CZECH PARTICIPATION AT FACILITY

FOR ANTIPROTON AND ION RESEARCH (FAIR)

Rez

Neutral meson production in AgAg@1.58 A GeV

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for the HADES collaboration

Nuclear Physics Institute
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EUROPEAN UNION
European Structural and Investment Funds
Operational Programme Research,
Development and Education

MINISTRY OF EDUCATION,
YOUTH AND SPORTS

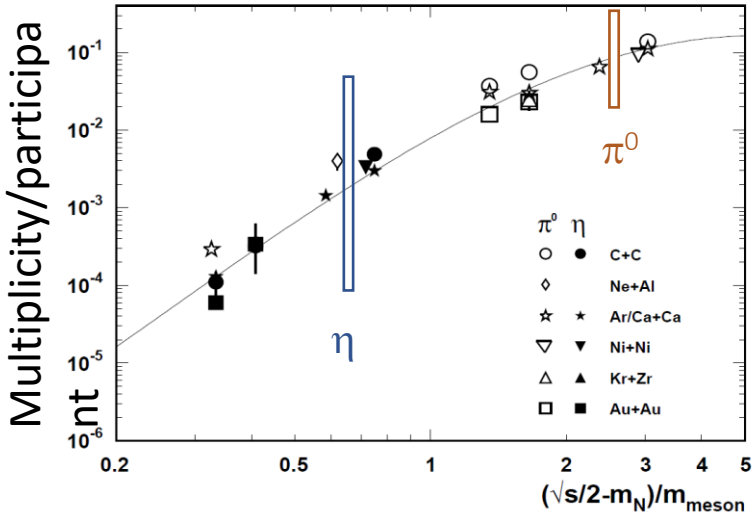
MESON 2021

Outline

- Motivation : Equation of State
- HADES overview with ECAL
- Data analysis
- Neutral pion yields
- Outlook

Motivation

- Thermal radiation under control
- Neutral pion production cross check
- With ECAL ->studying different decays with photons (e.g. hyperons)
- η production – lack of data for heavy systems**



**Phys.Rec. C67 (2003) 024903

Equation of state

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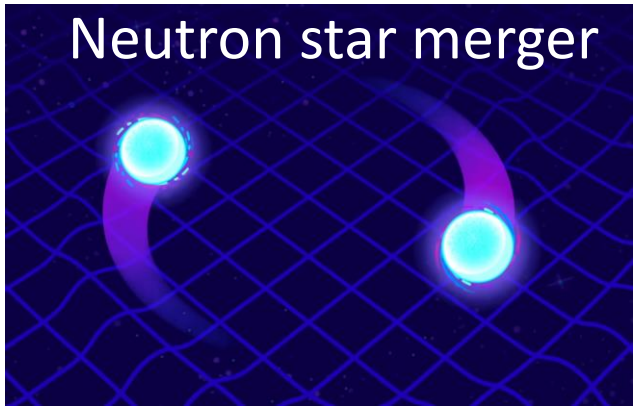

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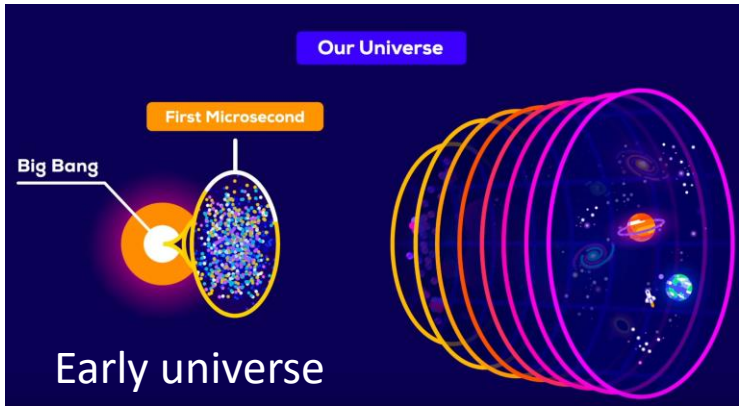
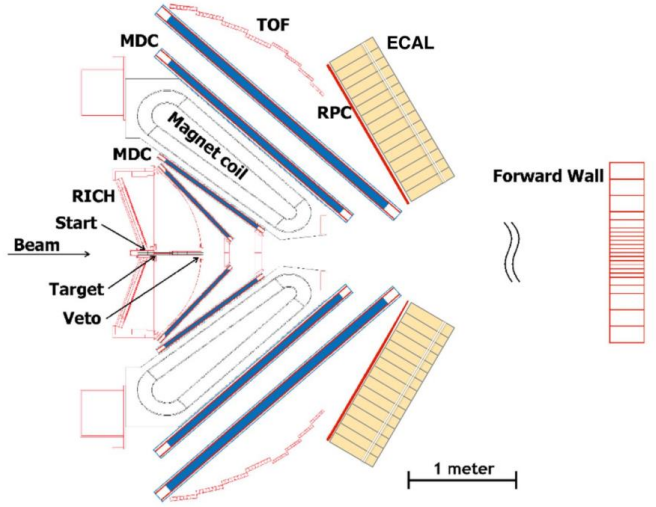


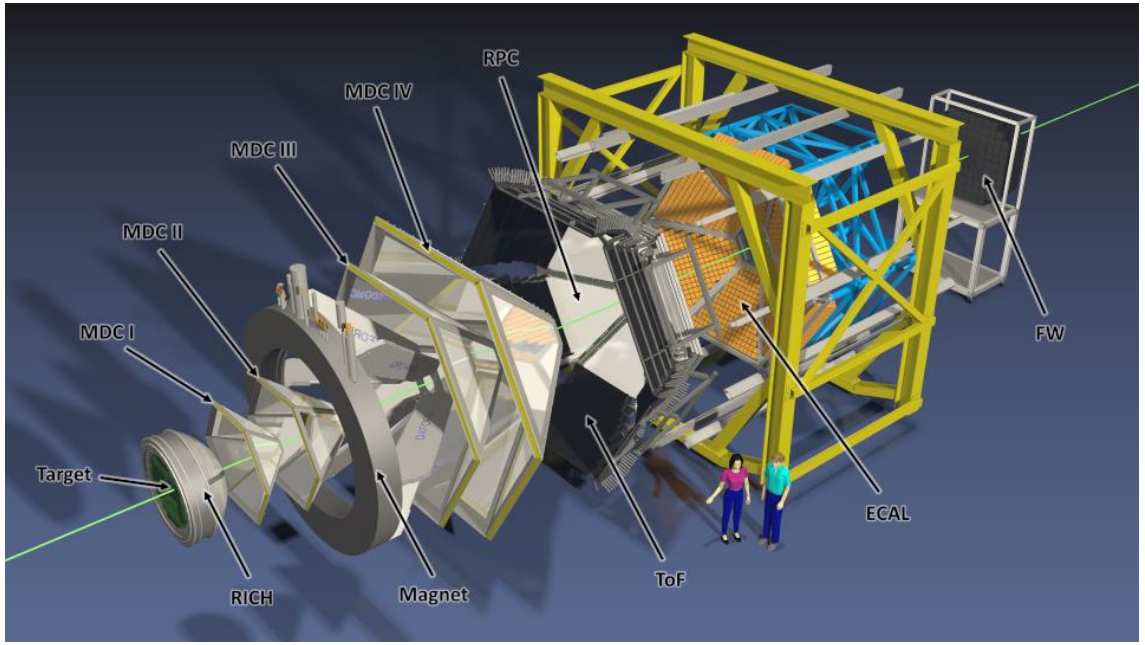
* kurzgesagt.org

High Acceptance Di-Electron Spectrometer

- Tracking system and magnetic spectrometer
- Forward Wall
- Time-of-flight determination
- RICH for lepton identification
- ECAL for identification of photons and their energy reconstruction
- *ECAL is FAIR Phase-0 detector*

HADES vertical cross section





Ag+Ag@1.58 A GeV beam time 2019 and perfomance

March 2019 → Ag+Ag@1.58AGeV → 14 billion events

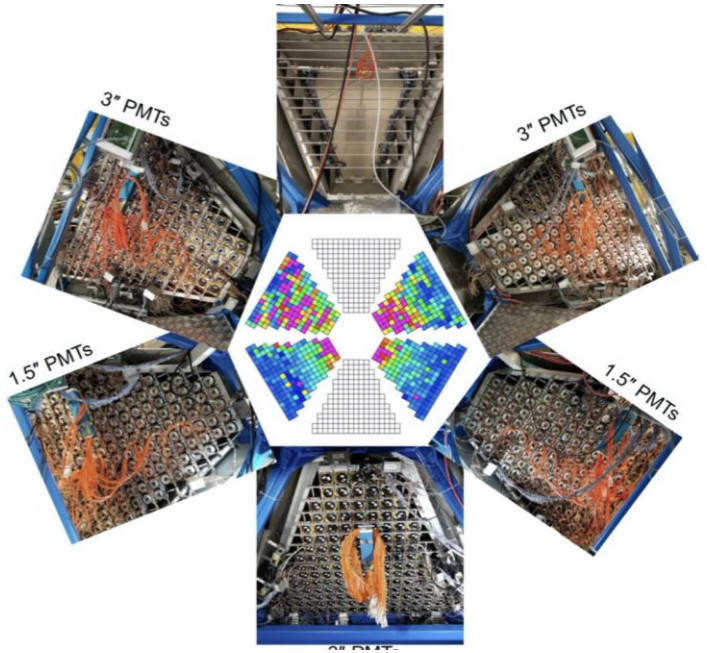
March 2019 → Ag+Ag@1.23AGeV → 0.7 billion events

focus in the presentation

π^0 DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
2γ	(98.823±0.034) %	S=1.5	67
$e^+e^-\gamma$	(1.174±0.035) %	S=1.5	67
γ positronium	(1.82 ±0.29) × 10^{-9}		67
$e^+e^+e^-e^-$	(3.34 ±0.16) × 10^{-5}		67
e^+e^-	(6.46 ±0.33) × 10^{-8}		67

η DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
Neutral modes			
neutral modes	(72.12±0.34) %	S=1.2	–
2γ	(39.41±0.20) %	S=1.1	274
$3\pi^0$	(32.68±0.23) %	S=1.1	179
$\pi^0 2\gamma$	(2.56±0.22) × 10^{-4}		257
$2\pi^0 2\gamma$	< 1.2 × 10^{-3}	CL=90%	238
4γ	< 2.8 × 10^{-4}	CL=90%	274
invisible	< 1.0 × 10^{-4}	CL=90%	–

ECAL in 2019



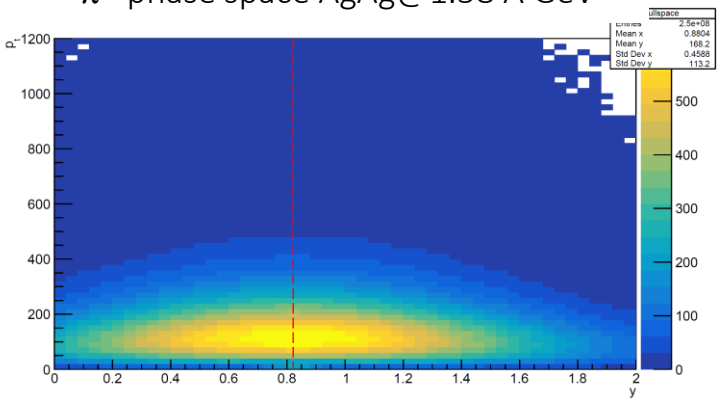
ECAL detector was used for the first time

- PMT readout with two different types
- 4 sectors ready for beamtime in 2019
- 5th ready now, 6th in 2022

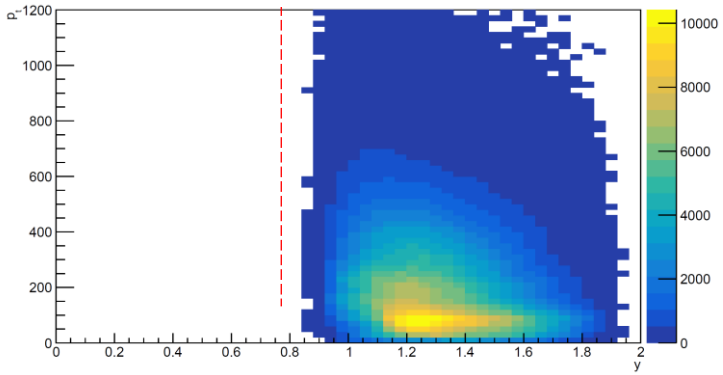
Electromagnetic calorimeter

"Every particle will end up someday in a calorimeter…"

π^0 phase space AgAg@1.58 A GeV



phase space in acceptance of ECAL

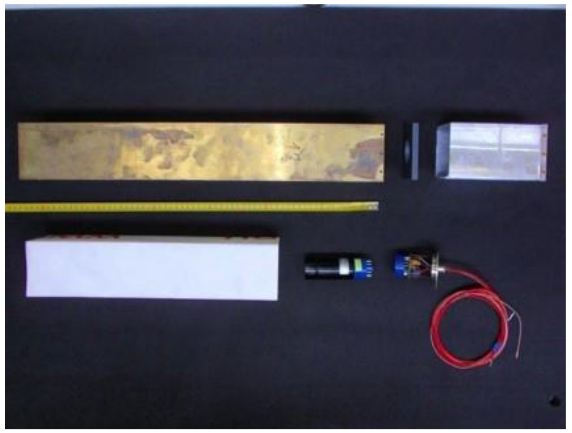


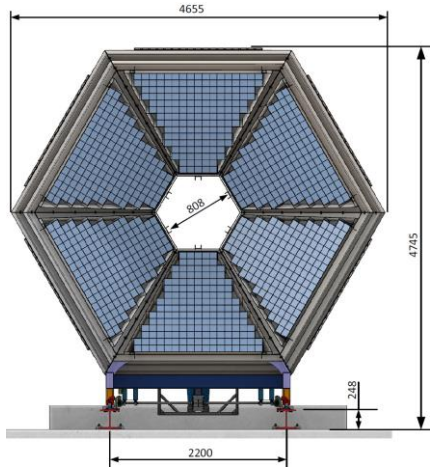
Detectors modules

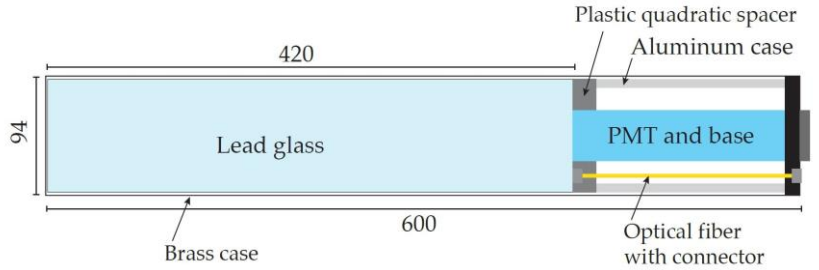
- 6 sectors covering $12^\circ < \theta < 45^\circ$
- Cherenkov lead glass modules from OPAL end cap calorimeter (163 modules x 6 sectors = 978 each 16 kg)
- Module dimenstions : 9.4 x 9.4 x 60 cm^3

PMT read out (with two different types)

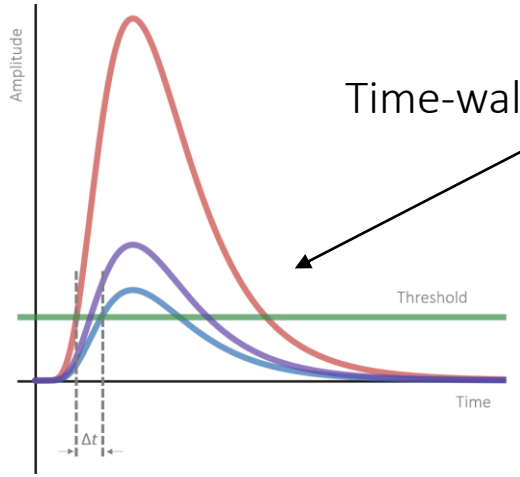
- EMI 9903kB (1.5")
- Hamamatsu R6091 (3")







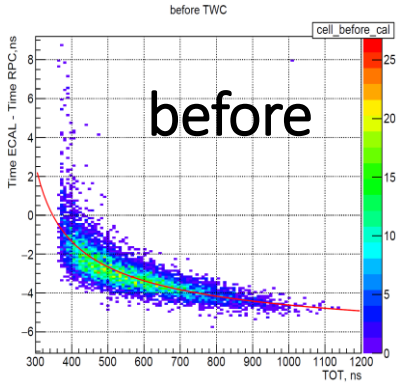
Calibration of ECAL by leptons

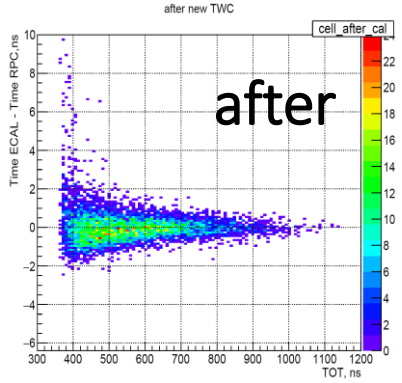


Time-walk effect

leptons develop in ECAL
elmg. shower like photons

$$TWC = Time_{\mathrm{ECAL}} - Time_{RPC} = a_0 + \frac{a_1}{\sqrt{TOT - a_2}}$$

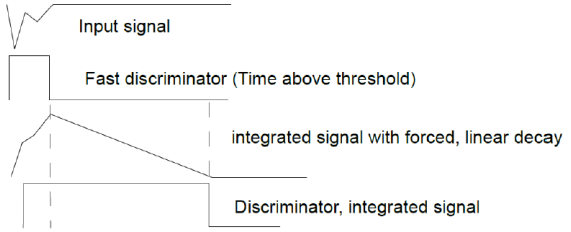




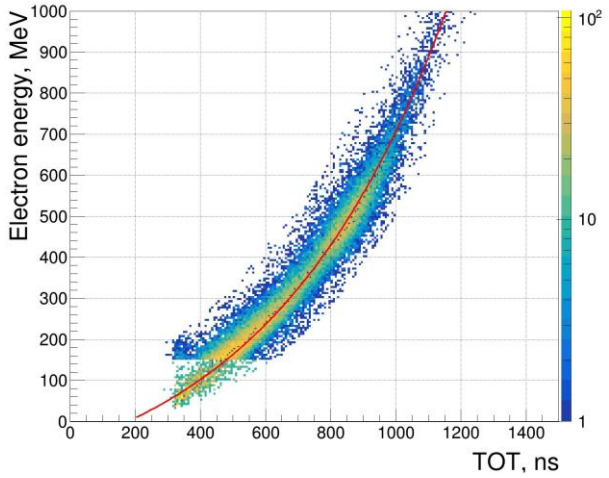
Time precision - 200ps

COME & KISS * : Charge Measurement with an FPGA

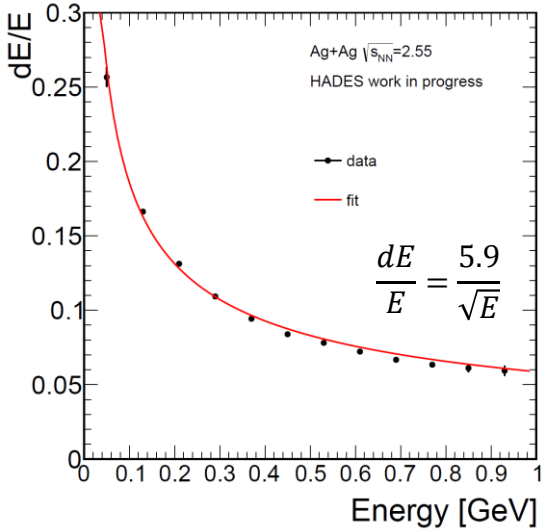
- **Idea:** Modified Wilkinson ADC
- Integrate input signal with a capacitor
- Discharge via a current source
  → fast crossing of zero
- **Q2W**: Measure time to reach zero
  ~**Q** using an **FPGA-TDC**



$$E = a_0 + \exp(a_1 + a_2 TOT)$$



E ∝ the charge of PMT signal ∝ Time-over-Threshold



Energy precision - 5.9%

* use commercial elements and keep it small & simple

Photon identification and event selection

Photon definition :

- No match with charged particle tracks from MDC+RICH
- No match with RPC
- Signal in ECAL

Photon pair cut:

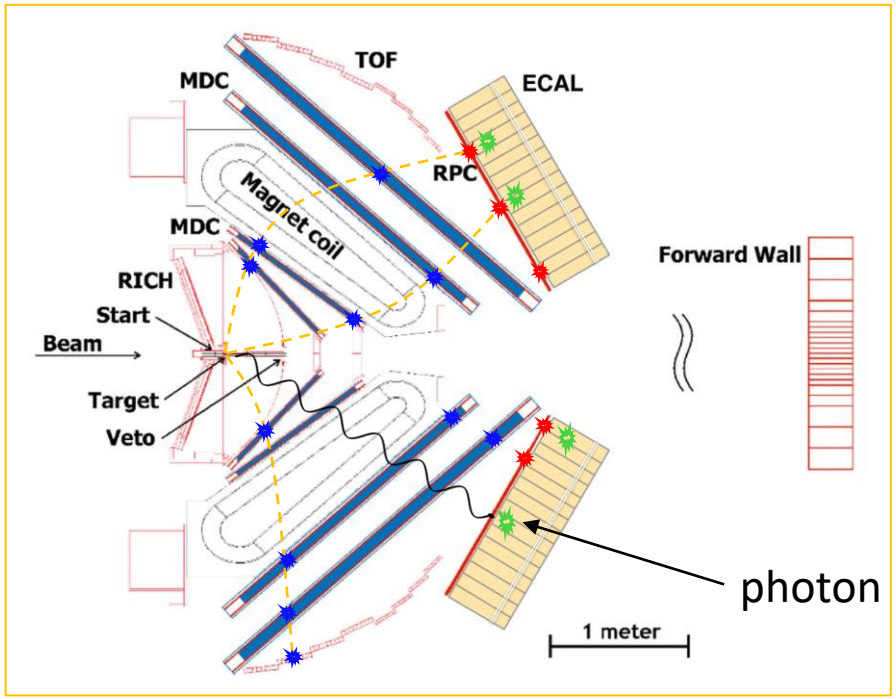
opening angle θ_{op} cut > 10°

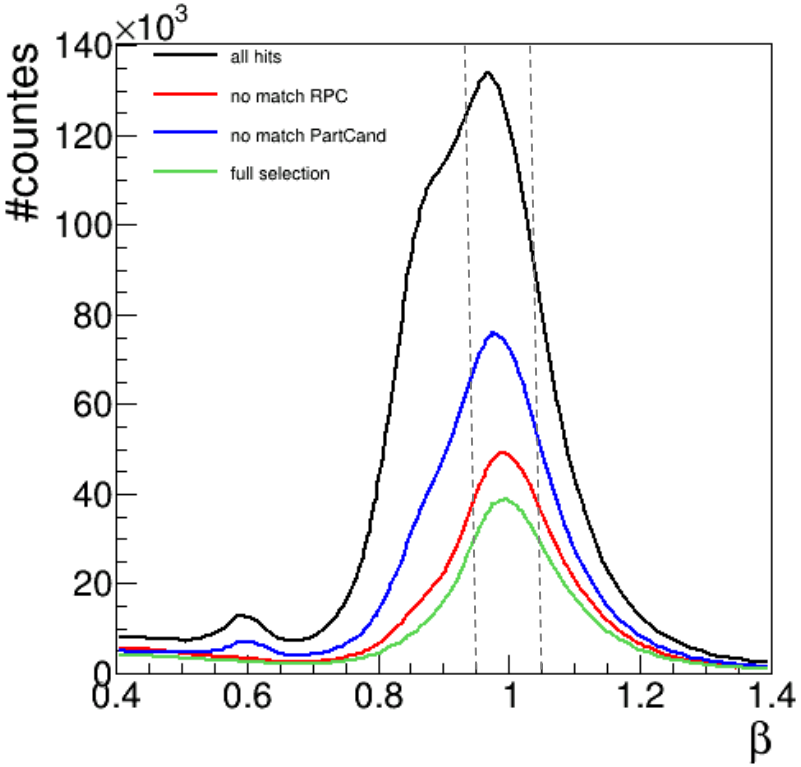
0< p_t <800

0.9< y <1.9

Event selection cut:

Centrality 0-30%



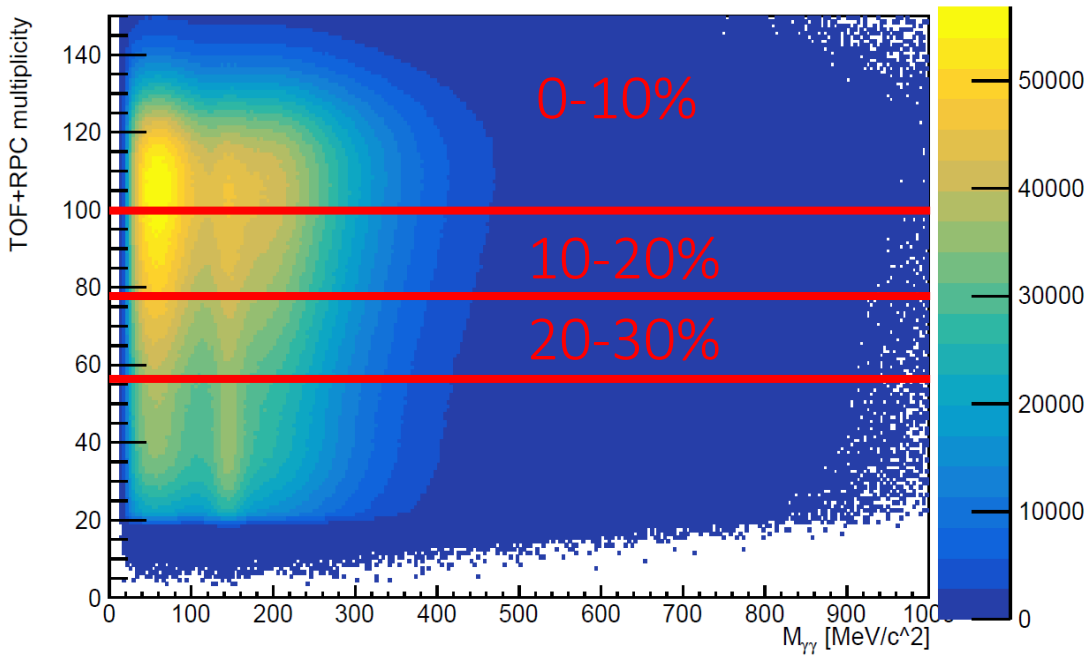


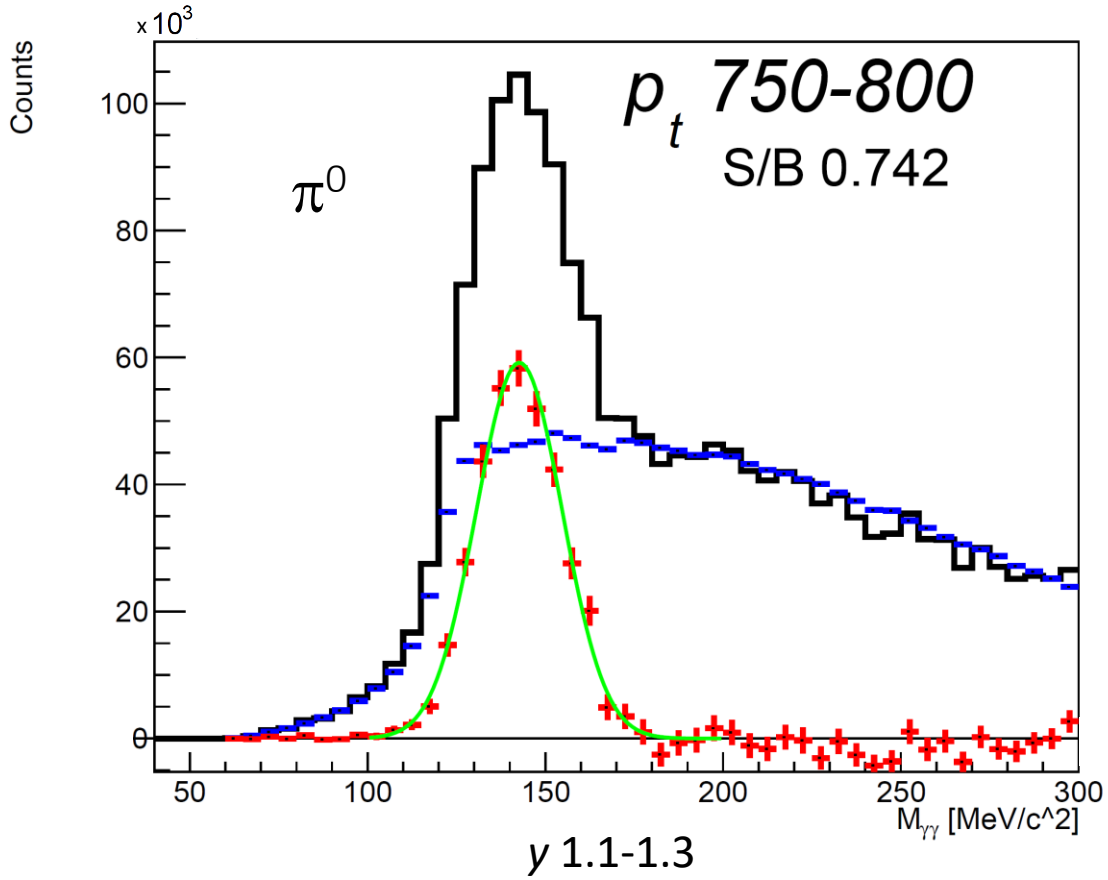
Diphoton combinations

Events classification used for mixing:

- centrality class
- photon multiplicity
- target segment

Centrality





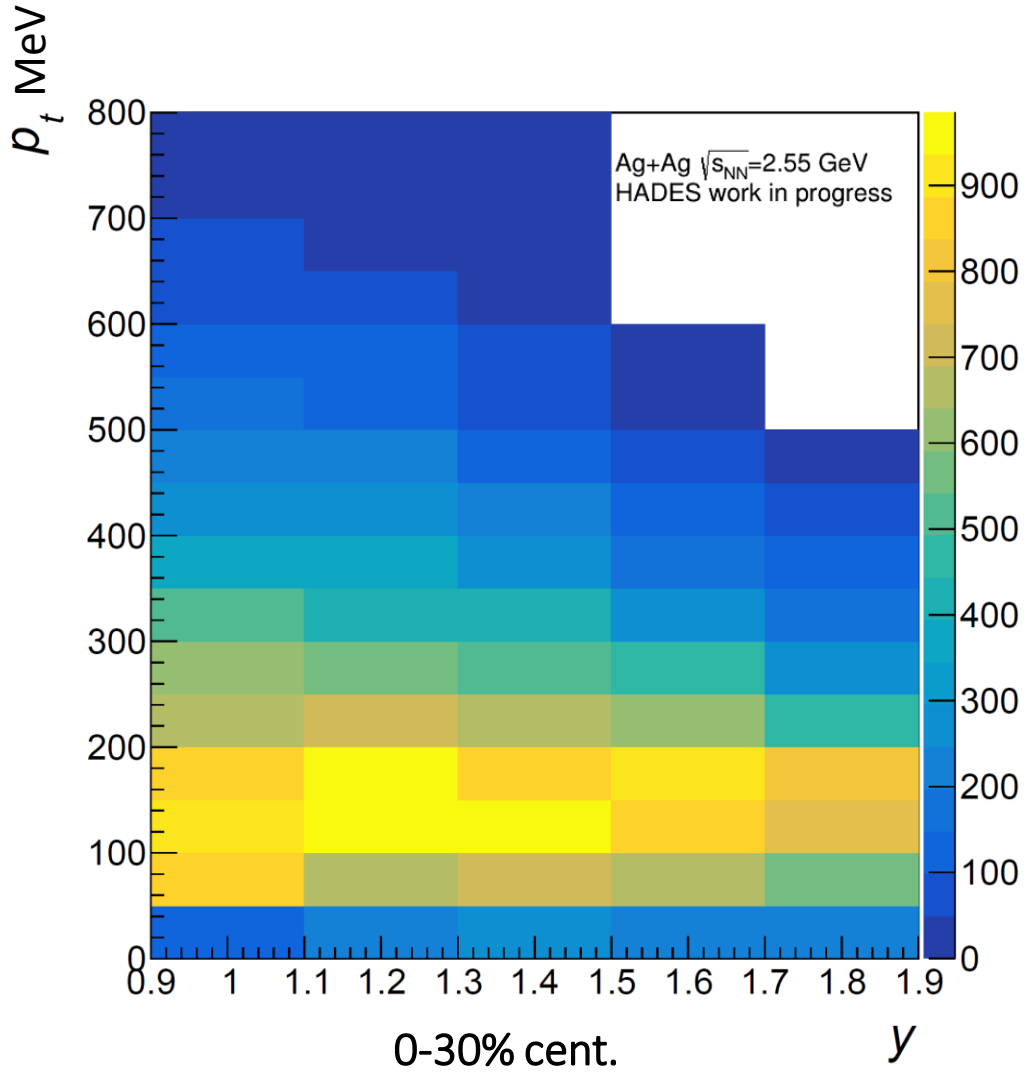
All – experimental data

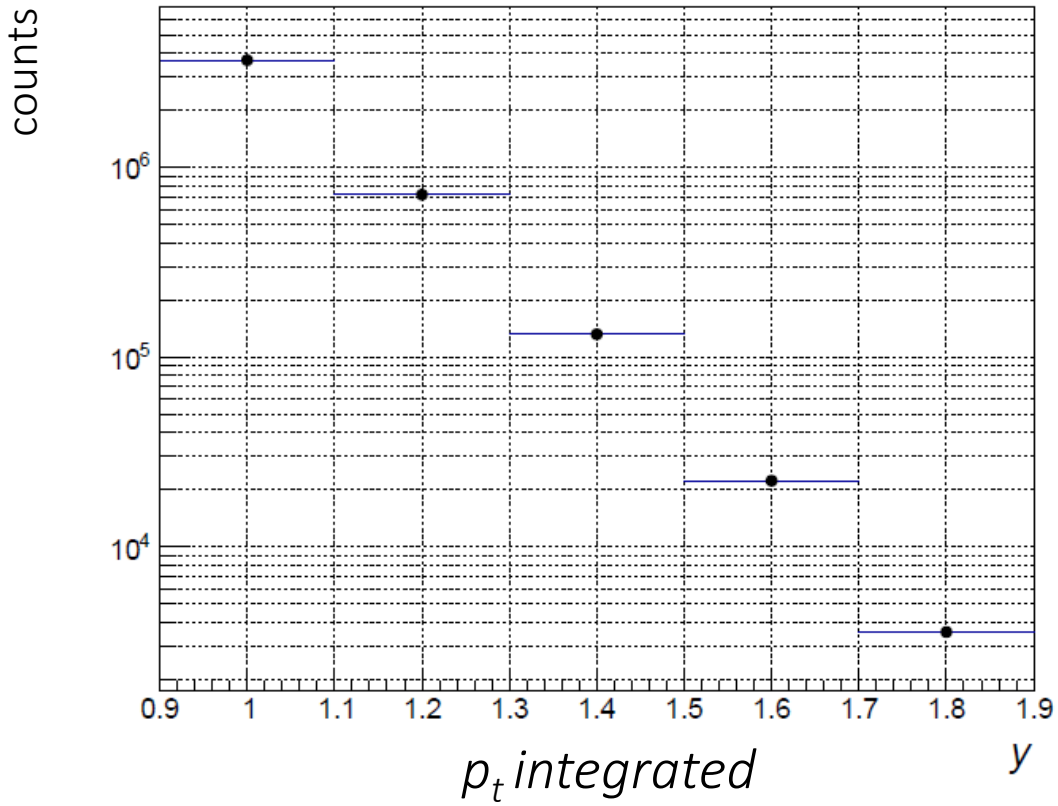
CB – mixed-event combinatorial background

Sig – signal

Signal is fitted with Gauss

Multi-differential analysis



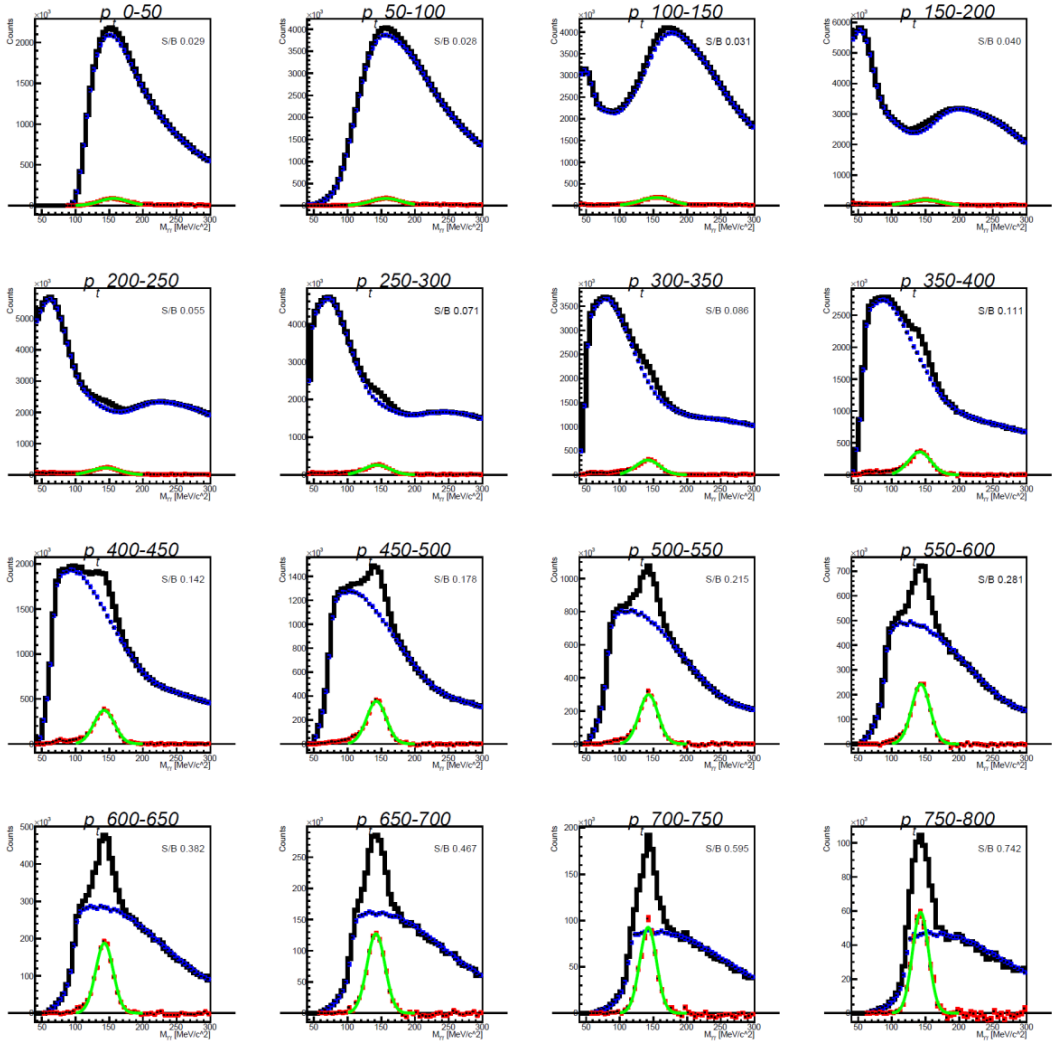


Systematics are under investigation

All yields are corrected by acceptance and efficiency

Multi-differential analysis

0-30% cent. y 1.1-1.3



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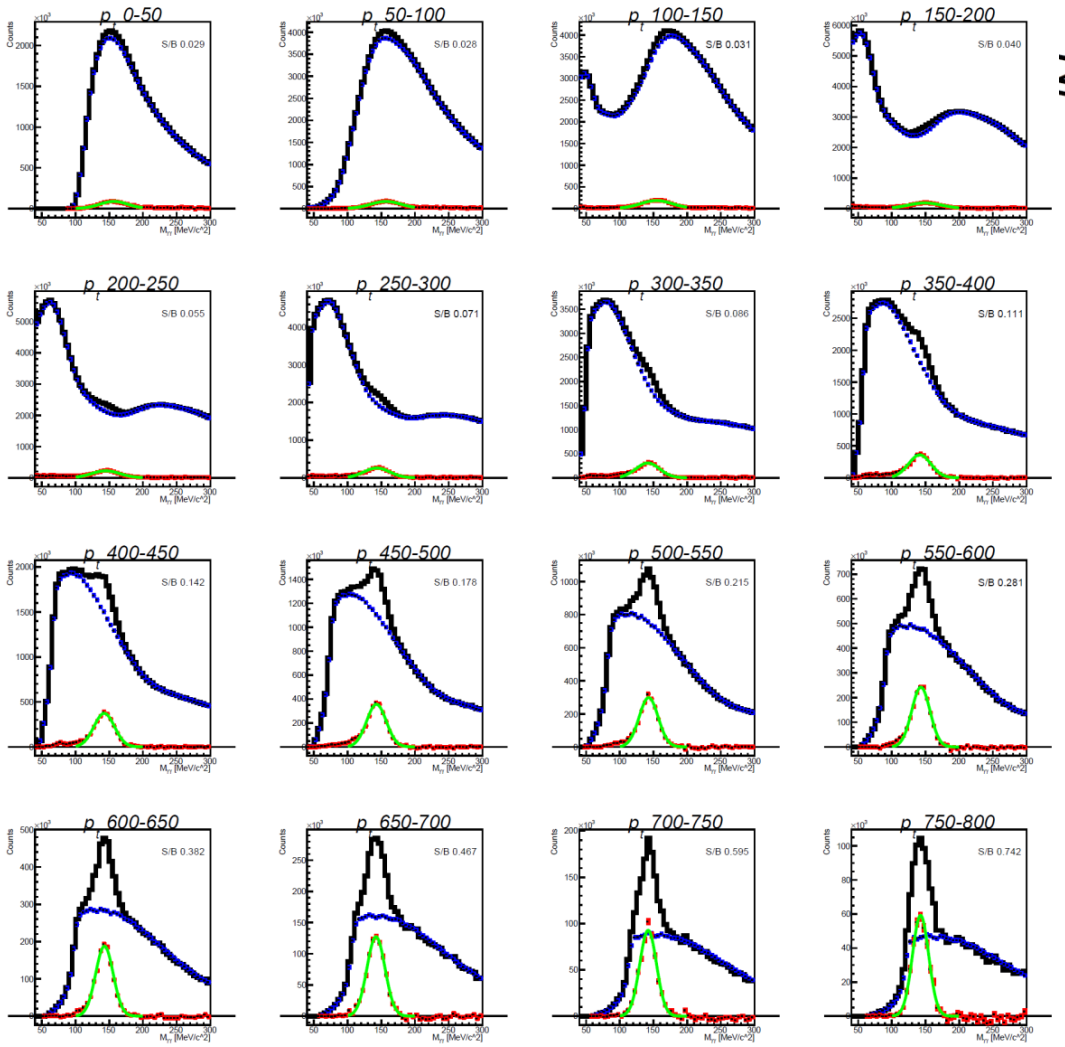
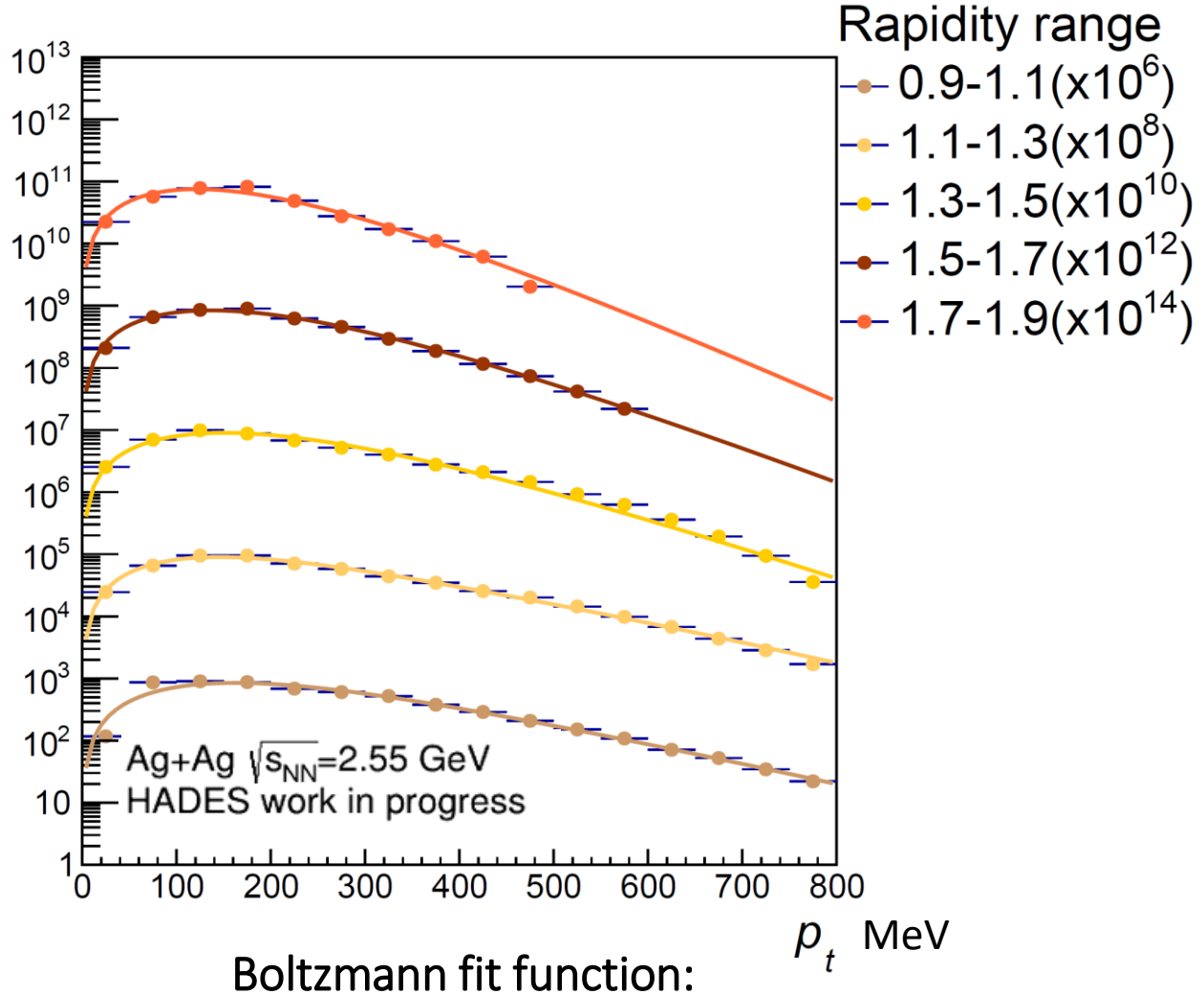


$\frac{dN}{dp_t}$



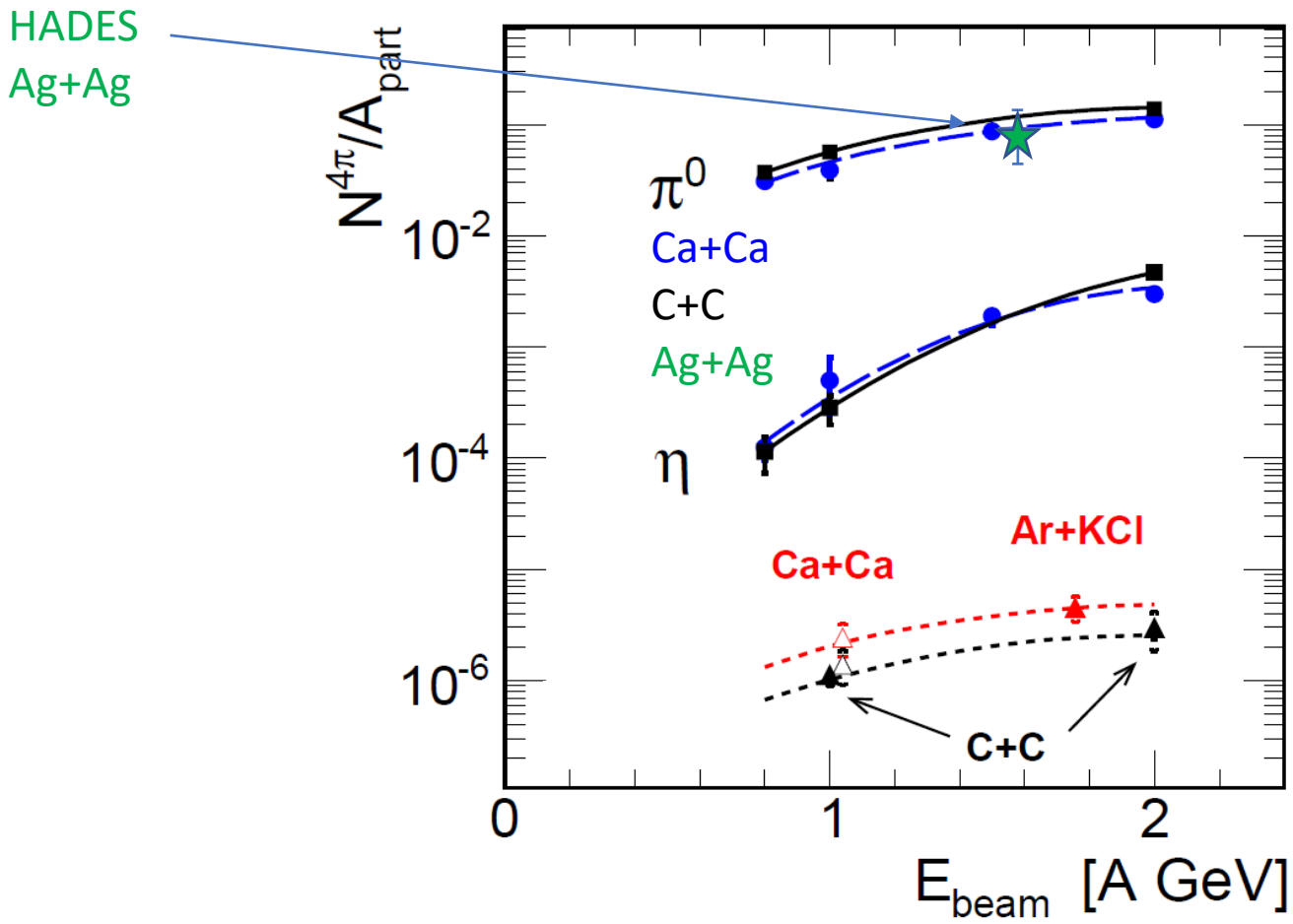
Boltzmann fit function:

$$\frac{dN}{dp_t} = C\, p_t\, m_t e^{-\frac{m_t}{T}},$$

Normalized pion multiplicity comparison for different collision systems

Extrapolated to 4π using model (UrQMD)
π^0 azimuthal distribution

Systems are normalized by number of participants



Eta outlook

- Eta yields measurement at HADES beam energies with the same centrality selection as e^+e^- spectra
- constrain the contribution to the freeze-out cocktail in e^+e^- spectra
- can be used as an input to Statistical Hadronization Models

η DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
Neutral modes			
neutral modes	(72.12±0.34) %	S=1.2	–
2γ	(39.41±0.20) %	S=1.1	274
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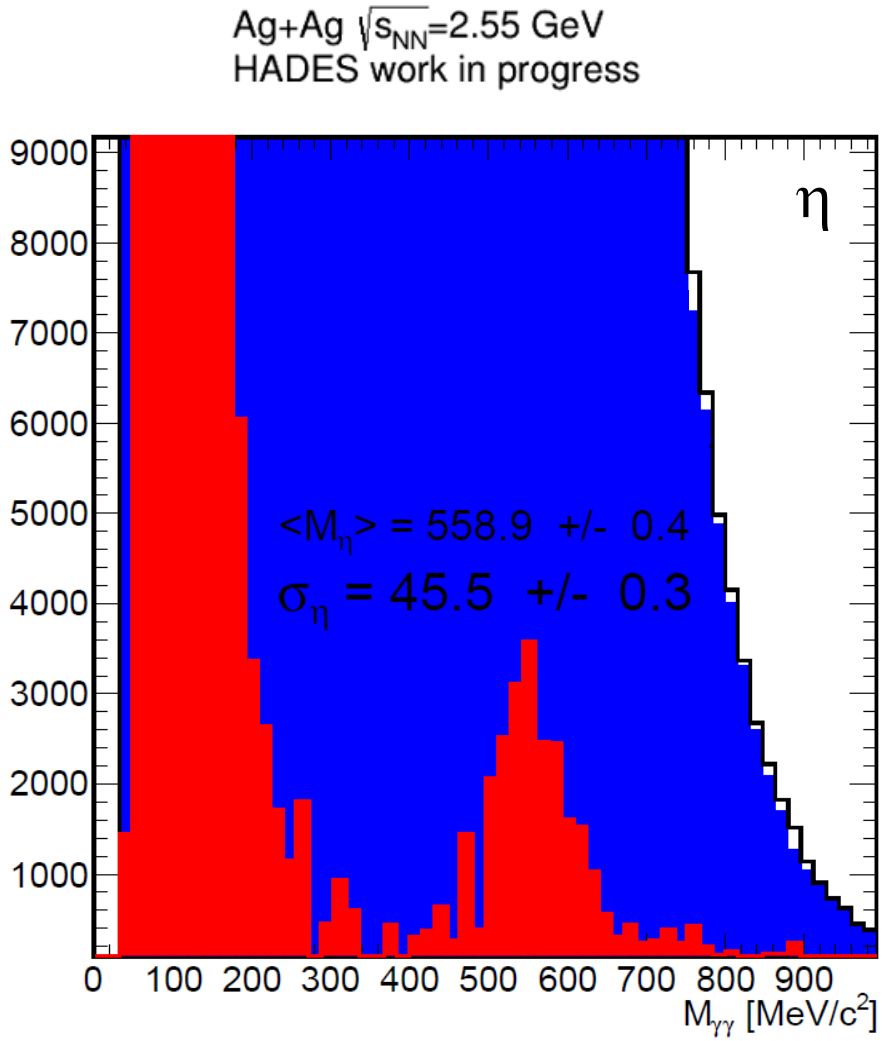


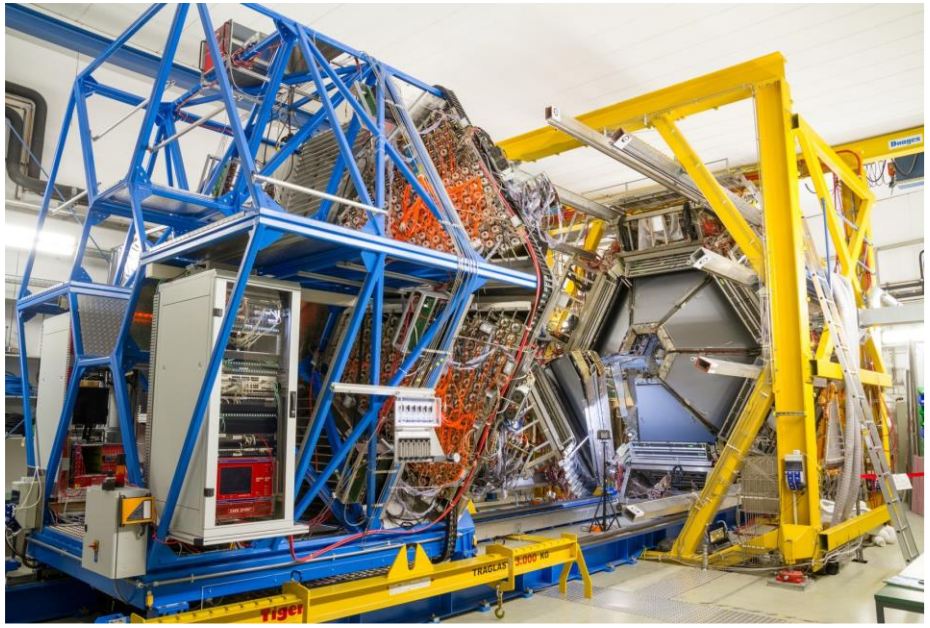
0-30% cent.

Summary and Outlook

- First results on neutral pion yields at such energies in heavy projectile-target collision system and comparison to the world data – an input to world systematics
- A newly installed electromagnetic calorimeter was successfully used in experiment!
- A calibration based on leptons was performed – achieved 5,9% energy precision

More to come:

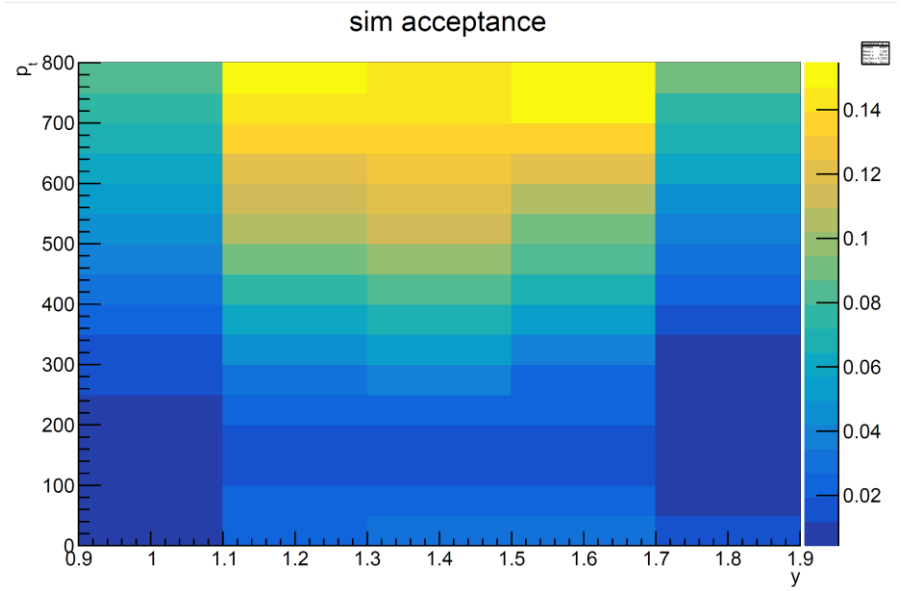
- Flow of neutral pions
- Eta particle analysis
- Compare yields with different methods used in HADES(Dalitz and photon conversion)

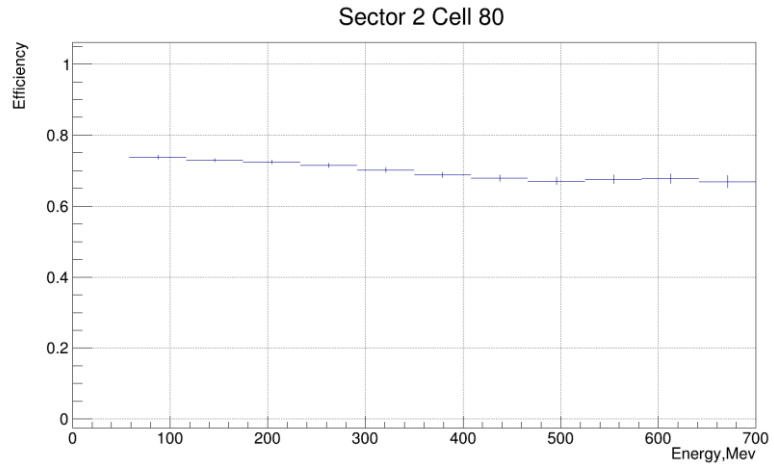


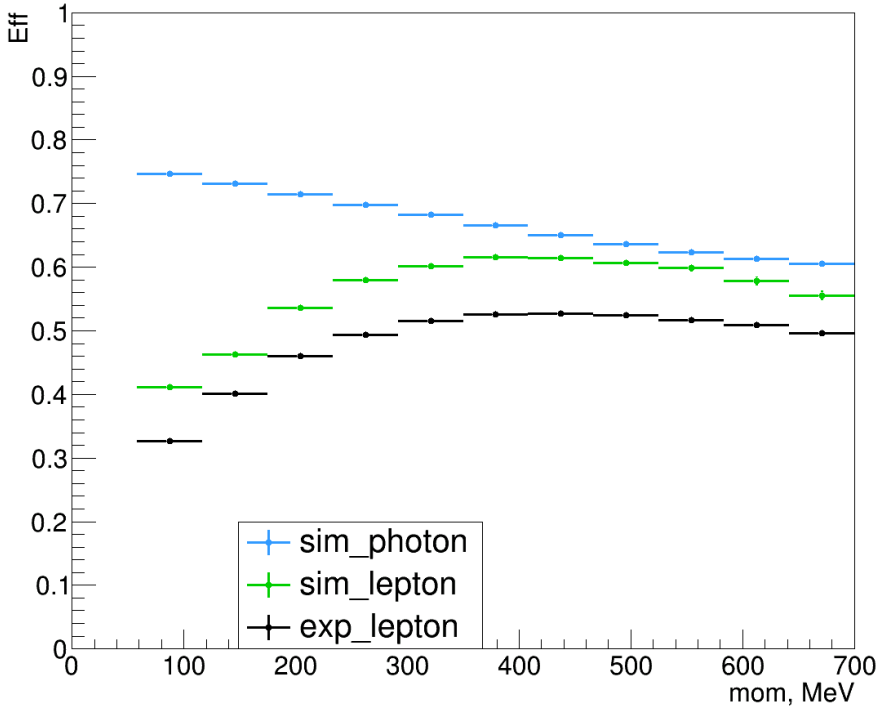
Thank you for your attention!

- Work supported by:
- MEYS CZ - LM2018112 grant
- FAIR-CZ-OP grant CZ.02.1.01/0.0/0.0/16_013/0001677
- LTT17003

Efficiency







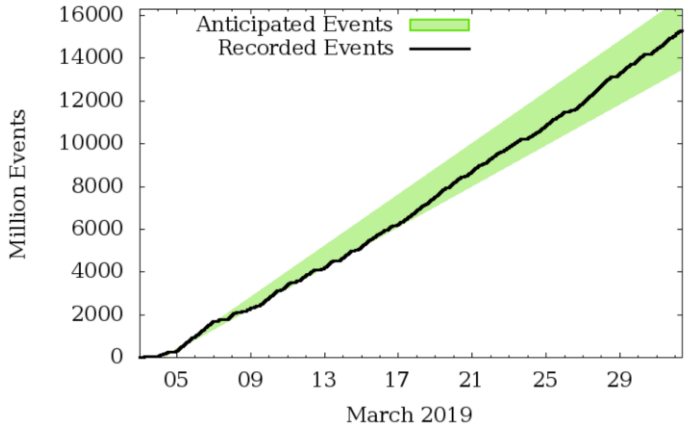
$$Efficiency_{\gamma} = \frac{identified\ photons\ from\ primary\ \pi_0}{all\ emmited\ photons\ from\ primary\ \pi_0}$$

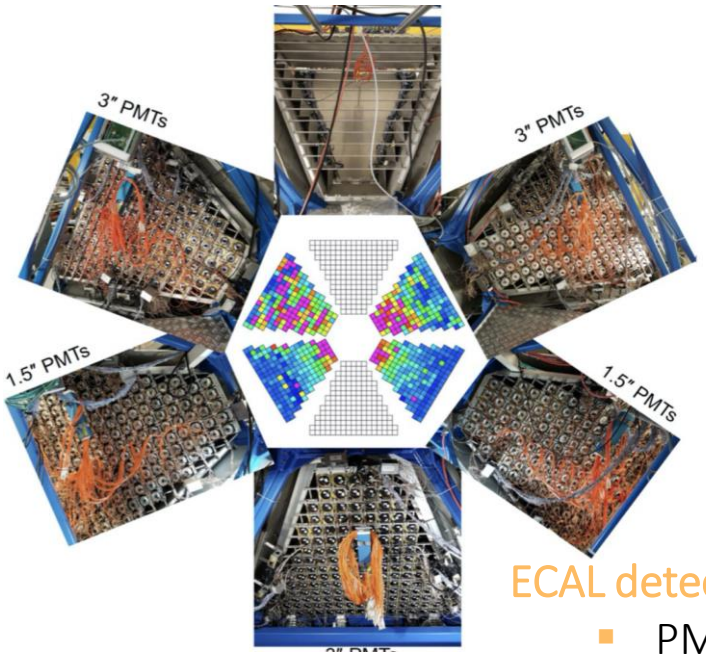
$$Efficiency_{e^{\pm}} = \frac{identified\ leptons\ in\ ECAL}{identified\ leptons\ in\ HADES}$$

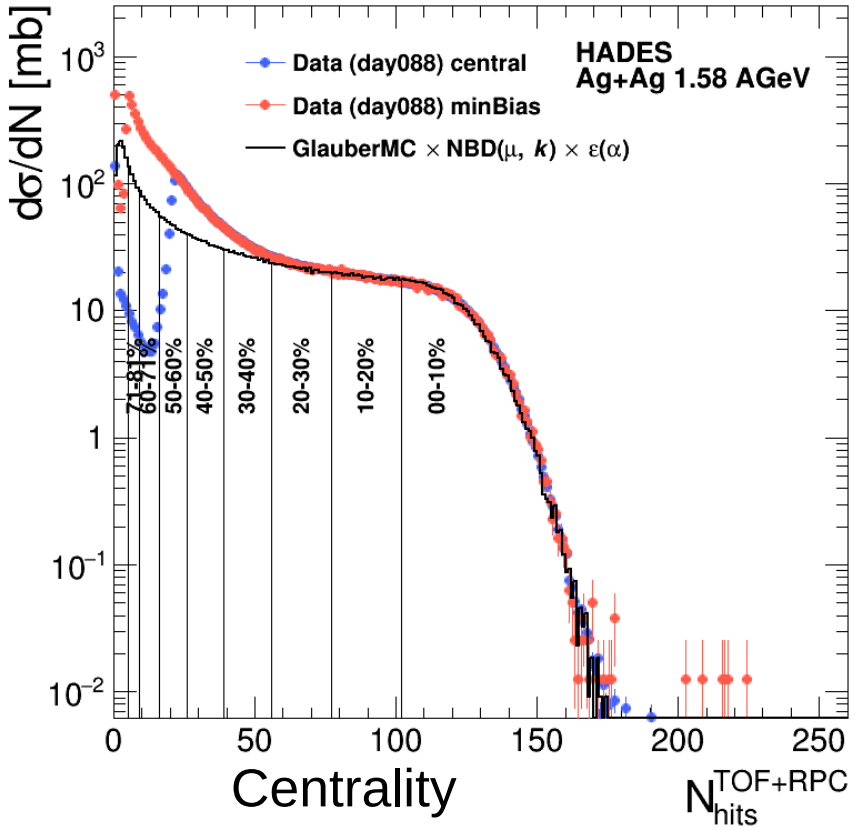
(wrt. photon acceptance)

Ag+Ag@1.58 AGeV beam time 2019 and perfomance

- In March of 2019 - experiment Ag+Ag at 1.58 AGeV
- 15 billion events collected
- 16-18 kHz event rate
- FAIR Phase-0 program





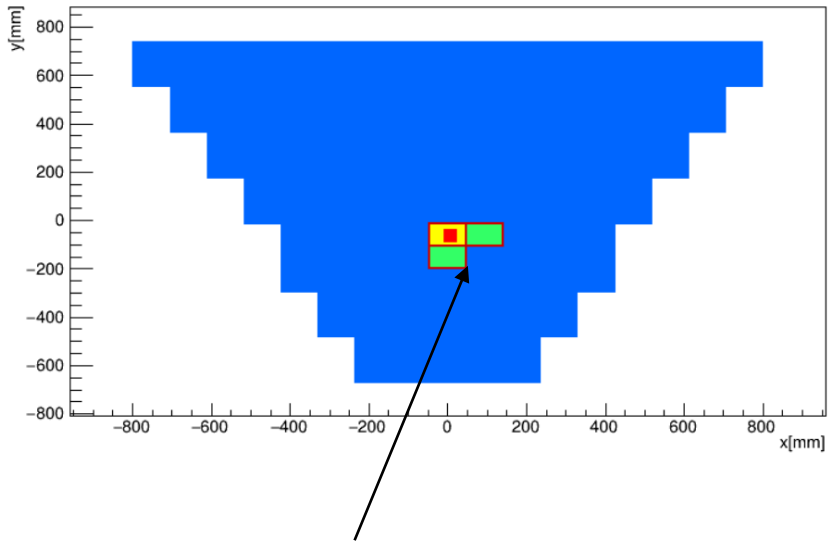


- 0-30% most central
- Deduced from a Glauber MC model

ECAL detector was used for the first time

- PMT readout with two different types
- 4 sectors ready for beamtime in 2019
- 5th ready now, 6th in 2022

Clustering in ECAL

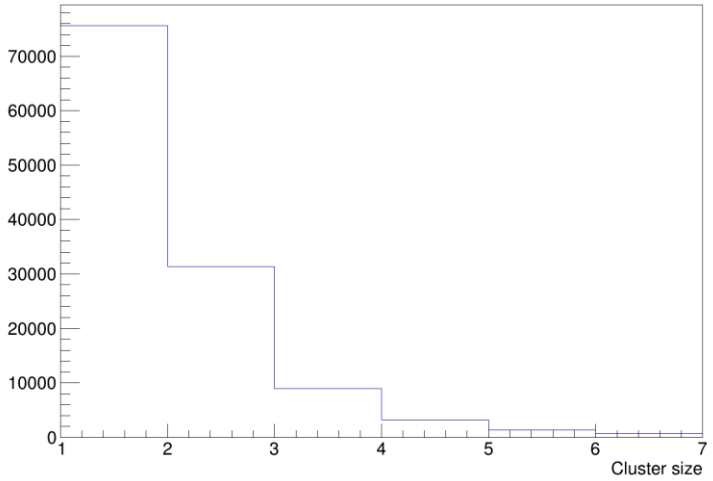


Cluster size 3 photon

Several adjacent fired modules are grouped in so-called **clusters**.

For the calibration ->
use only cluster size 1 leptons

Photon cand distribution

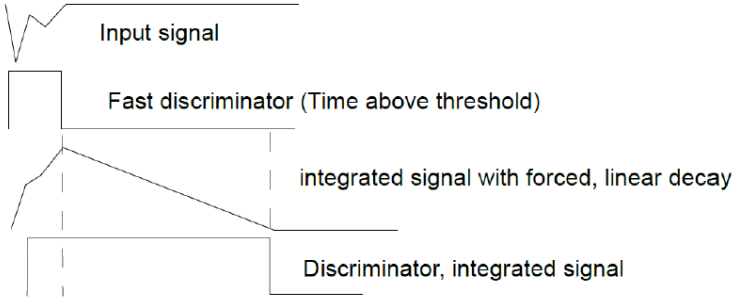


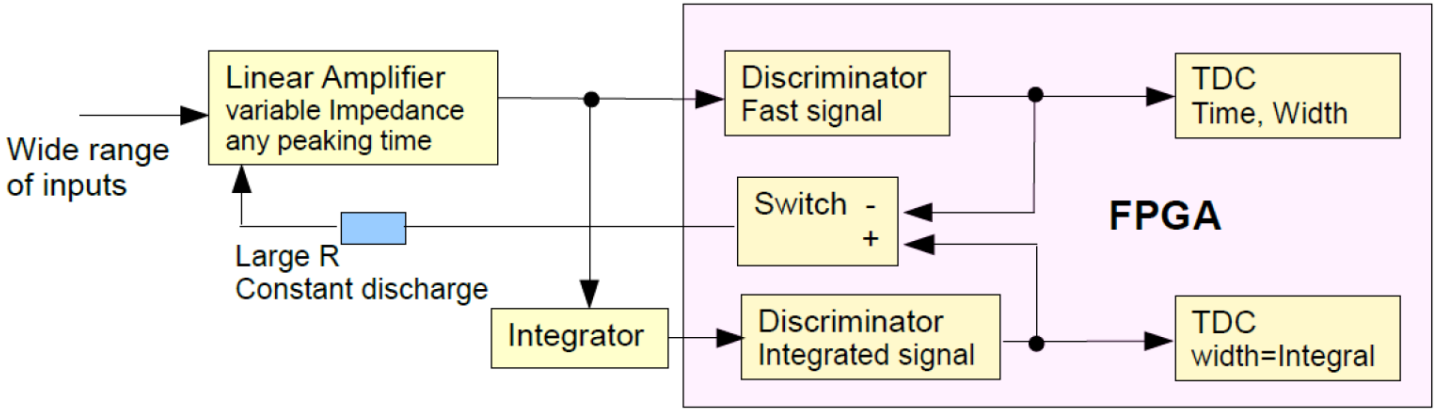
COME and KISS

COME & KISS: Charge Measurement with an FPGA

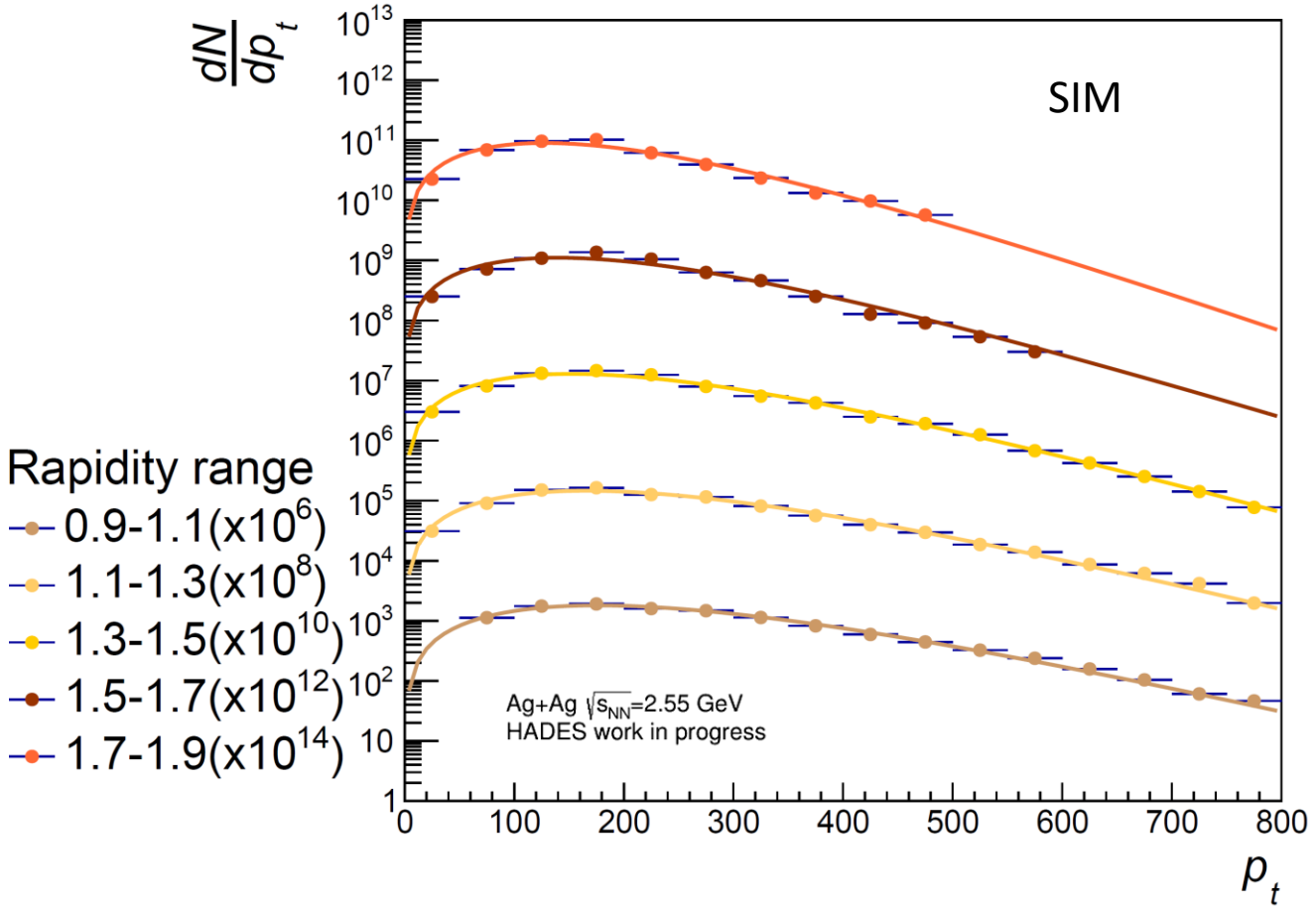
TECHNISCHE UNIVERSITÄT DARMSTADT

- **Idea:** Modified Wilkinson ADC
- Integrate input signal with a capacitor
- Discharge via a current source
  → fast crossing of zero
- **Q2W**: Measure time to reach zero
  ~Q using an **FPGA-TDC**



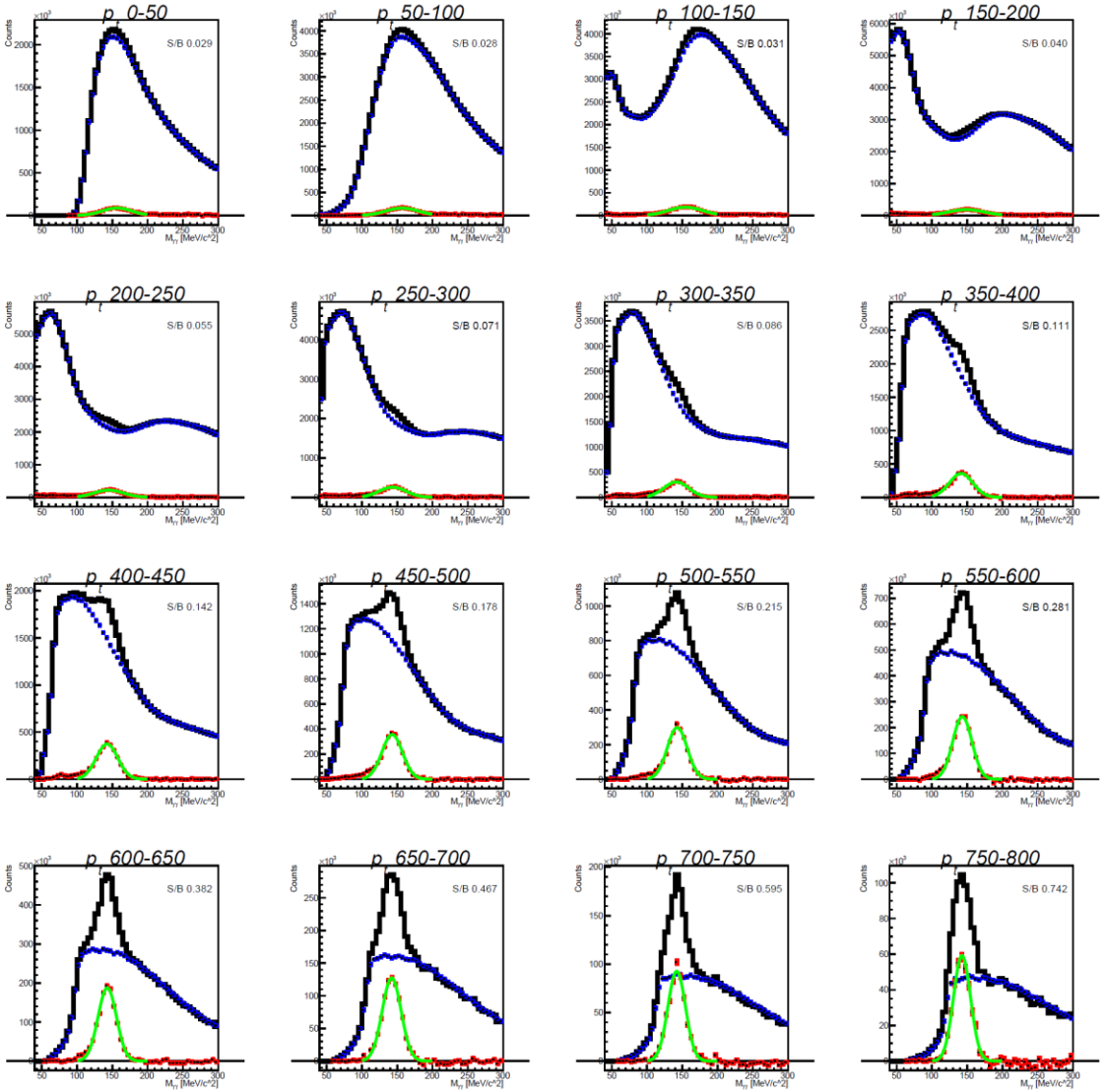


GEANT+analyzed+eff.correcred+acceptance corrected



Rapidity bin 1.1-1.3

EXP



SIM – urqmd+hgeant+digitizer