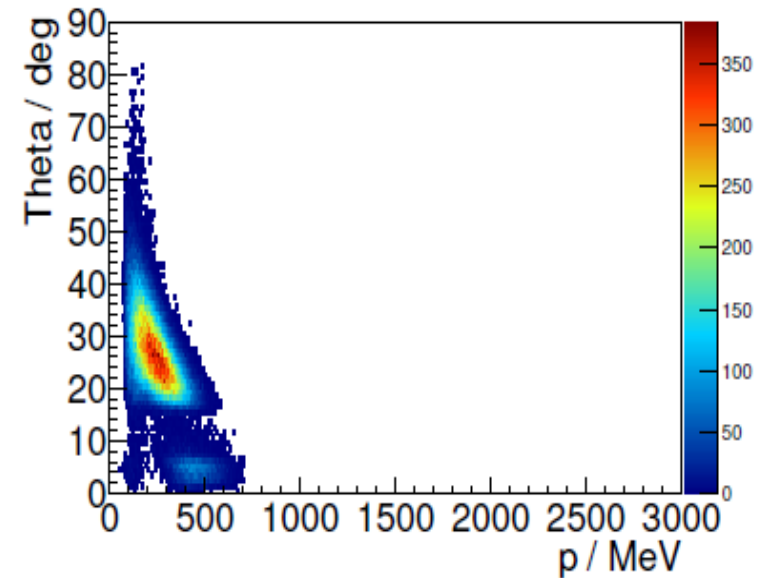
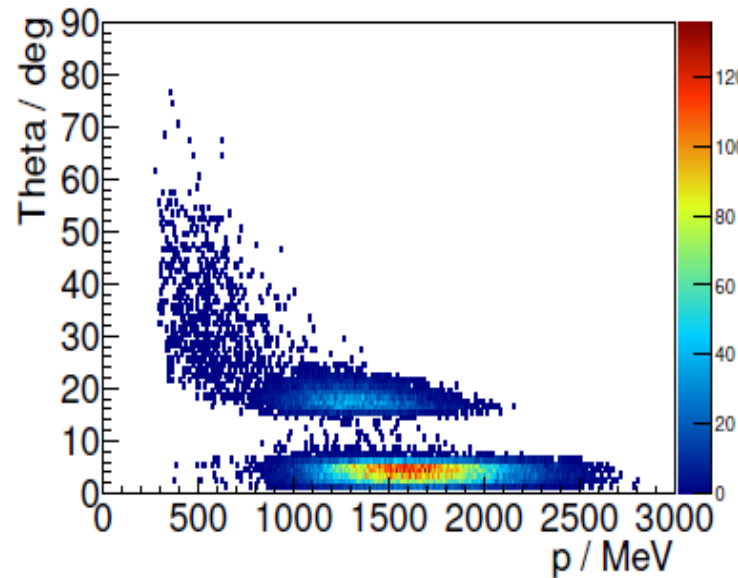


Almost 90% of protons form the decay are emitted with $\theta < 7$ deg!

K. Nowakowski
JU group Krakow

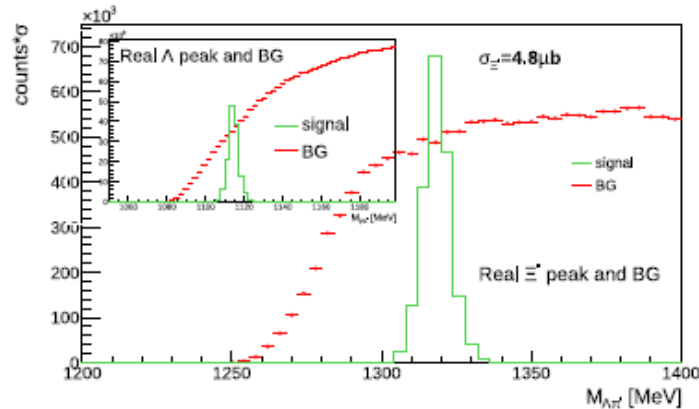
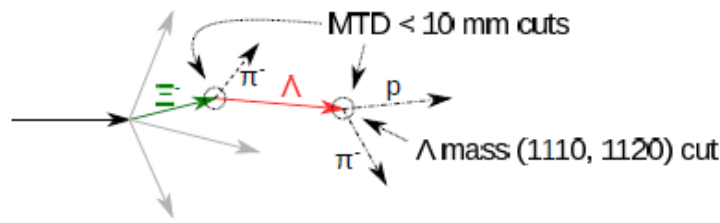
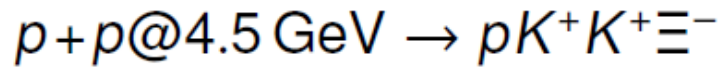


Pluto+Geant simulations



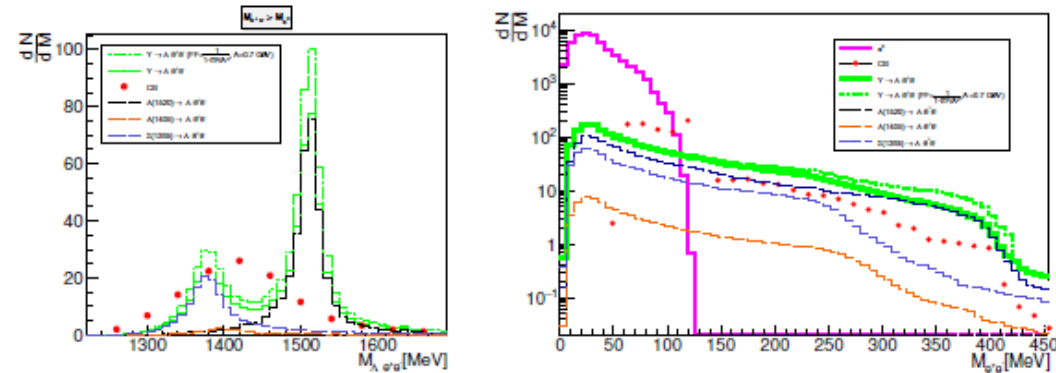
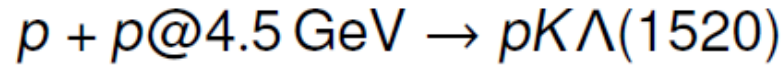
Benchmark channels - preliminary

Ξ^- production



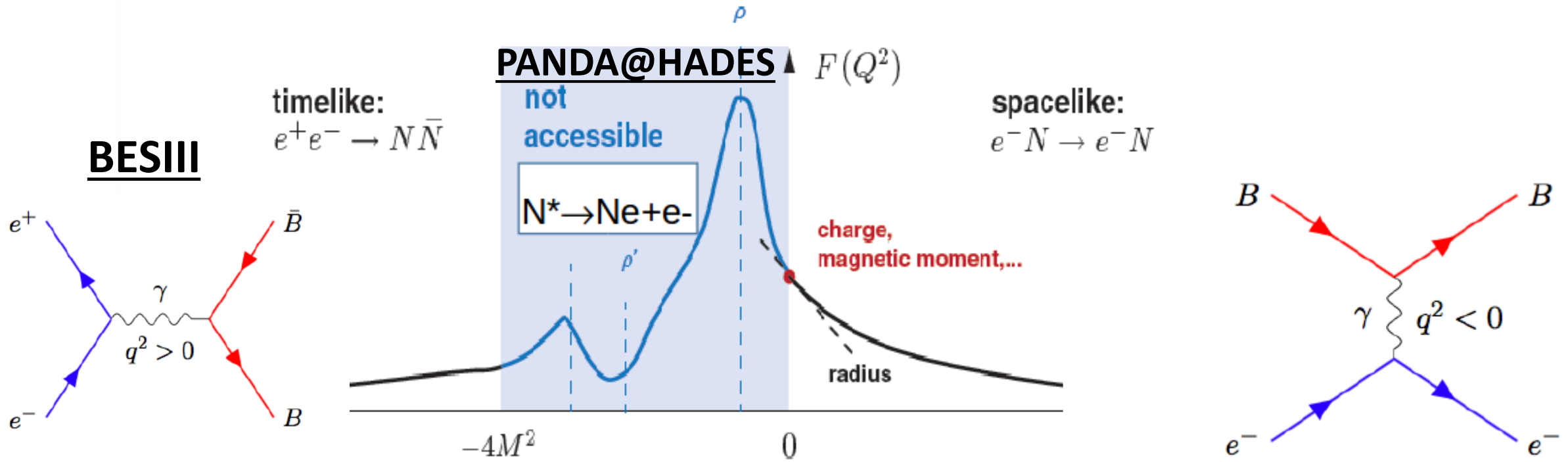
- ▶ expected $\approx 406 \times 10^3 \Xi^-$
- ▶ reconstruction efficiency:
 $\varepsilon_{\Xi^-} \approx 0.79\%$

$\Lambda(1520)$ Dalitz decays



- ▶ $\Gamma_{\Lambda(1520)} = 15.6 \text{ MeV}, \Gamma_{\gamma} = 167 \pm 43 \text{ keV}$
- ▶ $\text{BR}_{\Lambda(1520) \rightarrow \Lambda e^+ e^-} = 7.8 \times 10^{-5}$
 CLAS, PRC74, 065202 (2006)
- ▶ within 4 weeks of beam: $\approx 613 \Lambda(1520)$
 \rightarrow PE target: x7
- ▶ reconstruction efficiency:
 $\varepsilon_{\Lambda(1520)} \approx 0.5\% (\angle e^+ e^- > 4^\circ)$

The physics program of UU hyperon group



G. Eichmann *Acta Phys.Polon.Supp.* **7**, 597 (2014)

The physics program of UU hyperon group

- The Dalitz decays of neutral hyperons, e.g. Σ^0 and $\Lambda(1520)$, with PANDA@HADES. → Forward Detector

($\Delta \rightarrow N e^+ e^-$ similar to $\Sigma^0(1385) \rightarrow \Lambda^0 e^+ e^-$)

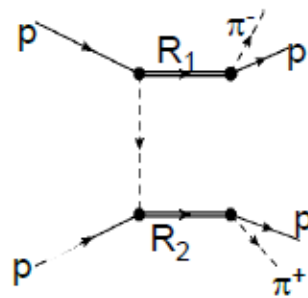
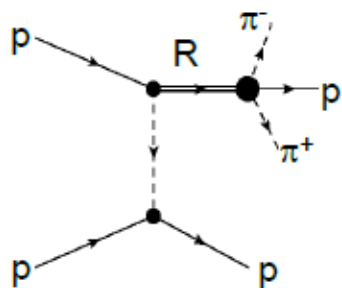
- Low- q^2 quantities of hyperons, such as magnetic dipole moments and helicity amplitudes, by radiative decays $Y_1 \rightarrow Y_2 \gamma$ with PANDA@HADES. → ECAL

- Search for $Y^* \rightarrow Y \gamma$ decays of excited hyperons, e.g. $\Sigma^*(1385) \rightarrow \Sigma \pi \gamma$ and $\Sigma^*(1385) \rightarrow \Lambda \pi \gamma$ with PANDA@HADES. → ECAL + Forward Detector

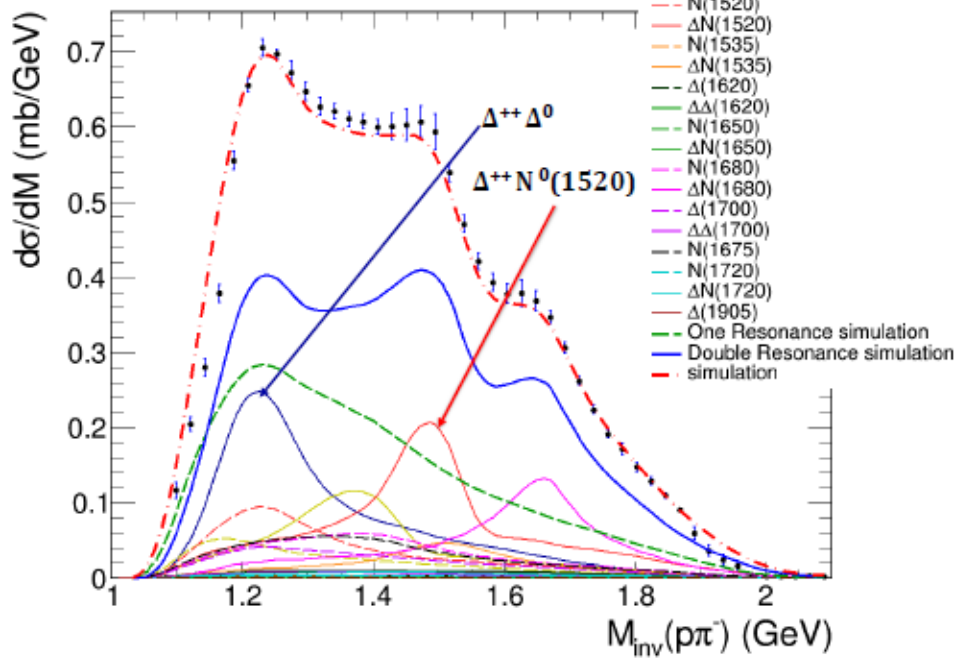
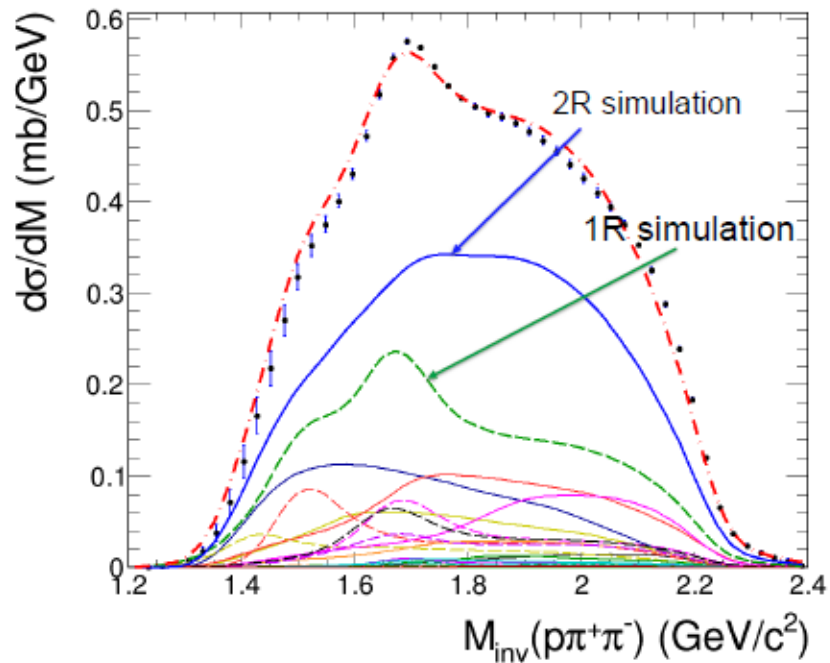
Backup

$pp \rightarrow pp\pi^+\pi^-$ $E=3.5$ GeV

Extraction of one and two baryon production cross sections



preliminary



ECAL Module

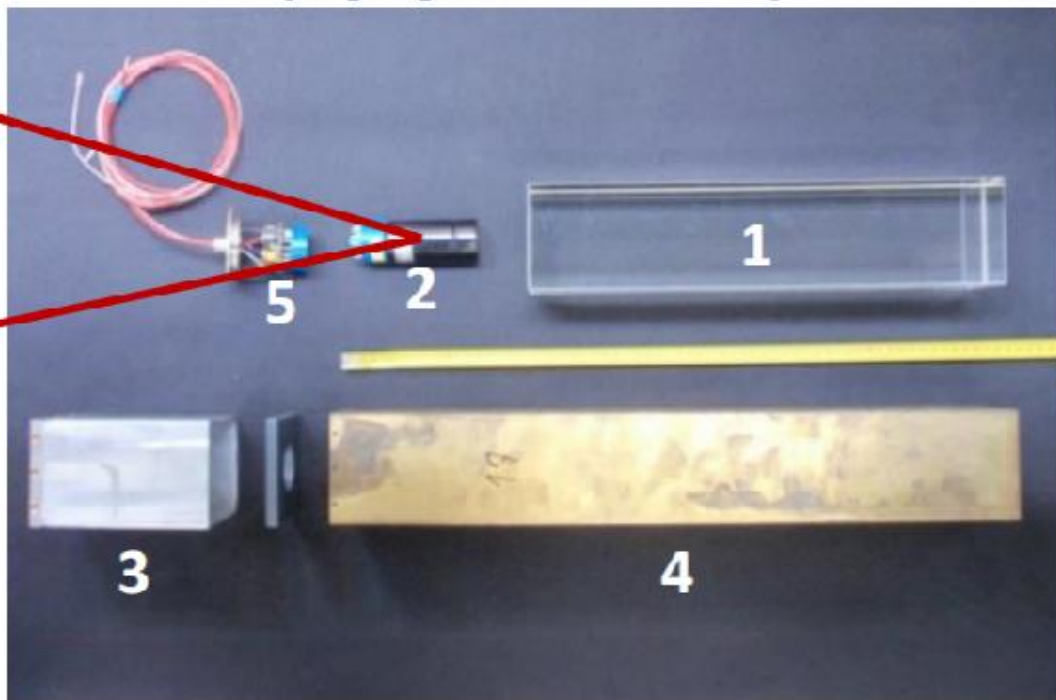
Calorimeter module (Info for reminder)



1.5 inch EMI
9903KB



3.0 inch
Hamamatsu
R6091



Cherenkov detector module of the ECAL
1 – Lead glass CEREN25; 2 – PMT; 3 – Alumin .
cover; 4 – brass can; 5 – Optical LED-system

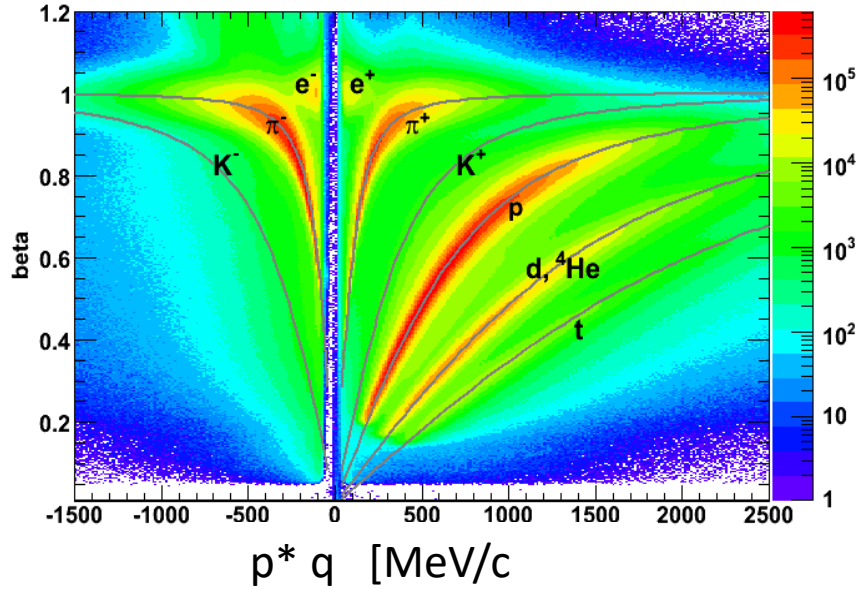
Glass properties:

- chemical composition:
SiO₂ -39%, PbO – 55%, K₂O - 2%, Na₂O – 3%)
- density: 4.06 g/cm³
- radiation length (X₀): 2.51 cm
- refractive index: 1.708 (at 400 nm)
- Molière radius: 3.6 cm

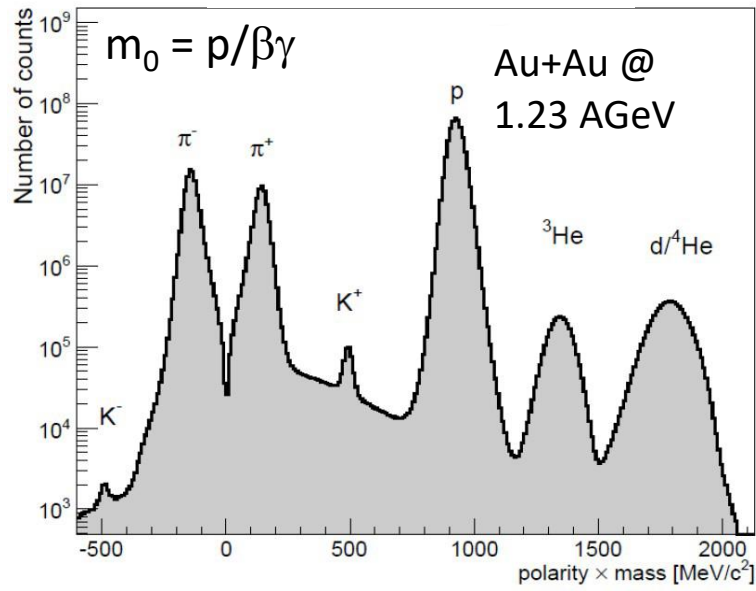
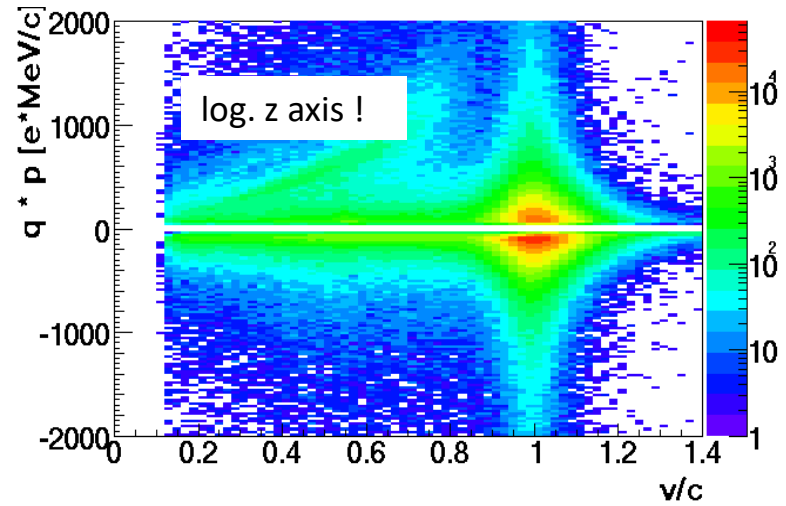
ECAL-Modules have PMTs Hamamatsu R6091, PC-diam.3 inch

and PMTs THORN EMI 9903 KB, PC-diam.1.5 inch

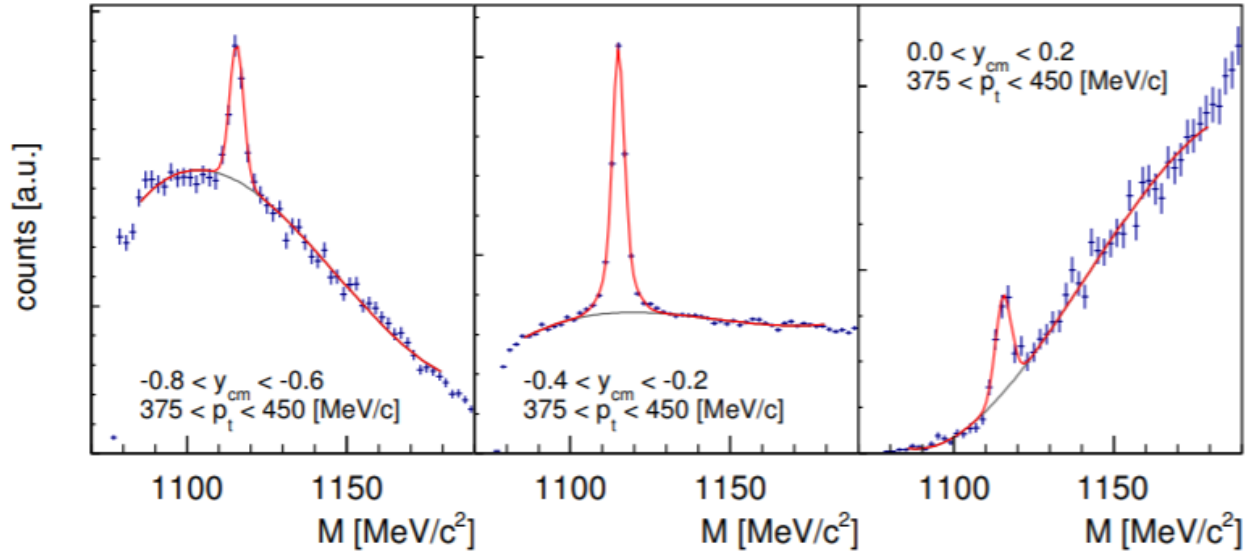
Particle identification with HADES



Momentum + RICH + TOF + Pre Shower

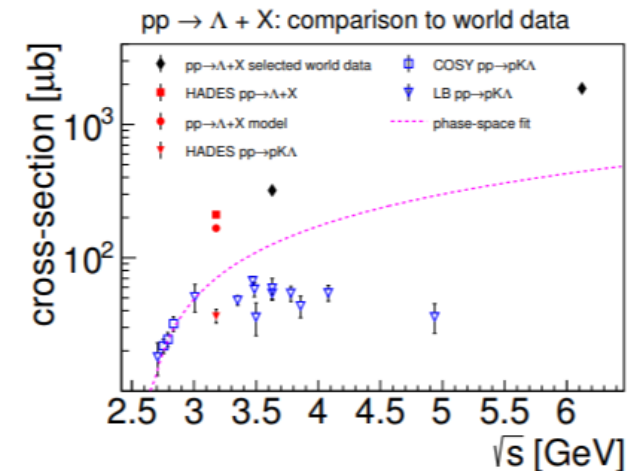


Strangeness, hyperon production @HADES



Inclusive analysis $pp \rightarrow \Lambda + X$

Phys. Rev. C 95, 015207 (2017)

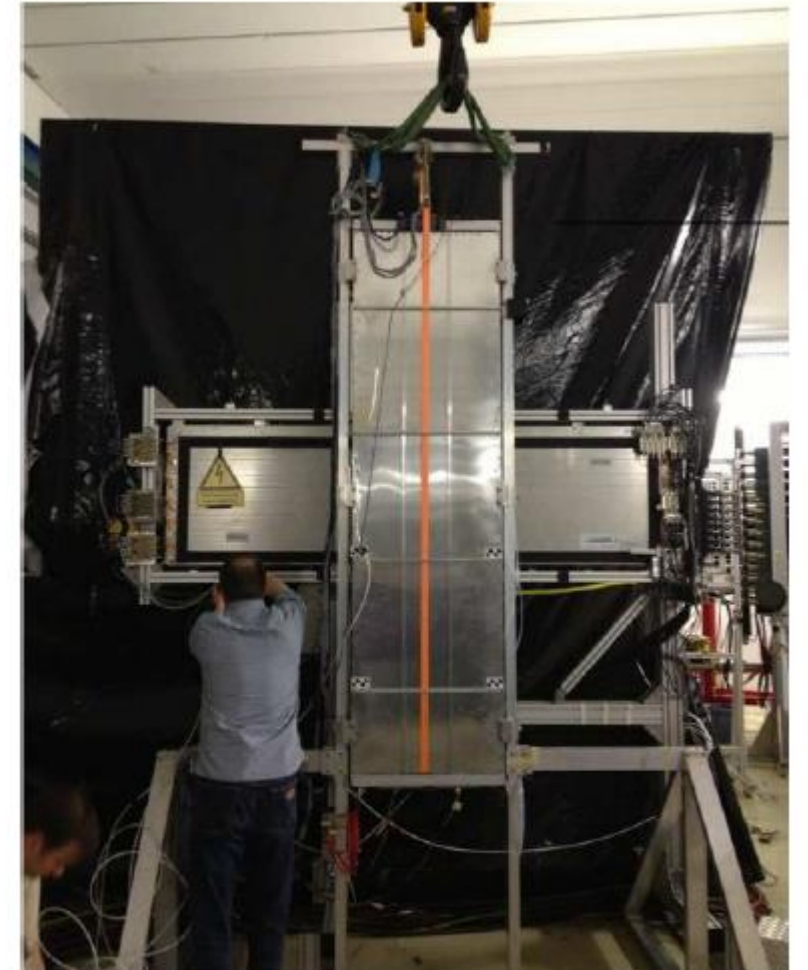
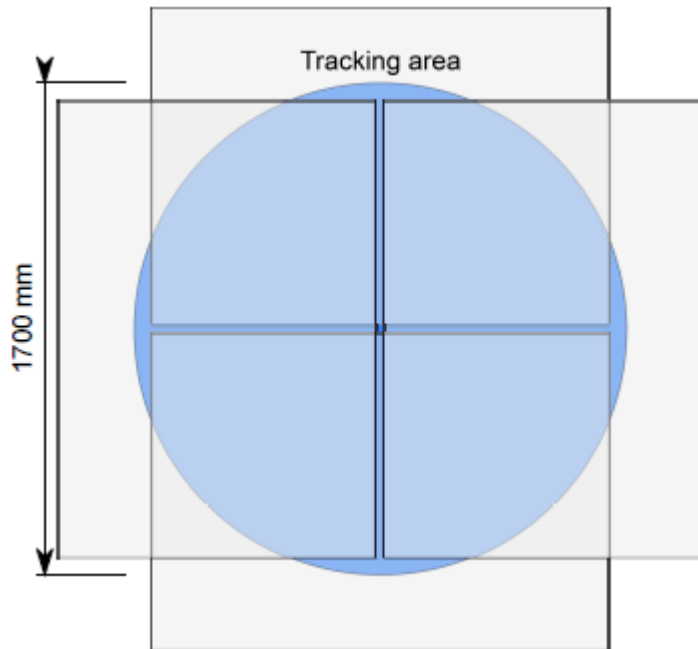


The extracted cross section:

$\sqrt{s} = 3.18$ GeV of $\sigma(pp \rightarrow \Lambda + X) = 207.3 \pm 1.3$
 $+6.0 -7.3$ (stat.) ± 8.4 (syst.) $+0.4 -0.5$ (model)
 μb

RPC (Resistive Plate Chambers) TOF detector

- Timing resolution < 100 ps,
- Efficiency > 98 %,
- Single module: 1380 960mm
- Two vertical and horizontal modules for TOF



NeuLAND RPC

STS1 (FZ Jülich):

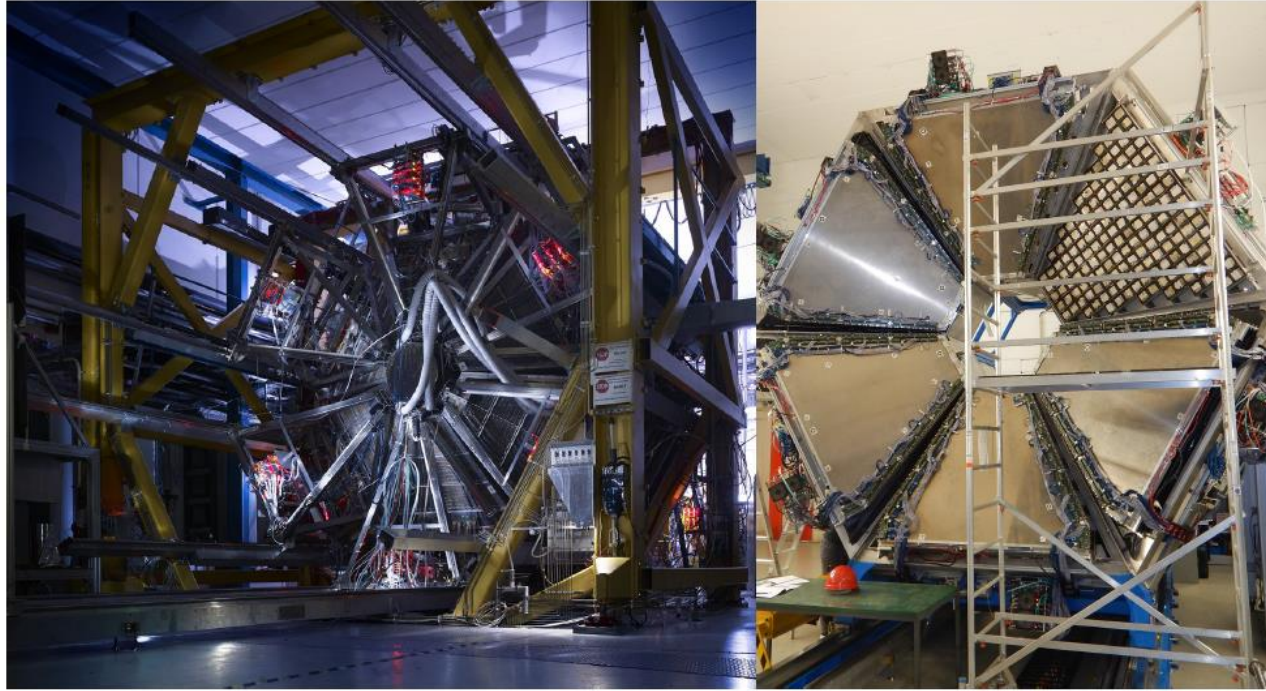
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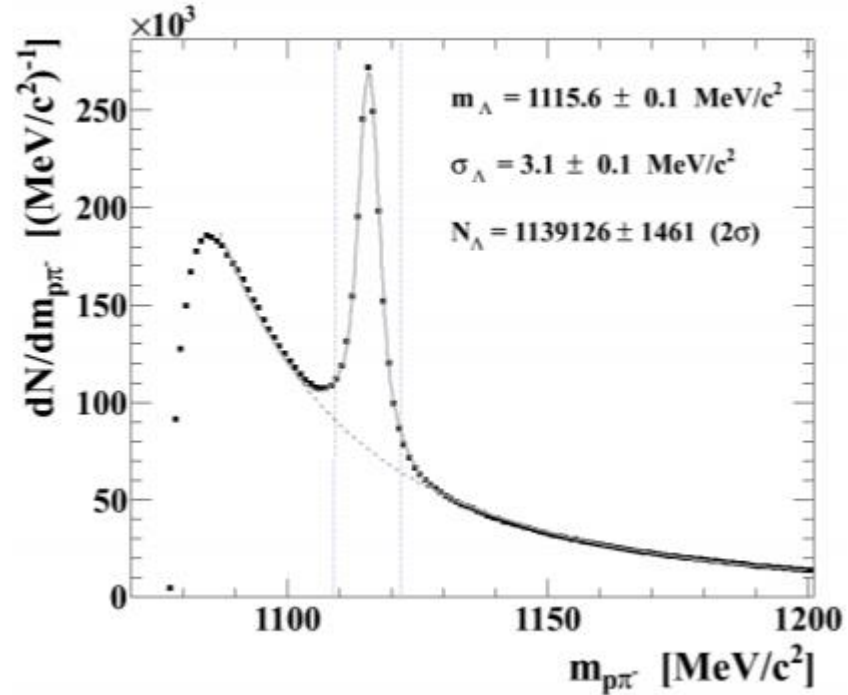
ECAL



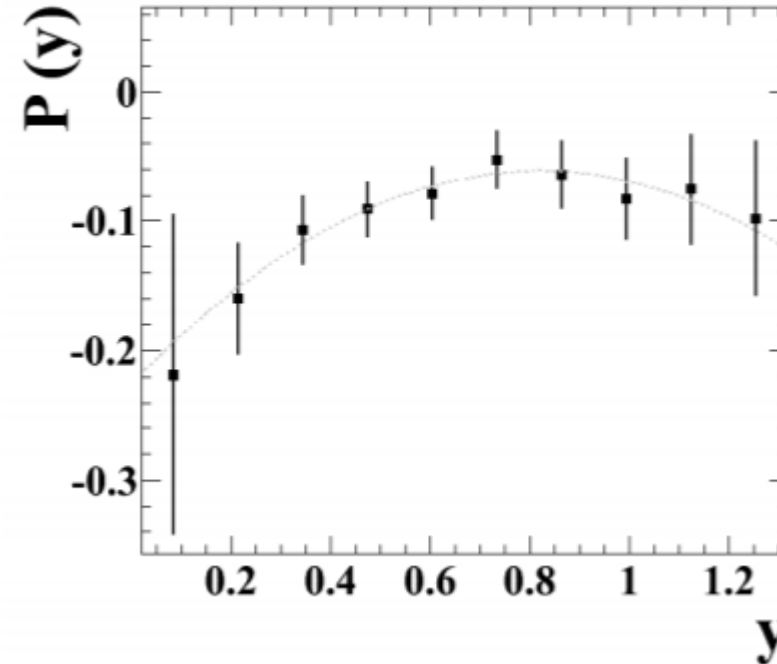
HADES ECAL basic design

Basic design of the HADES Electromagnetic calorimeter ECAL
(6 Sectors with $163 \times 6 = 978$ Modules)

Hyperon production @HADES p + Nb @ 3.5 GeV



Eur. Phys. J. A 50 (2014) 81



Average polarisation

$$\langle P \rangle = -0.119 \pm 0.005 (\text{stat}) \pm 0.016 (\text{syst})$$

The HADES spectrometer –Forward Wall

- **Detector geometry**

full azimuthal range covered, 6 sectors
polar angle: $16^\circ < \theta < 84^\circ$

- **Tracking**

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24 Mini Drift Chambers

- **Particle identification (e, p, K, p)**

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**Designed for di-electron spectroscopy,
also suited for the charged hadron detection**

