“HADES:JINR participation”

(prolongation for 2019 -2021 yy)

theme: 02 - 1- 1106

A.Belyaev, O. Fateev, A. Ierusalimov, V.Ivanov, V.Ladygin, S.Lebedev, G.Lykasov, A.Troyan, A.Zinchenko

Professor Y.V.Zanevsky organized the participation of JINR at HADES and he was a leader of JINR group for many years.

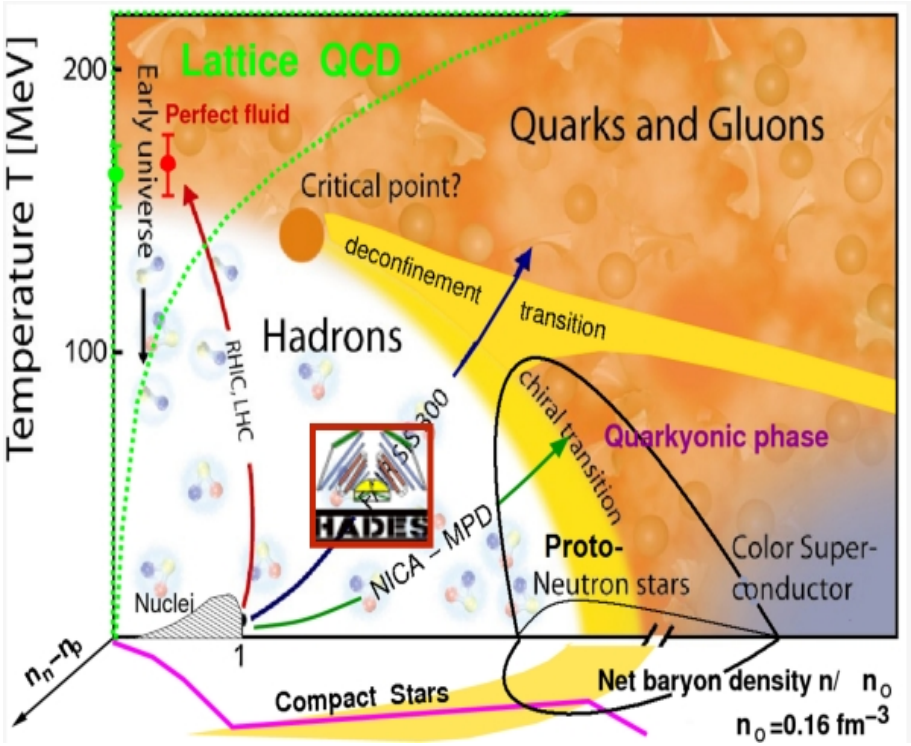
2015 – prolongation for 2016-2018
2016 – changing of the leaders (V.L., O.V.Fateev)
2017 – HADES was moved to the scientific topic CBM (t.1106).
Similarly to situation at FAIR, where
HADES+CBM = HQM (Hadron-Quark Matter) pilar

HADES Collaboration

Bratislava (IOP SAS), Slovakia
Catania (INFN-LNS), Italy
Coimbra (LIP), Portugal
Cracow (SIP JUC), Poland
Darmstadt (GSI), Germany
Darmstadt (TU), Germany
Dresden (HZDR), Germany
Dubna (JINR), Russia
Frankfurt (Goethe-University), Germany
Garching (Excellence Cluster Universe), Germany
Garching (TU München), Germany
Giessen (JLU), Germany
Milano (INFN), Italy
Moscow (INR), Russia
Moscow (ITEP), Russia
Nicosia (Univ.), Cyprus
Orsay Cedex (IPN), France
Rez (NPI AS CR), Czech Republic
Santiago de Compostela (USC - S. de Compostela), Spain
Valencia (IFIC), Spain

The HADES Collaboration includes 23 Institutes from 9 European countries.
http://www-hades.gsi.de/ **- is groing permanently**

Motivation and Actuality of HADES



- Collisions of heavy ions allow to probe nuclear matter at high densities and temperatures
- Astrophysical applications: composition, equation of state
  — mass-radius relation for compact massive stars

The physics motivation for HADES includes the investigation of in-medium modification of light vector mesons as well as the study of dilepton continium in the warm(T<100MeV) and dense(up to $3\rho_0$) hadronic matter at SIS 18, GSI.

HADES strategy:

Systematic di-electron and hadron measurements in NN, AA, pA, πN and πA collisions

HADES, JINR activity

- **Low mass Multilayer Drift Chambers MDC II and Front End Electronics**
  (constructed, tested and integrated into the HADES spectrometer).

- **Track reconstruction Software Development**

- **MDC upgrade (for SIS100), maintenance**

- **Participation in physical program, data analysis, theoretical interpretation**

HADES MILESTONES, JINR PARTICIPANTS

Production beamtimes (SIS-18) - from 2002
HADES upgrade - from 2010
Production beamtime (SIS-100 FAIR) - ~ 2024

Participants :

LHEP JINR - Belyaev A. (0.5), Fateev O. (0.1), Ierusalimov A.(1.0), Ladygin V. (0.1), Troyan A.(0.2), Zinchenko A.(0.1)

DLNP JINR - Lykasov G.

LIT JINR - Lebedev S., Ivanov V.

GSI / Frankfurt Uni. - Pechenov V., Pechenova O.

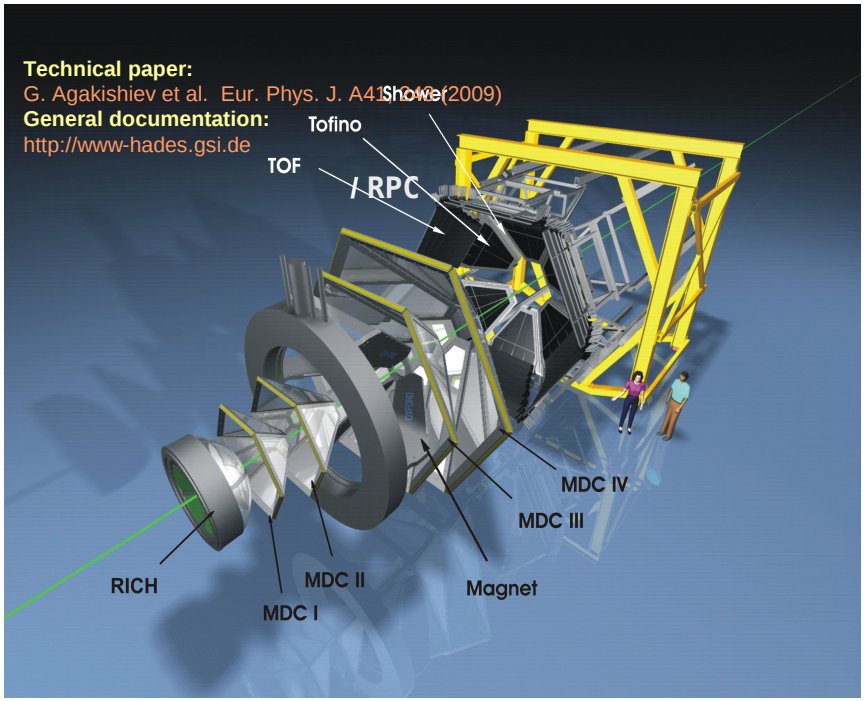
Project Leader at JINR - Fateev O., Ladygin V.

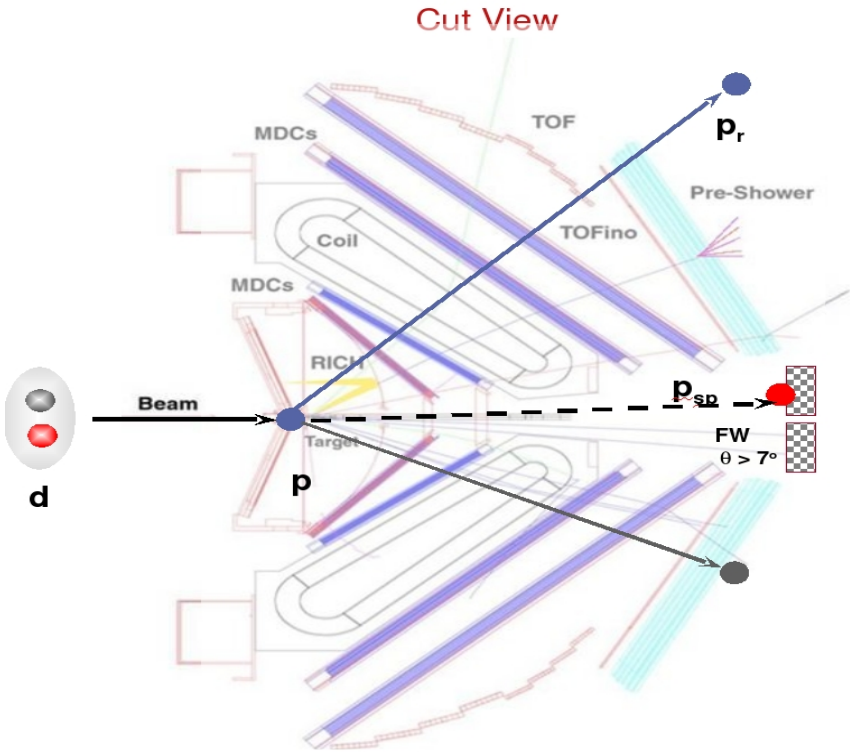
JINR activity is supported by BMBF-JINR grants

The HADES detector at GSI

SIS 18, GSI Darmstadt
(p, π, A) + A collisions
$\rho \leq 3\,\rho_0$, $T \leq 100$ MeV

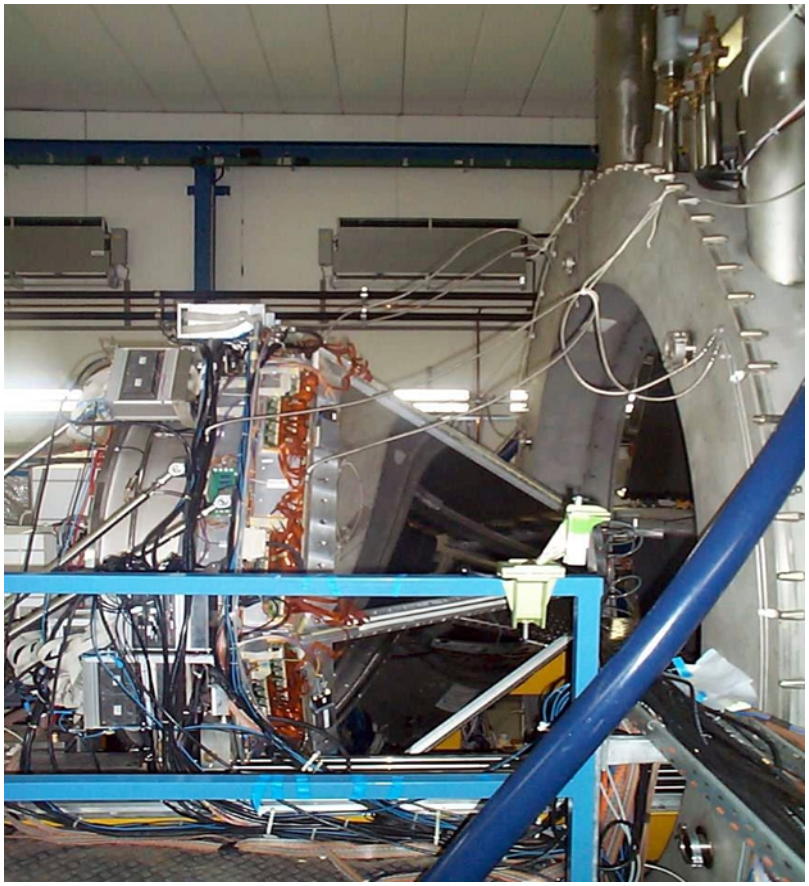
HADES - 2nd generation dilepton spectrometer



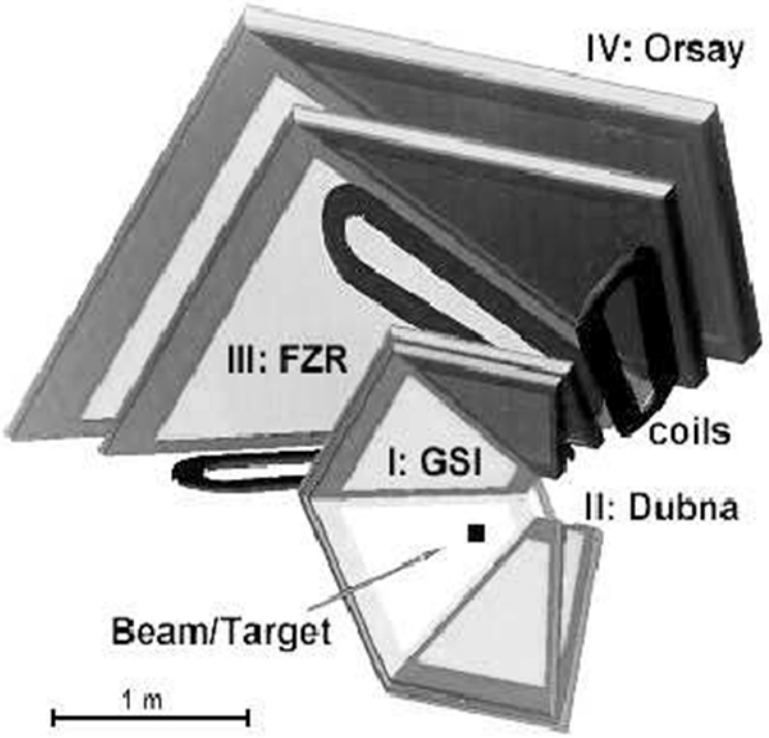


Acceptance: **Full azimuth, polar angles 18° - 85°, Pair acceptance ≈ 0.35**
Particle identification: **RICH, Time Of Flight, Pre-Shower (pad chambers & lead converter) and MDCs.**
Momentum measurement Leptons: $\Delta x \sim 140\ \mu$ per cell, $\Delta p/p \sim 1$-2 %
$\Delta M/M \sim 2\%$ in ρ mass region

Drift Chambers



DUBNA DRIFT CHAMBERS (plane 2)



4 planes of Drift Chambers

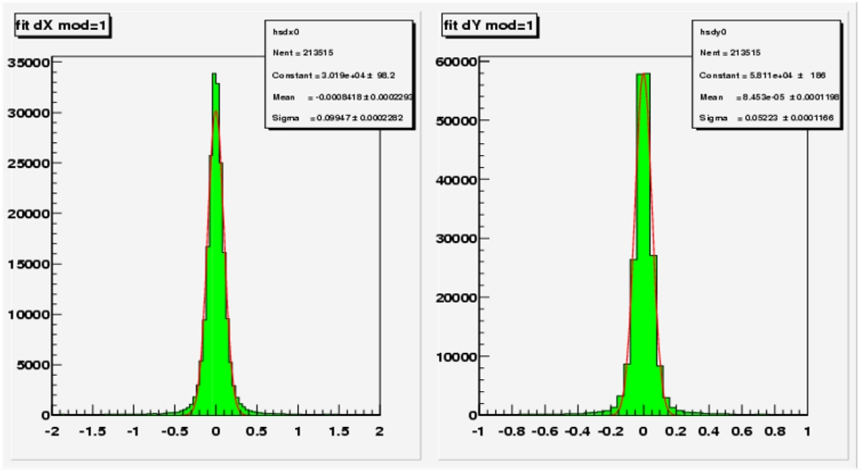
I, II - inner planes; III, IV - outer planes

- 6 modules in each plane.
- Each module contains 6 chambers (with different wires angles).

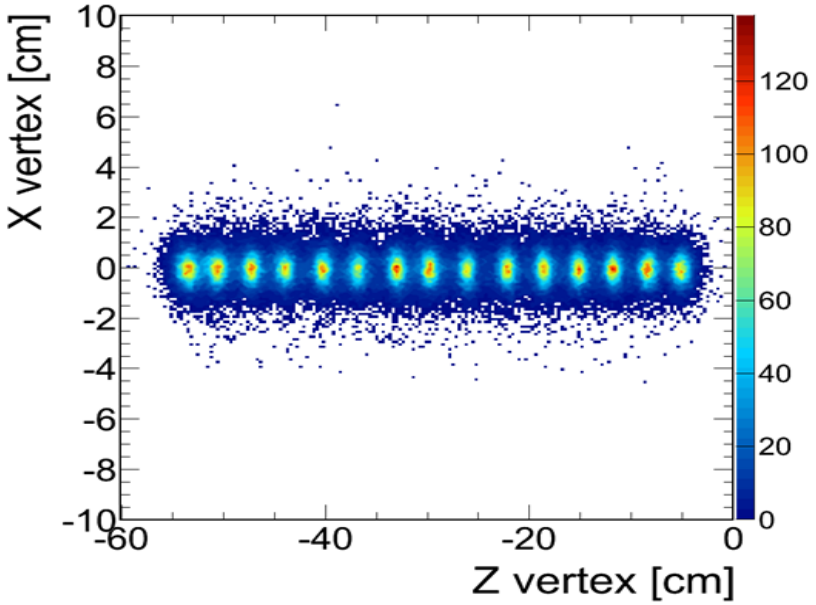
Total 24 modules (33 m²)

- Helium based counting gas
- Aluminum cathode/field wires
- 27 000 cells

Space Resolution of Drift Chambers



	GSI	Dubna	Rosendorf	Orsey
resolution Y (mk)	52	57	87	79
resolution X (mk)	98	112	148	138



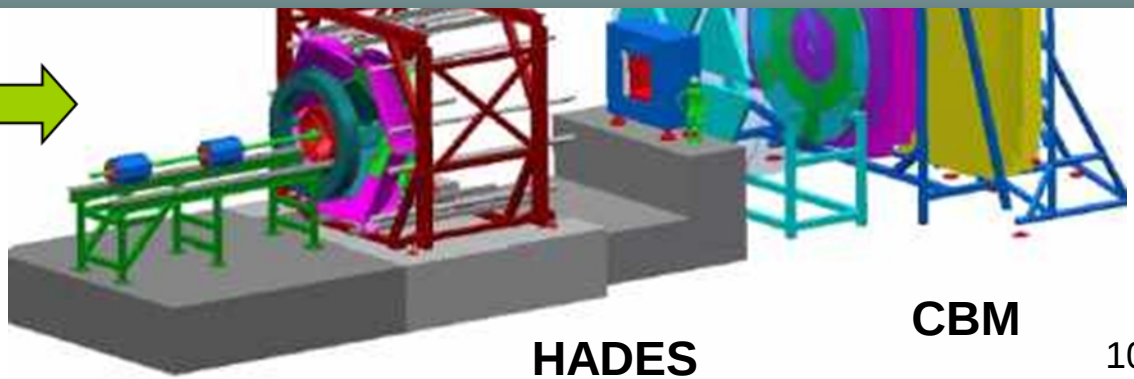
15 discs (Diam. 2mm) of Target position reconstructed via MDC tracking

Run : Au + Au 1.23 AGeV

HADES program for 2012-202x

before 2012	**C+C, p+p, Ar+KCl, d+p, p+Nb 1 - 3.5 AGeV**	**dielectron spectra, medium effect, Δ Dalitz decay, vector meson, hadronic channels, reference for medium effects**
2012	**Au + Au 1.23 AGeV,**	**Low mass e^+e^- "excess"; kaon production ; K^0_s, K^-; Hyperon production; Λ,Σ,Ξ(1321); φ production; Λ-p, p-p, ππ correlations.**
	πp, π + A 1.7, 0.656-0.800 AGeV	**Strangeness in-medium; Resonances in di-electron and di-pion channel**
2014		**Ag+Ag, πp (CH2-C), p+p and p+A**
2018-2020		

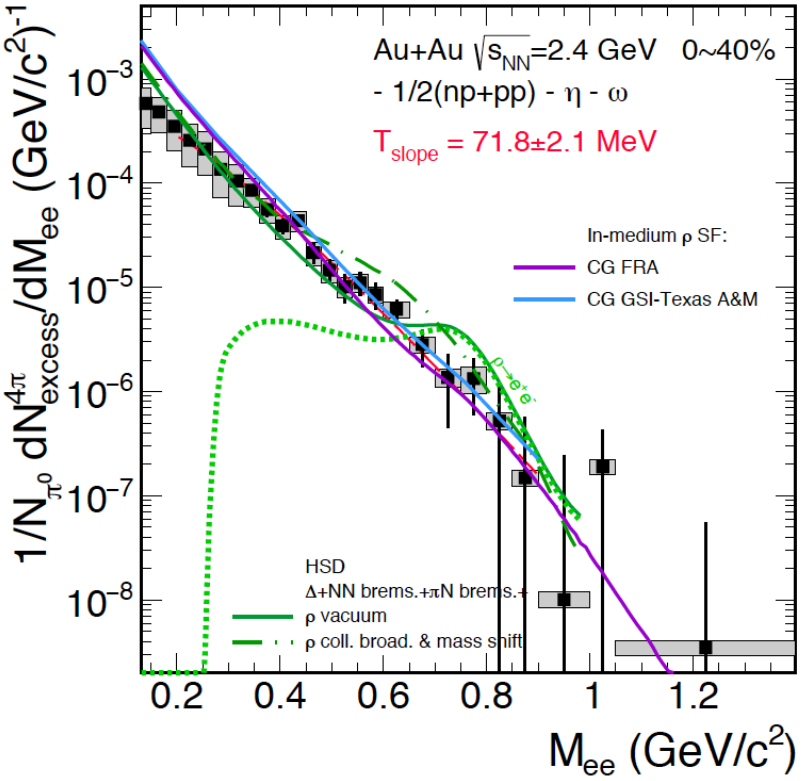
SIS-100

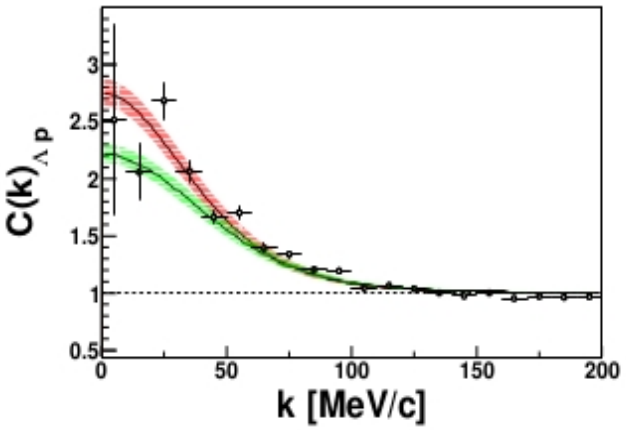


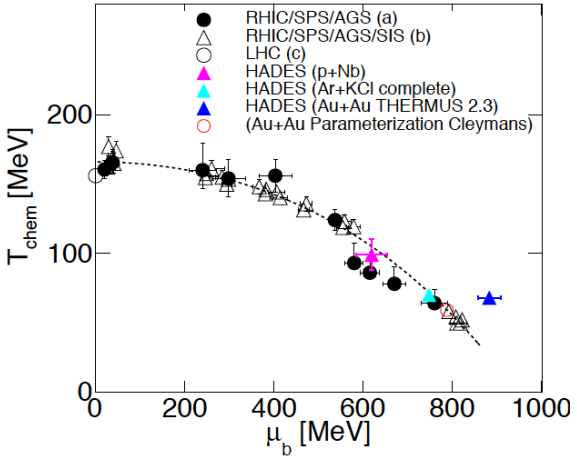
HADES **CBM**

HADES expects to get several runs at SIS-18 during 2018-202x.

HADES selected results

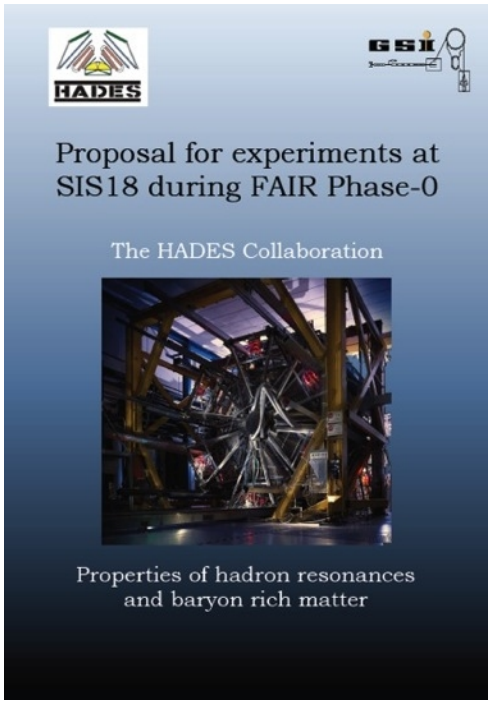


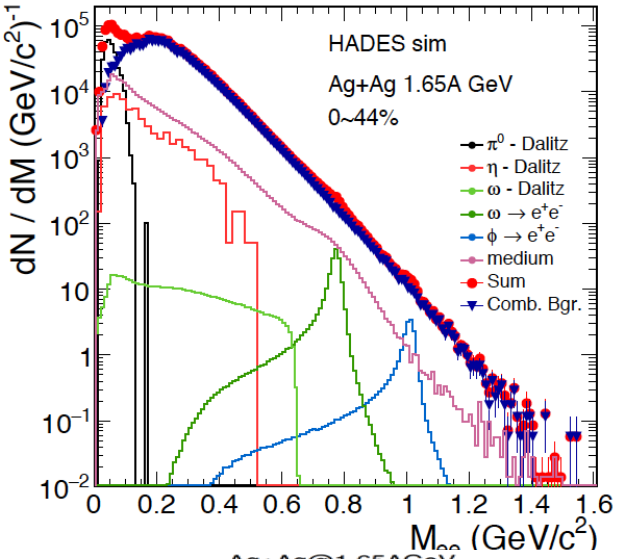


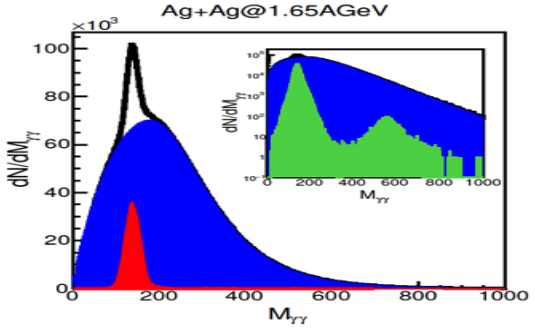


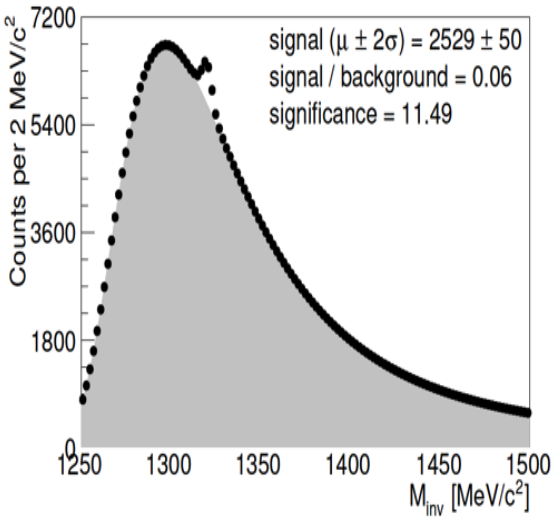
2 first papers on Au+Au at 1.23 AGeV are published

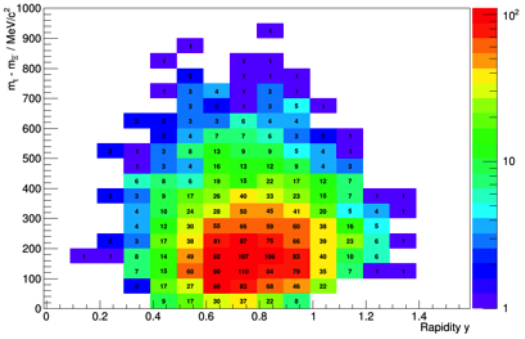
HADES: FAIR Phase 0 program











88 shifts for Ag+Ag at 1.65 AGeV in 2018

Pion beam in 2019
Proton beam at 4.5 GeV in 2020(?)

HADES MWDCII plane repair

Aging of HADES Drift Chambers under high rates. *

C. Wendisch [†1], *L. Lopes*[2], *C. Müntz*[3], *and O. Fateev* [4]
[1]GSI, Darmstadt, Germany; [2]LIP, Coimbra, Portugal; [3]Goethe-Universität, Frankfurt, Germany; [4]Joint Institute of Nuclear Research, Dubna, Russia

The future physics program of HADES at FAIR demands high detection standards, meanig in precision and also stability of the tracking system comprising four layers of planar drift chambers (MDC-I - IV). Unless the exposure of 18 beam-times within 15 years stable operation of the wire chambers has to be ensured for factors 2-3 higher particle load than the maximum so far.

Progression of Driftchambers during 15 years

Built in the end of 1990s the drift chambers operate started with a gas mixture of helium/isobutane (60/40) to gain the lowest material budget for the HADES detector. Later the gas was changed to Argon/isobutane (84/16) to increase the primary ionization. During the beam-time in 2012 (Au+Au reactions at E_{kin} = 1.23 AGeV) massive wire aging occurred, revealing in the Malter-Effect causing self sustained currents [1]. Therefore isobutane tending to polymerize was substituted and finally Ar/CO_2 (70/30) is used to prevent further aging in high load experiments. Since 2013 MDC II operating at high voltage of -1770 V (drift cell size 6 x 5 mm^2) and H_2O additive to recover stability [2]. An overall stable operation was observed with the admixture of 1000-3000 ppm water vapor to the counting gas, tested in beam and equivalent x-ray irradiation.

During x-ray tests corresponding to the highest load so far a sense wire broke inside inside sector 4 of MDCII. The consequent repair offered the opportunity to microscopically investigate the reasons for stability breakdown, expected to be aging of wires since observed persistent Malter-effect points to wire deposits.

Wire inspection

The visual inspection of the drift chamber interior 13 wire planes, depicted in figure 1, revealed abundant black deposits randomly distributed on all cathode and field wires (aluminum, diameter 80 μm) providing the high voltage.

Investigating the deposits material compounds by energy dispersive X-ray spectroscopy (EDX) found carbon oxide in several μm thick layers covering the wire surface , see figure 2. Further no sign for aging of anode wires (tungsten, diameter 20 μm) found.

Cleaning all wires to remove deposits was tested manually and via solvents in an ultrasonic bath to be not successful. But operating with water vapor as gas additive turned out to be the stable solution and should also prevent further polymerization.

We acknowlage Helmholtz-Zentrum Dresden-Rossendorf for the support with EDX analysis.

* Work supported by BMBF, HIC for FAIR and GSI.
† c.wendisch@gsi.de

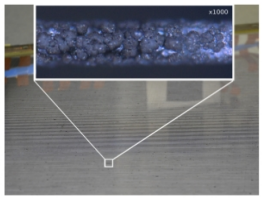


Figure 1: Single wire plane, showing dark deposits on field wires (diameter 80μm, Al) magnification 1000x, optical microscope.

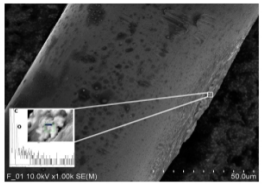


Figure 2: Scanning electron microscope view of field wire surface (diameter 80 μm, Al) magnification 1000x. Inlay shows EDX spectroscopy results: atomic compounds of deposits are carbon 73.2 %, oxygen 26.8 %.

References

[1] L. Malter, Phys. Rev., vol. 50 (1936) 48-58.
[2] A. Boyarski, Nucl.Instrum.Meth.A515 (2003) 190-195.

During 2016-2018:

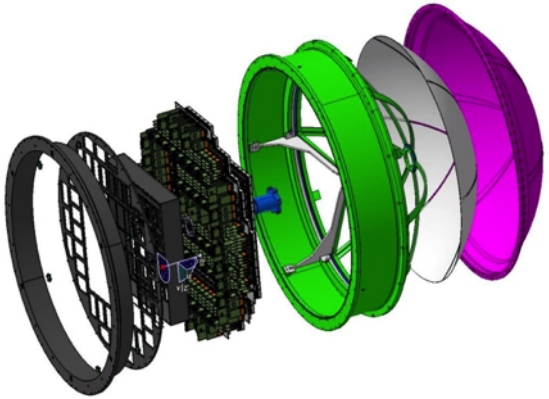
1. Sector 4 is repaired and installed into the plane II of MWDC.

2. 7-th sector is repaired and prepared as a spare.

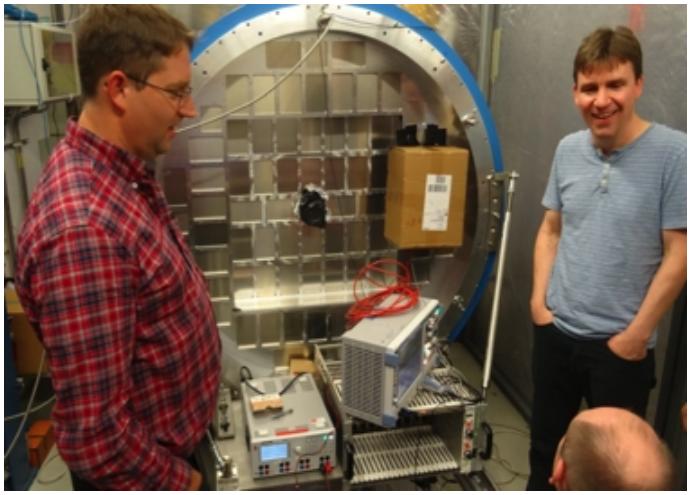
3. Gas mixture is optimized for high rates.

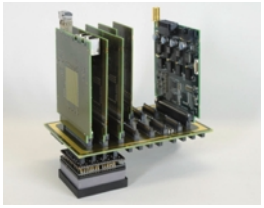
4. X-rays tests were performed -last in March 2018.

HADES FAIR Phase 0 : CBM – RICH700 (2018)

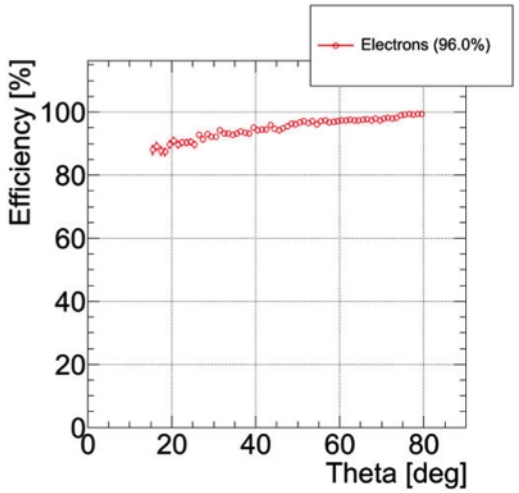


428 MAPMTs





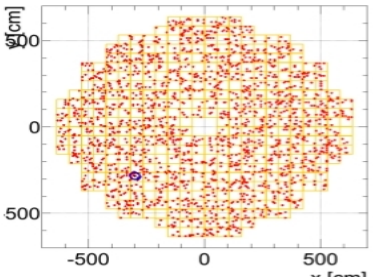
DiRICH read out



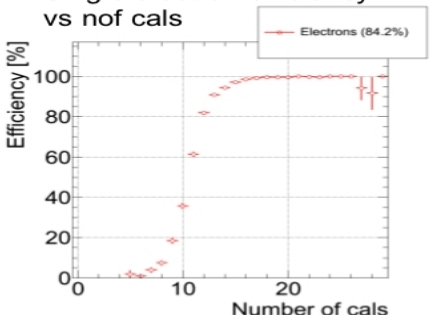
LIT JINR contributes by the RICH reconstruction algorithms development

HADES Software development : RICH700

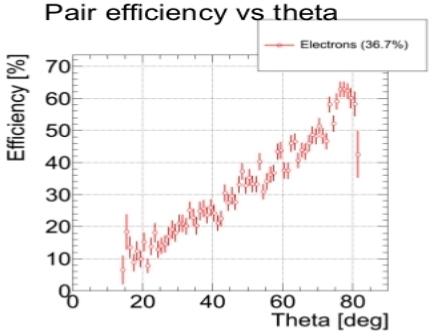
Examples with 2000 noise hits per event (~7,5% of pixels).

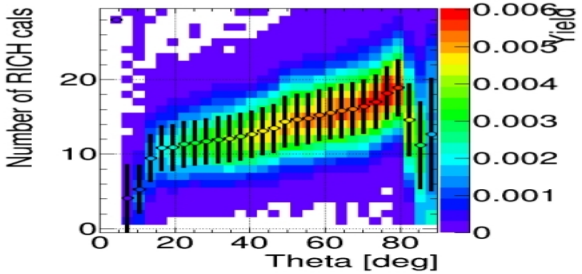


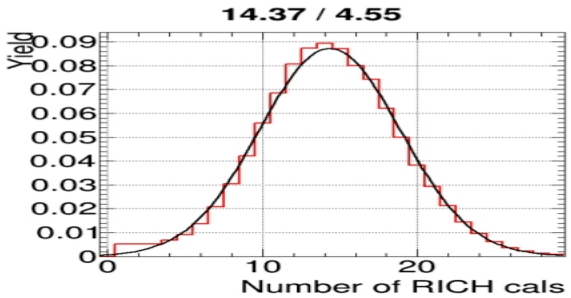
Single electron efficiency vs nof cals



Pair efficiency vs theta

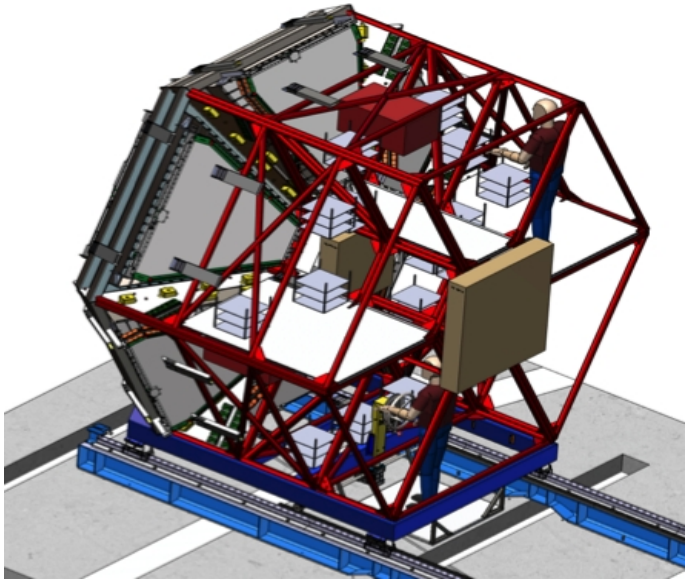






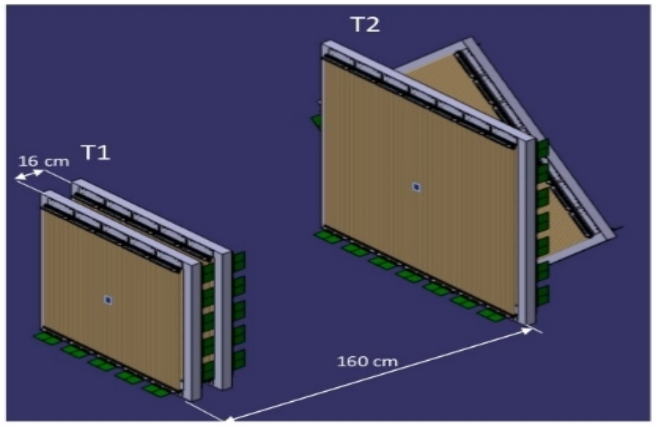
The reconstruction algorithm is based on Hough transformation Application at CBM.

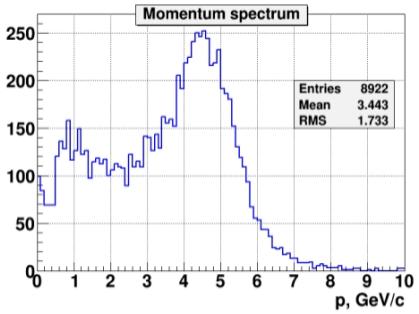
HADES FAIR Phase 0 :PANDA– FD (2019...)

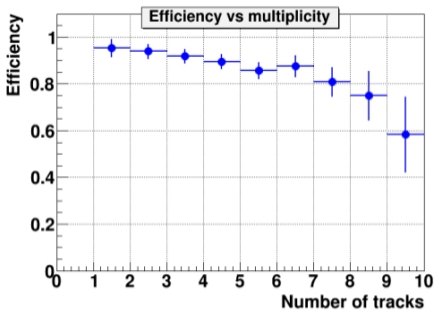


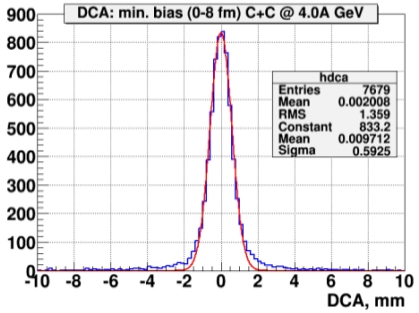
LHEP JINR : software reconstruction in straw tracker, simulation, physics

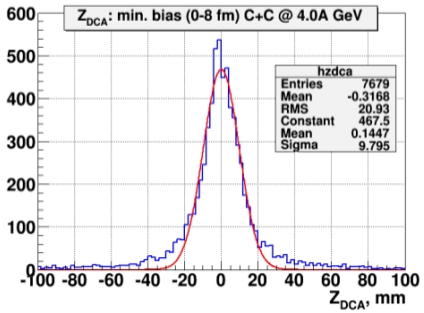
HADES Software development : FD





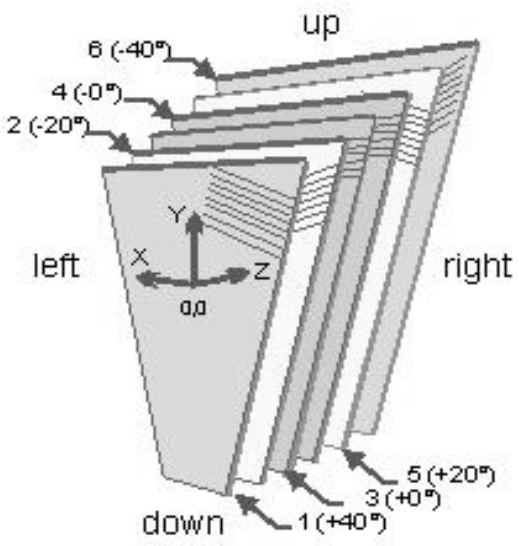


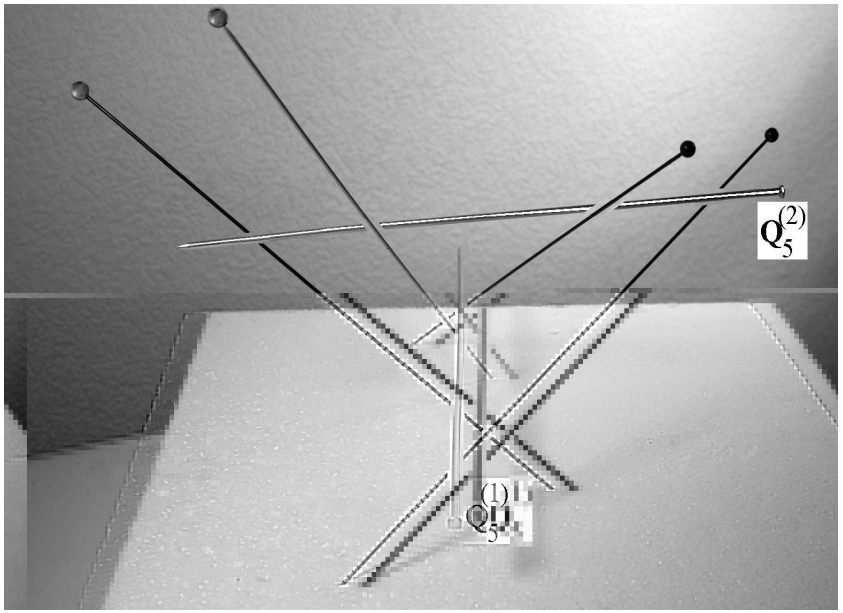




The reconstruction algorithm is based on vector track finder approach. Application at CBM and MPD.

HADES Software development : tracking





A.Belyaev et al.

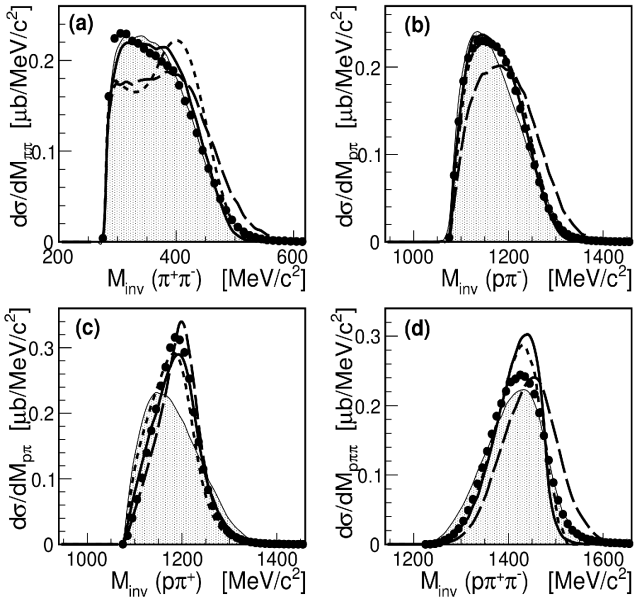
The reconstruction algorithm is based on the solve of the H.Schubert problem for 4 straight lines.

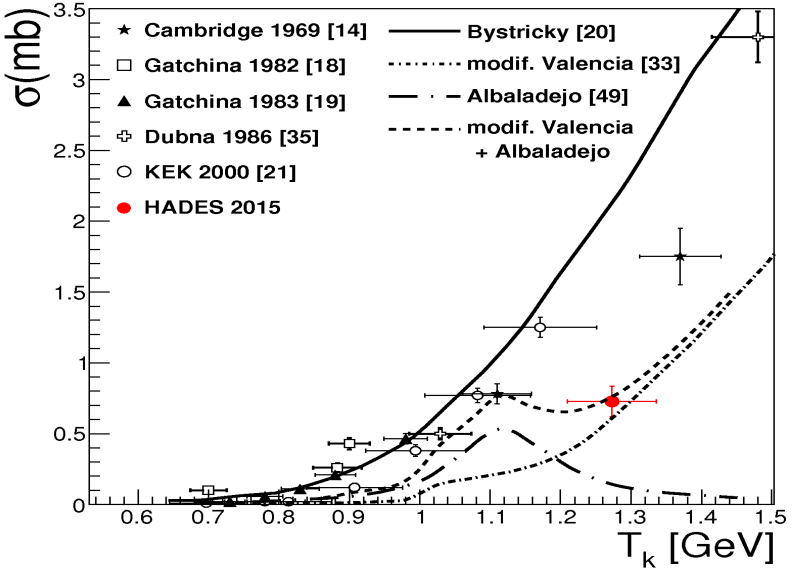
New approach for wire (strip) detectors.

ROOT class is under development.

2 papers are under preparation (NIM A, CPC)

HADES results : JINR contribution



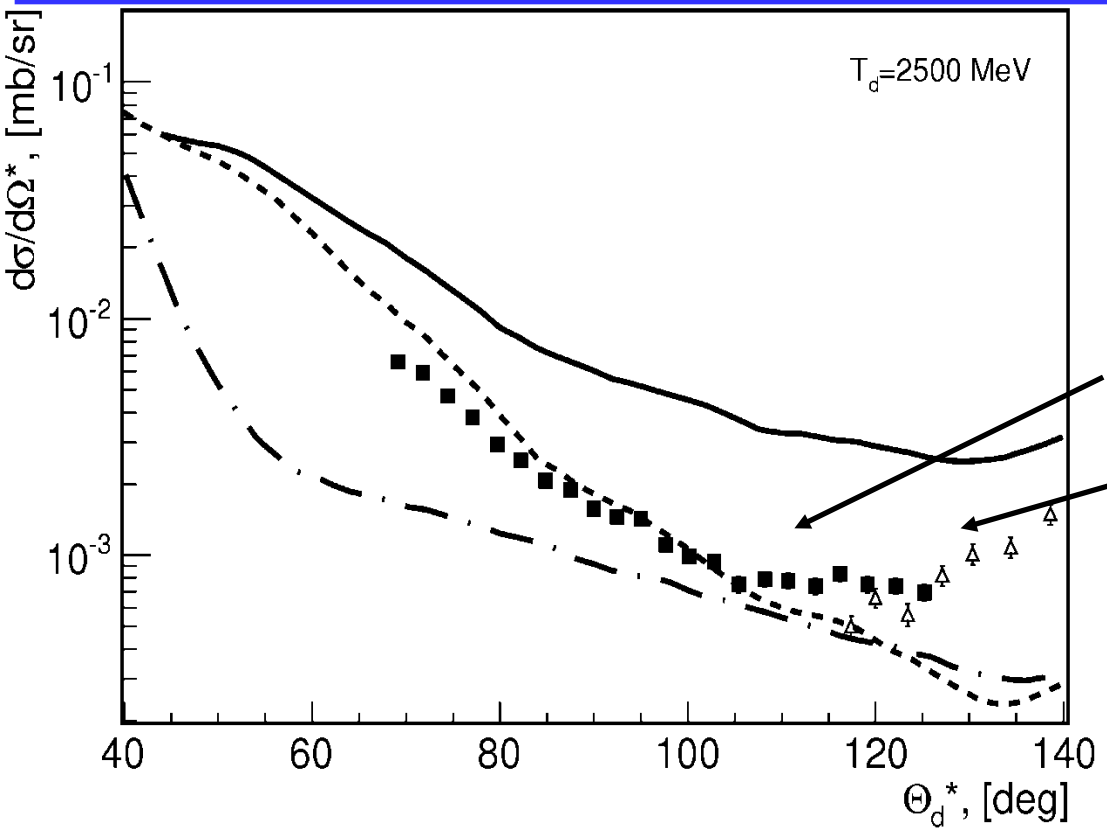


Results of the data analysis on the quasi-free $np \to np\pi^+\pi^-$ reaction at 1.25 GeV and OPER model development are published in:

1. G. Agakishiev et al., Phys.Lett. B750 (2015) 184.
2.A.P.Jerusalimov et al., Eur.Phys.J. A51 (2015) 83.

2-nd LHEP JINR award in 2015.

HADES results : JINR contribution



SS

SS+DS

SS+DS w/o pvp

HADES results

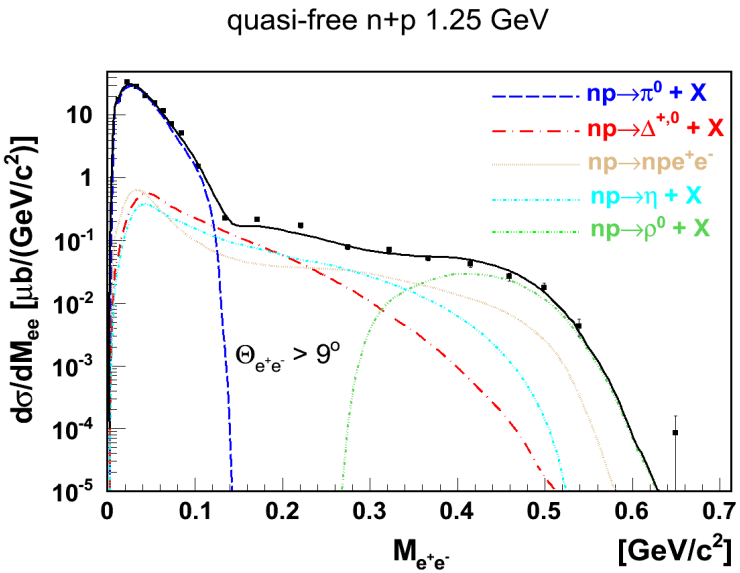
World data at 1.3 GeV/u

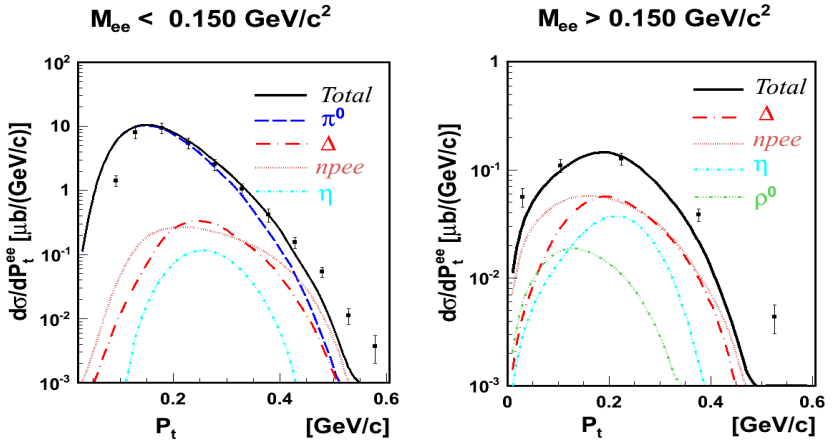
Experimental data:
E.Coleman et al., Phys. Rev. Lett. 16, 741 (1966)

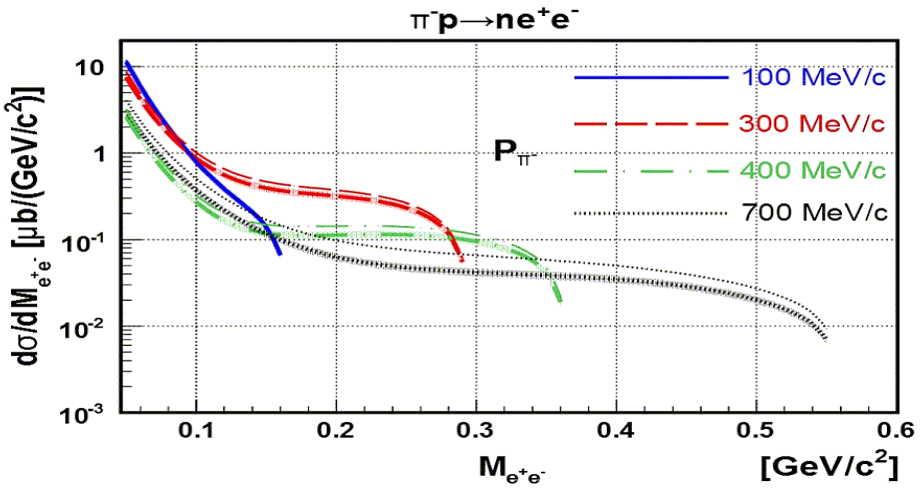
Theoretical calculation:
N.B.Ladygina, Eur.Phys.J, A42 (2009) 91

Paper passed 1-st turn of the internal HADES review

HADES results : interpretation





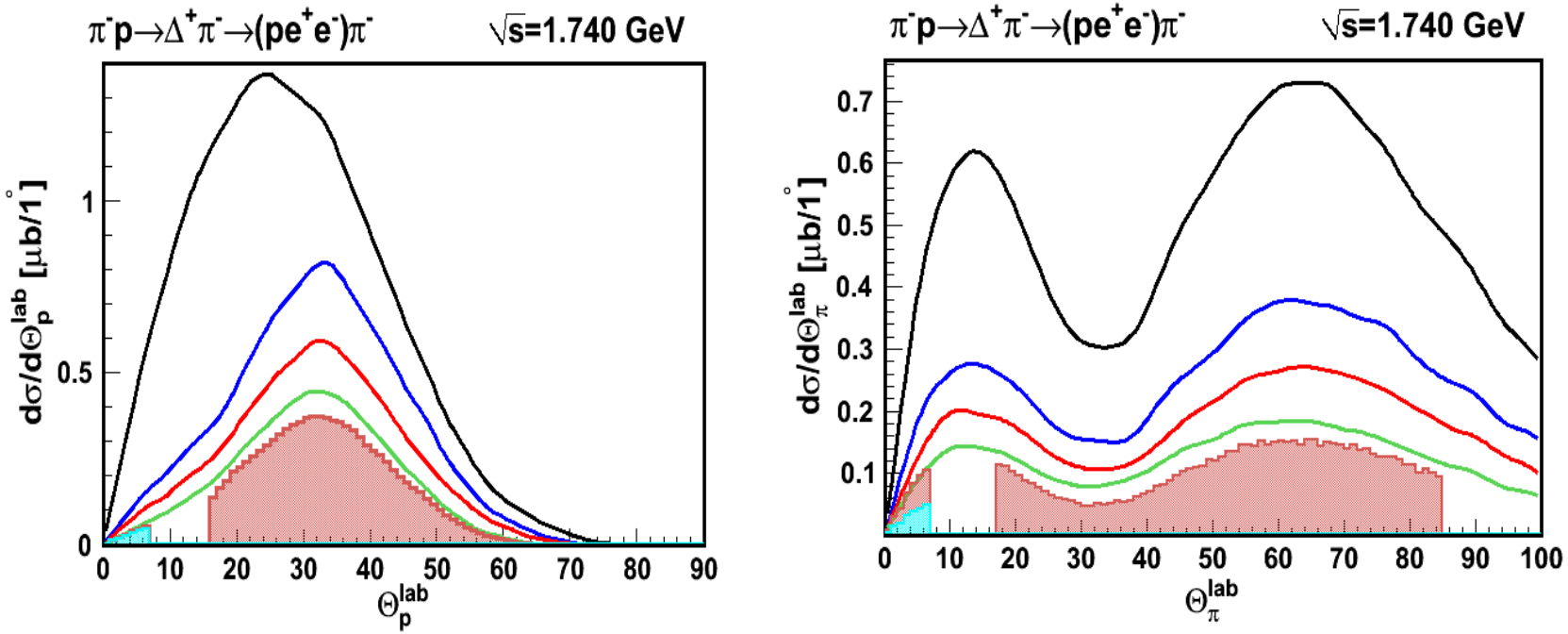


Calculations for quasi-free $np \to e^+ e^- X$ and $\pi^- p \to n e^+ e^-$ reactions:
A.P.Jerusalimov, G.Lykasov,
Int.J.Mod.Phys. A32(2017) 1750100;
arXiv:1705.07446[hep-ph].

HIC at SIS18 energies
G.Lykasov and A.Malakhov,
arXiv:1801.07250[hep-ph].

HADES results : baryon formfactors

Δ+ formfactor in time-like region from the $\pi^- p \to \pi^- p e^+ e^-$ reaction



Feasibility study has been performed for 2019 setup using OPER model. Similar program can be realized at SPD and MPD with proton beams. Development of the kin.fit is very useful.

Publications, Presentations at the Conferences

Period 2015-2018

Total: 41

Regular Journals — 16 (5 with JINR principal authors)

JINR communication - 1

Conferences - 7 (4 from JINR)
Orsay workshop (May 2018) - 2 from JINR

HADES CM talks - 15

MoU between JINR and GSI

MEMORANDUM OF UNDERSTANDING

for Cooperation in the Investigation of Hot and Dense Baryonic Matter and in the Development of the GSI and JINR Accelerator Facilities

between

GESELLSCHAFT FÜR SCHWERIONENFORSCHUNG mbH,
hereinafter referred to as GSI, Darmstadt

and

JOINT INSTITUTE FOR NUCLEAR RESEARCH,
hereinafter referred to as JINR, Dubna

May 2008

2.1. construction of pulsed ion source and in other areas of accelerator physics and technology is foreseen as well.

2.2. Cooperation in the design, calculation and fabrication of CBM, PANDA, MPD and SPD spectrometer magnets.

2.3. Continuation of the R&D work and further participation in the construction of both the CBM and PANDA set-ups for FAIR, and MPD and SPD for NICA as well. In particular, collaboration in the development of the inner and outer trackers and time-of-flight system.

2.4. Further participation at the HADES experimental program at SIS-18 and SIS-100.

2.5. Collaboration in the development of the shared software packages, in particular, for the Simulation, Reconstruction and Data Analysis in the frameworks of FAIRRoot and NICARoot as well as the development of different types of event generators.

2.6. Promotion of outstanding opportunities for excellent students and young researchers in both theory and experiment from JINR and GSI collaborating laboratories. The parties shall concentrate their efforts to attract young physicists and engineers for realization of the FAIR and NICA/MPD projects including their active participation in international graduate schools and young scientists meetings.

III. IMPLEMENTATION

3.1. Specific projects to be performed under this MoU shall be covered by the Working Agreements or Contracts to be negotiated and replaced as needed. These documents shall be developed by GSI and JINR and shall be considered as addenda to the present MoU. Such documents will address the scope of work for each project, responsibilities of each party, financial arrangements and any particular provisions or conditions that may not be covered or may be different from what is contained in the present MoU.

HADES MoU for 2018-2023 yy

Joint Institute for Nuclear Research (JINR), LHEP, Dubna

Members of the group

Vladimir Ladygin, Oleg Fateev, Alexander Ierusalimov, Alexander Belyaev, Alexander Malakhov, Alexander Troyan (perm.); Pavel Kurilkin, Alexei Kurilkin (PostDocs); Yaroslav Skhomenko (Student)

The institute will contribute to all types of experiments performed with HADES. The analysis activities will be focused on the baryonic resonance studies in hadronic and electromagnetic channels and short range correlations in proton/deuteron induced reactions.
The institute will contribute in the R&D for MCD plane-II and for Forward Detector.

Participation in analysis activities	**Resources**
Detector maintenance and commissioning (MDC)	0.7x FTE
Physics analysis:	2.0x FTE
Common funds	1 k€/year
Detector upgrade	**Resources**
R&D for MDC and Forward Detector	12 k€/year (from JINR-BMBF grant)
HADES at SIS100	
Interest in pp and dp program : baryonic resonances studies, SRC	

Vladimir Ladygin
Collaboration Board Member

Vladimir Kekelidze
Director LHEP JINR

Requested resources

	2019	2020	2021
Materials, equipment	**13kE**	**13 kE**	**13 kE**
International cooperation	**12 kE**	**12 kE**	**12 kE**
Total	**25 kE**	**25 kE**	**25 kE**

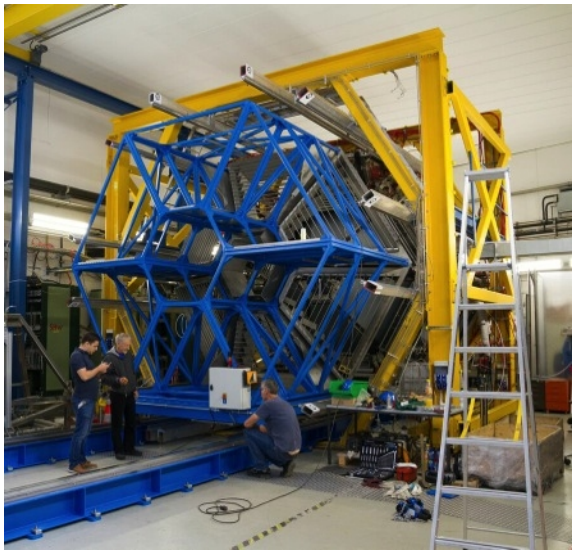
Total request for 2019-21yy - 75 kE (*from BMBF/JINR fund*).

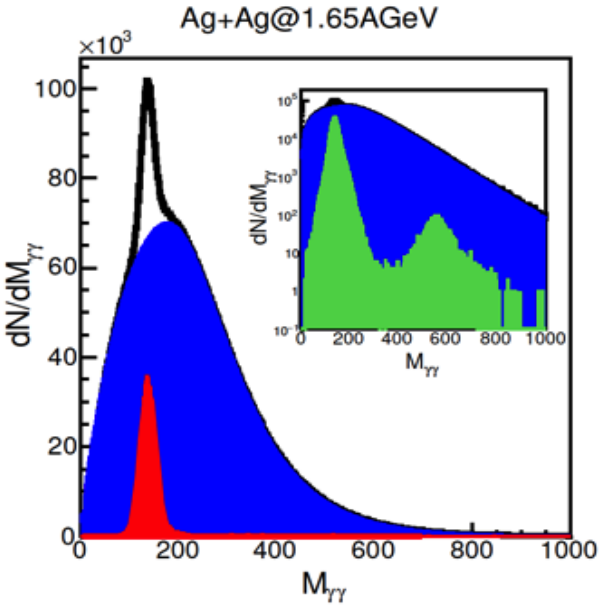
SUMMARY

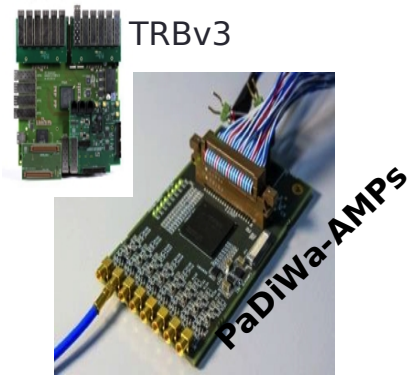
1. JINR participants of the HADES project are working on
   -mainteinance of MWDCs and FEE before and during beamtimes.
   -data taking, data analysis and theoretical interpretation.
2. Main activity on the HADES project in 2019-2021:
   - participation in data taking at SIS -18 - 2019-2020,
   - participation in data analysis and simulation for hadronic channels in Ag+Ag, NN, πA and pA collisions at 1.25-4.5 A GeV.
3. Participation in the upgrade of the Spectrometer and physics program for SIS-100.
4. HI program with Au-Au and Ag+Ag started at SIS-18 is interesting for physics program of BM@N and MPD as well.
5. Participation in the HADES project helped to build the new infrastructure for detectors construction (DetLab in blg.40), where the new detectors for MPD/NICA are under development.
6. The software development for HADES project performed by JINR can be used for NICA experiments (MPD, SPD, BM@N).

Thank you very much!

HADES Phase 0 – ECAL (2018)







At least 3 (from 6) sectors in 2018

Scientific Council
121st meeting,
23-24 February 2017

Results of implementation of the Seven-year plan for the development of JINR for 2010-2017 and plans for 2017-2023

Particle physics and high-energy heavy-ion physics, Information technology

Richard Lednicky

JINR, Dubna

Study of the hot & dense baryonic matter at extreme conditions in 2017-2023

At JINR

The study of heavy-ion collisions in the energy range up to $\sqrt{s_{NN}}$ = 11 GeV will be fulfilled using **BM@N** setup at the extracted Nuclotron beams and in the collider mode using the **MPD** setup.

The main goals of the LHEP in the 7-year plan are:

*To put in operation the **NICA** complex with both **MPD** and **SPD** setups, their final adjustment to the designed objectives and obtaining of new results.*

External experiments:

*Participation in the research programs at the **STAR** (RHIC, BNL). **NA61** (SPS, CERN), **ALICE** (LHC, CERN), and **CBM/HADES** (FAIR, GSI).*

The scale of participation in external projects will be determined by:
- *the consolidation work at the JINR accelerator complex;*
- *the progress in the NICA project realization.*

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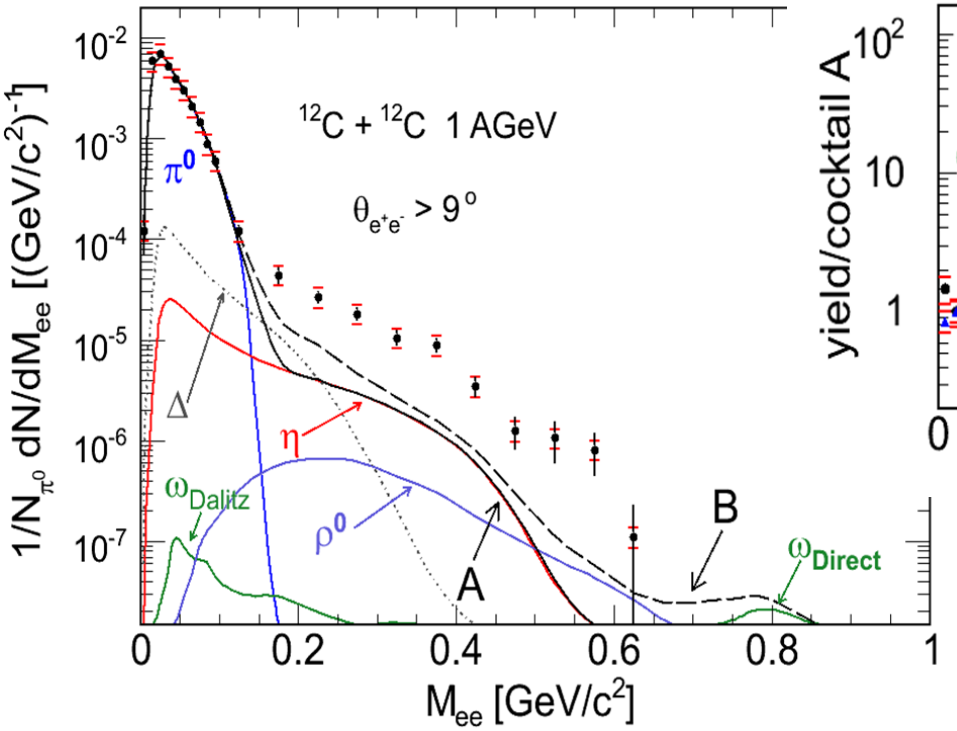
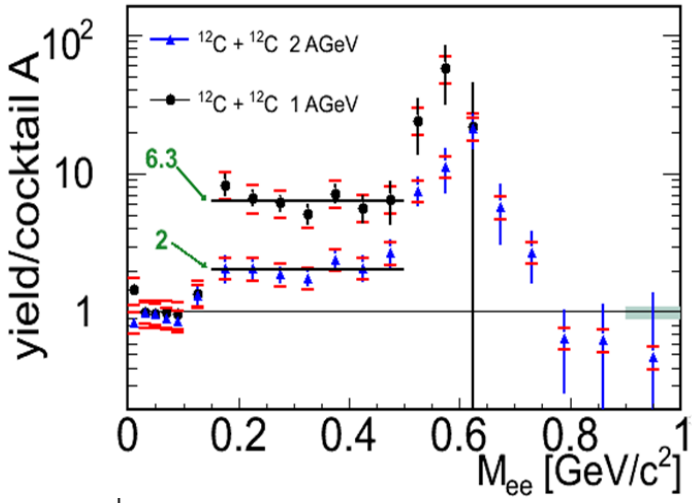
HADES experimental program

2001/2	C + C 2 AGeV	1 PRL (e+e-) + 1 submitted (hadron)
2004	C + C 1 AGeV	1 PLB (e+e-) + 1 submitted (hadron)
2004	p + p 2.2 GeV pp elastic, exclusive ppe+e- (π^0,η)	Analysis finished (draft) Validation of detector performance, measures of π^0 and η Dalitz decays (helicity distribution), "free" cocktail
2005	Ar + KCl 1.75 AGeV	Analysis ongoing dielectron spectra, medium effects
2006	p + p 1.25 GeV exclusive ppe+e- (π^0,Δ)	inclusive analysis finished (draft) Δ Dalitz decay first measurement
2007	p + p 3.5 GeV	ω line shape and cocktail (π, Δ, η, ω, ρ, ϕ...)!
2007	d + p 1.25 AGeV	- Contribution of pn Bremstrahlung / Δ Dalitz decay - hadronic channels
2008	p+Nb 3.5 GeV	Reference for medium effects

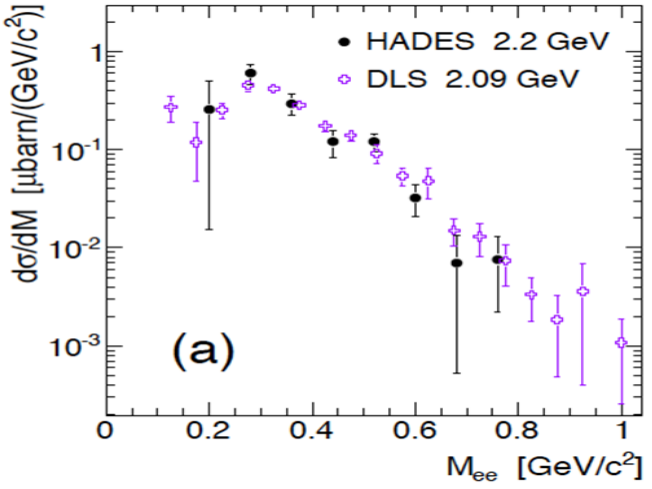
HADES results (DLS puzzle)

New HADES data confirms the DSL "puzzle"





HADES data in the acceptance of DLS, compared to DLS data.



DLS Data:
R.J. Porter et al.: PRL 79 (1997) 1229

HADES data: PLB 663 (2008) 43,
arXiv:1203.2549, PLB 690 (2010) 118