“HADES:JINR participation”
(prolongation for 2022 -2024 yy)
theme: 02-1-1106-2011/2022

A.Belyaev, O. Fateev, A. Ierusalimov, V.Ladygin, S.Reznikov, A.Troyan, A.Zinchenko

VBLHEP

V.Ivanov, S.Lebedev

LIT

G.Lykasov

DLNP

55-th meeting of PAC on Particle Physics, 21-22.06.21, JINR

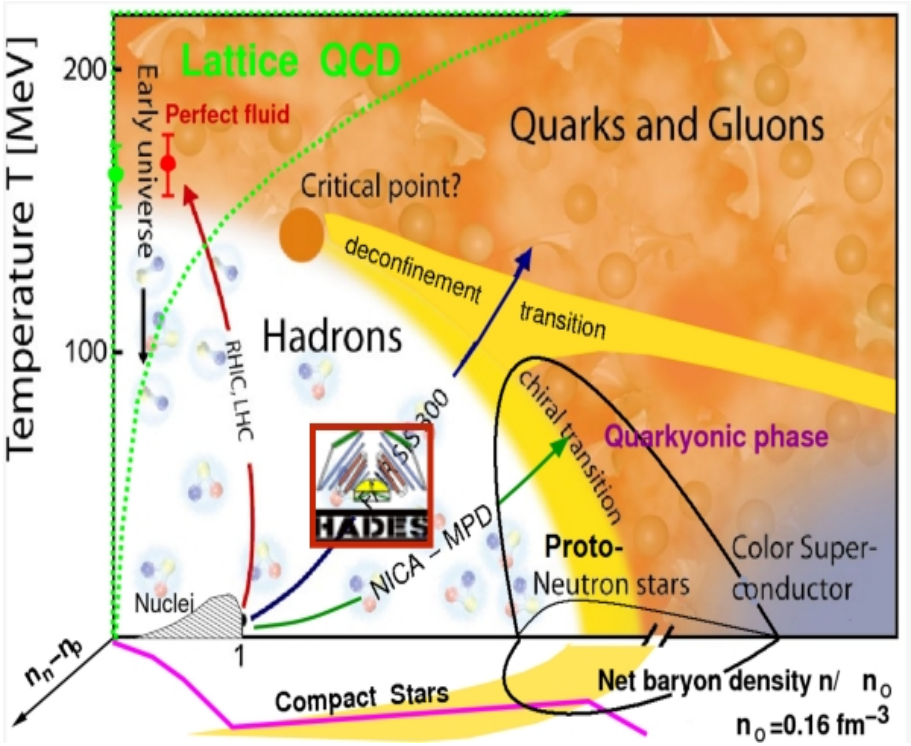
HADES Collaboration

Last face-to-face CM in Dresden, 2-6 March 2020

(Just before Virtual life)

The HADES Collaboration includes 26 Institutes from 9 European countries.
http://www-hades.gsi.de/ **- is growing permanently (167 members)**

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.

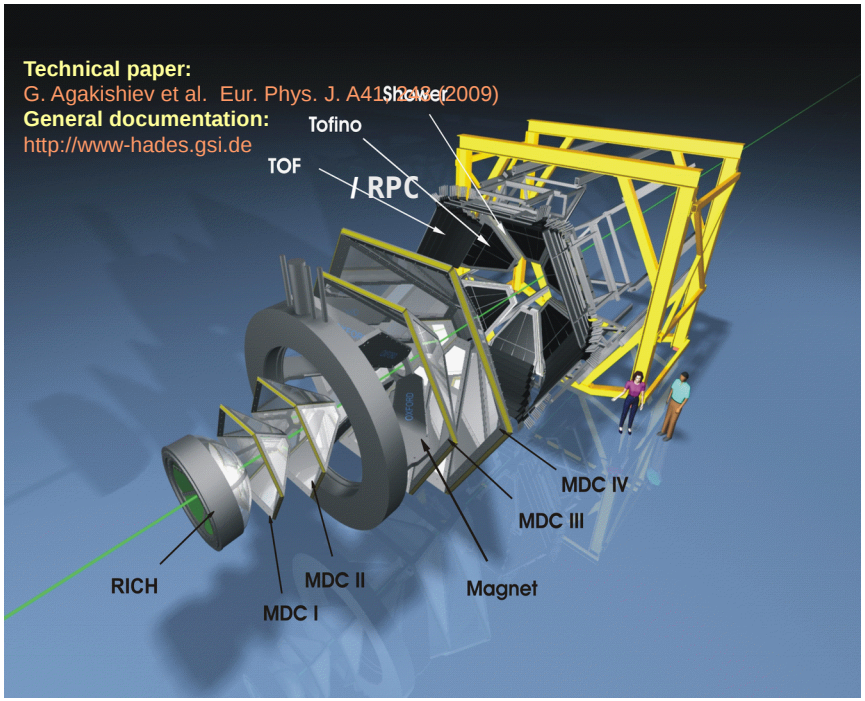
HADES strategy:

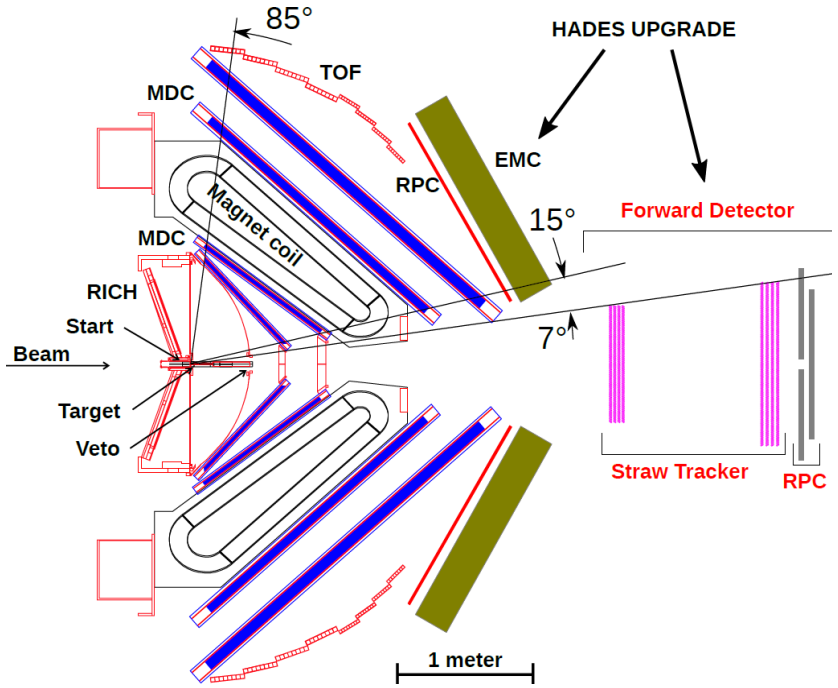
Systematic di-electron and hadron measurements in NN, AA, pA, πN and πA collisions

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, TOF/RPC, Pre-Shower, MDCs and EMC.**
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

HADES, JINR activity

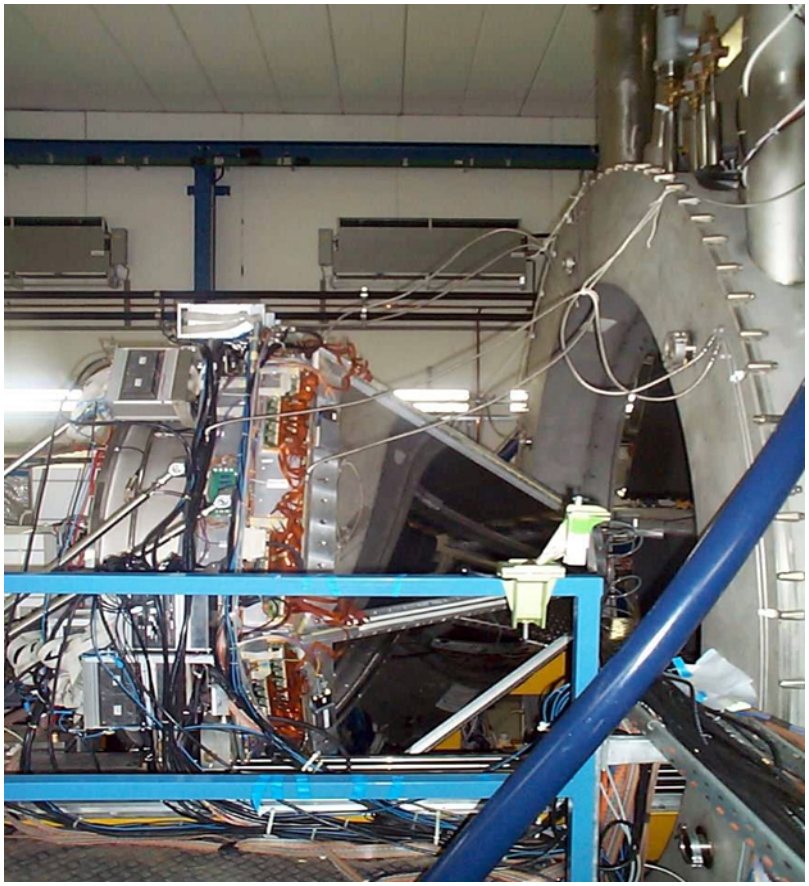
- **Low mass Multilayer Drift Chambers MDC II and Front End Electronics**
  (constructed, tested and integrated into the HADES spectrometer).

- **Tracks and rings reconstruction, software development**

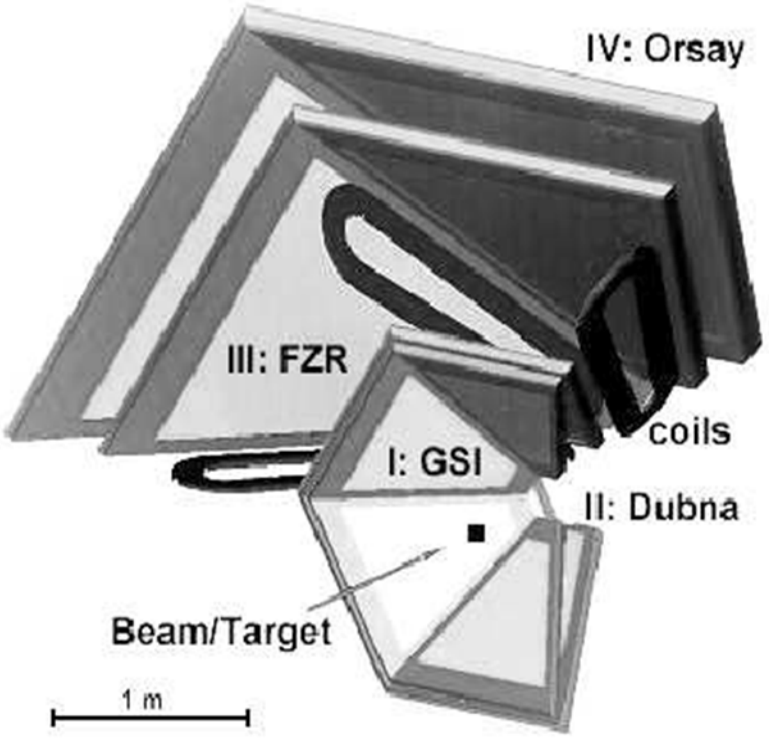
- **MDC upgrade including FEE (for SIS100), maintenance**

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

Drift Chambers



DUBNA DRIFT CHAMBERS (plane 2)



4 planes of Drift Chambers

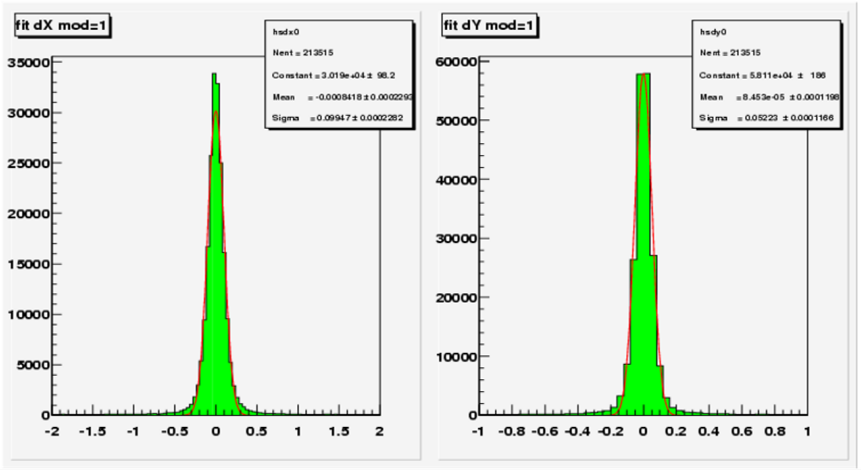
I, II - inner planes; III, IV - outer planes

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

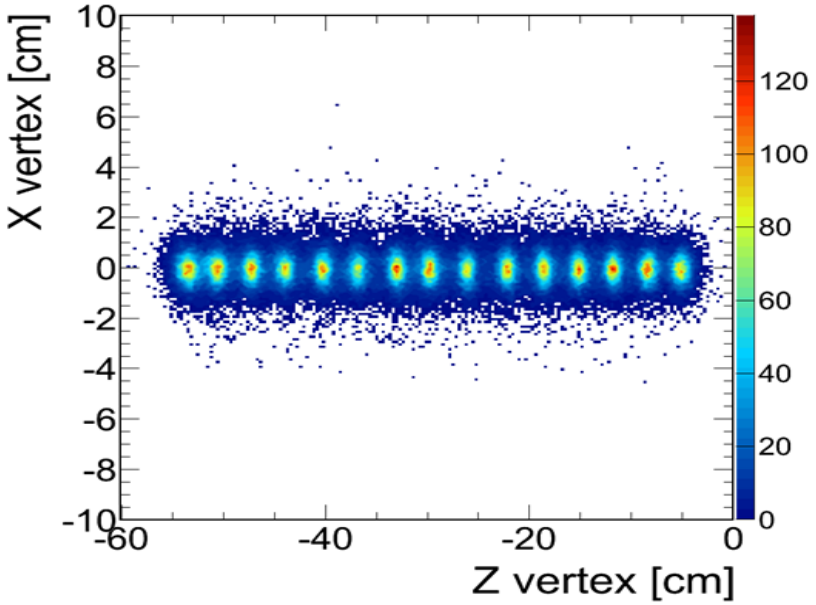
Total 24 modules (33 m²)

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

Space Resolution of Drift Chambers



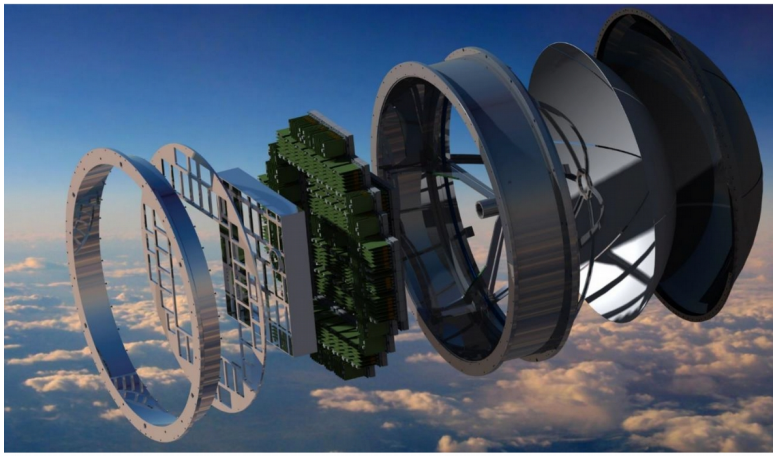
	GSI	Dubna	Rosendorf	Orsey
resolution Y (mk)	52	57	87	79
resolution X (mk)	98	112	148	138

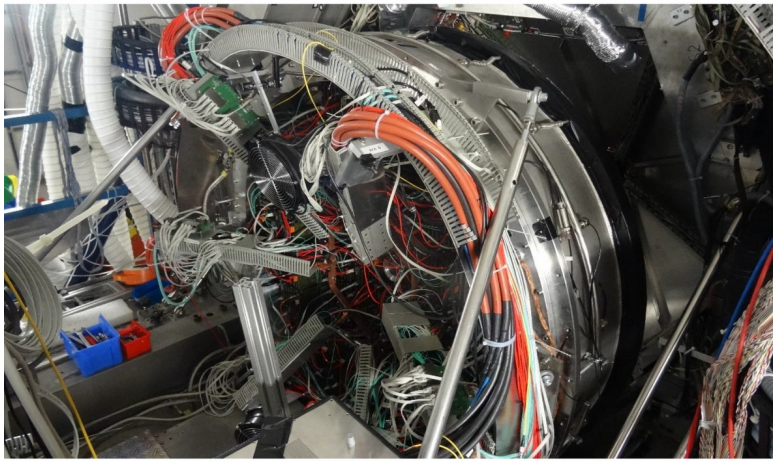


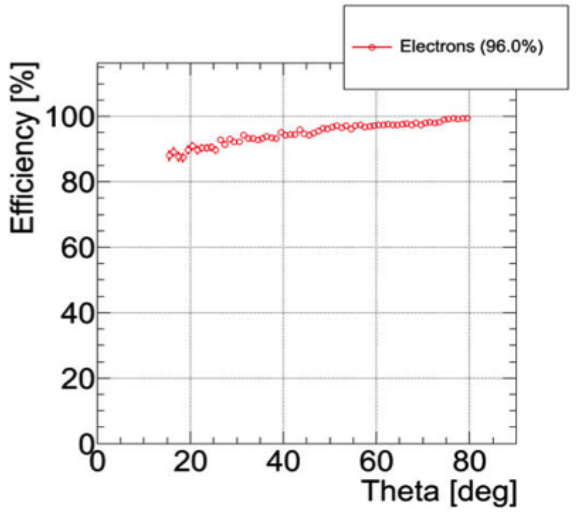
15 discs (Diam. 2mm) of Target position reconstructed via MDC tracking

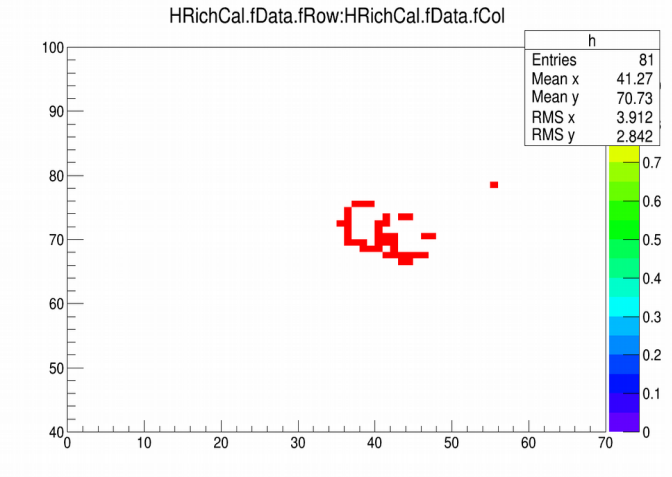
Run : Au + Au 1.23 AGeV

HADES Phase 0 : CBM – RICH700 (2019)



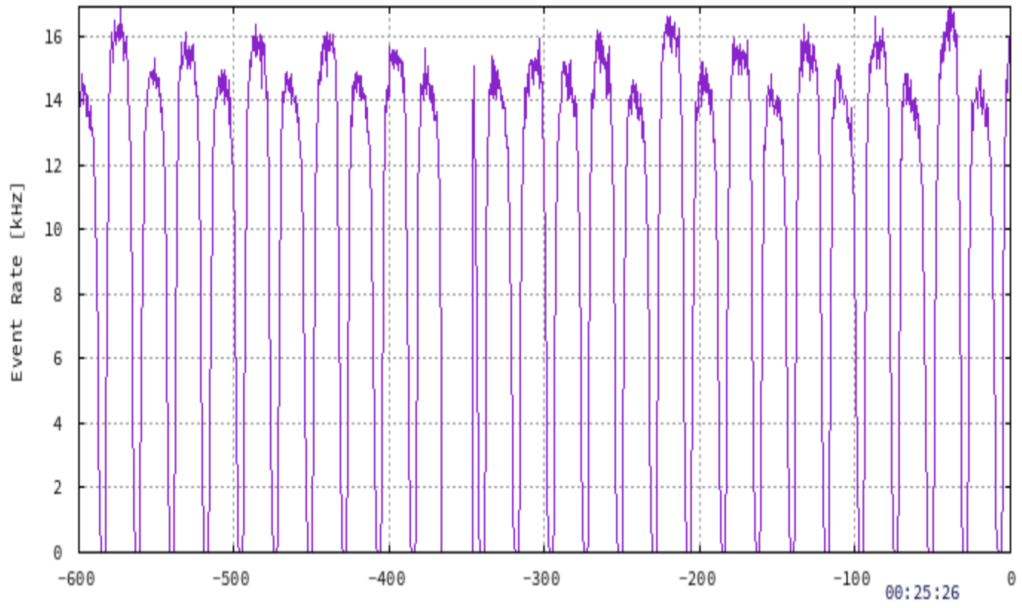


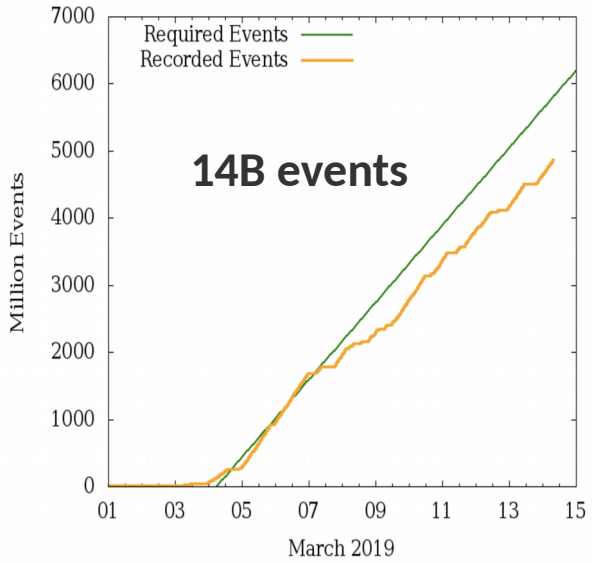




LIT JINR contributes by the ring reconstruction algorithms development for new HADES RICH

HADES Ag+Ag run in 2019





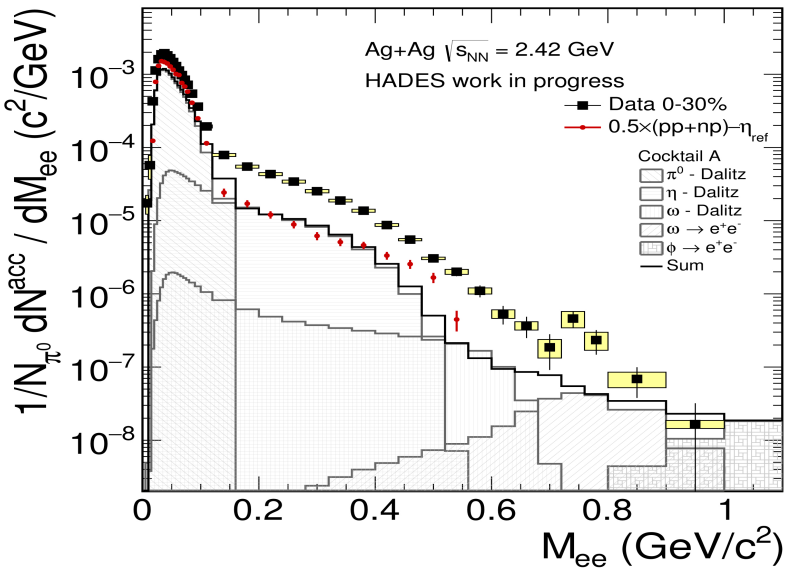
ECAL (four sectors) and MAPMT-based RICH fully operational

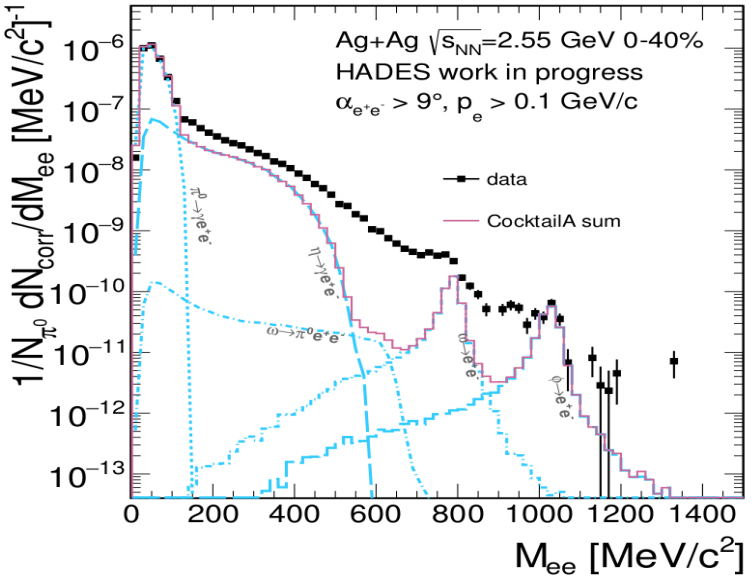
Data acquisition chain, including new TRB3-TDC boards, event building and storage can go up to 20 kHz in the flat top.

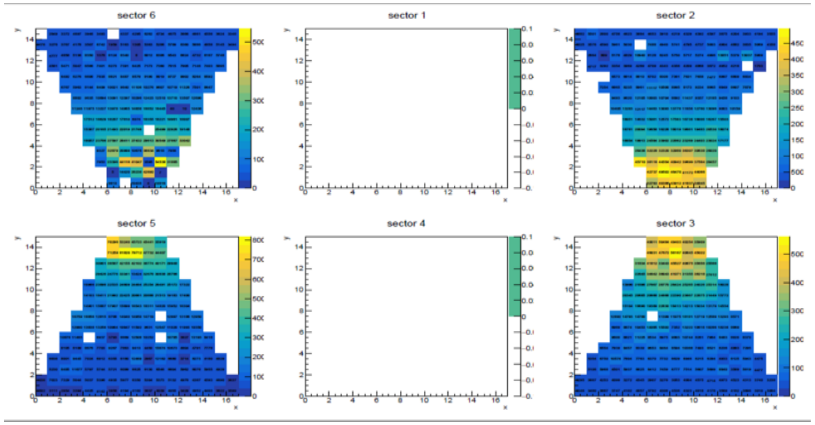
Due to compromise between detector stability, reconstruction performance and statistics we typically run with around 15 kHz.

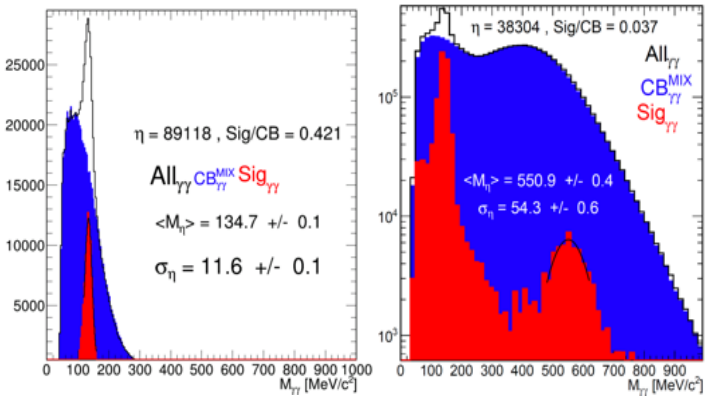
30 MWDC experts shifts from JINR

Preliminary results from Ag+Ag run

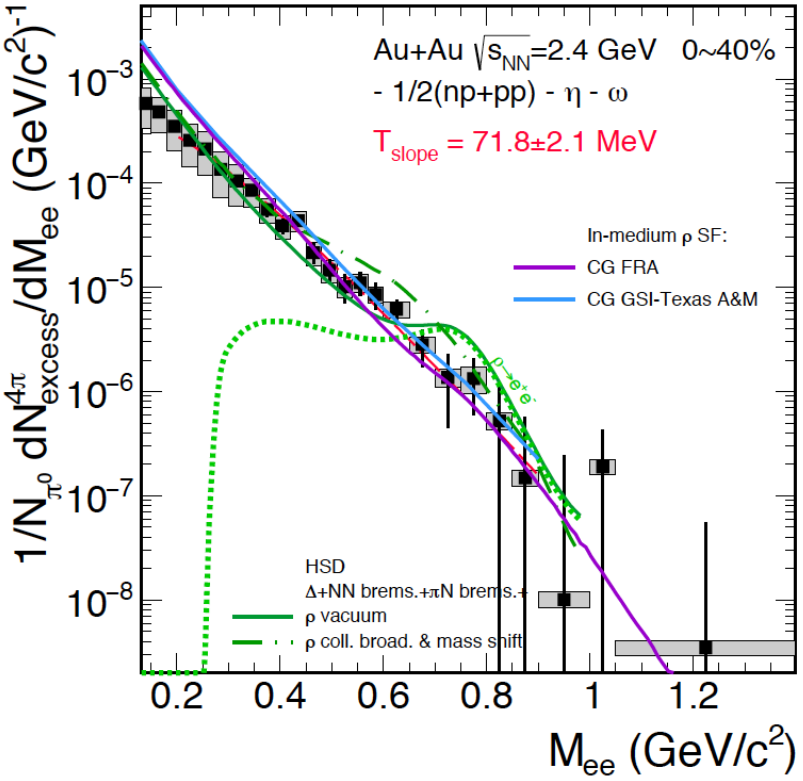


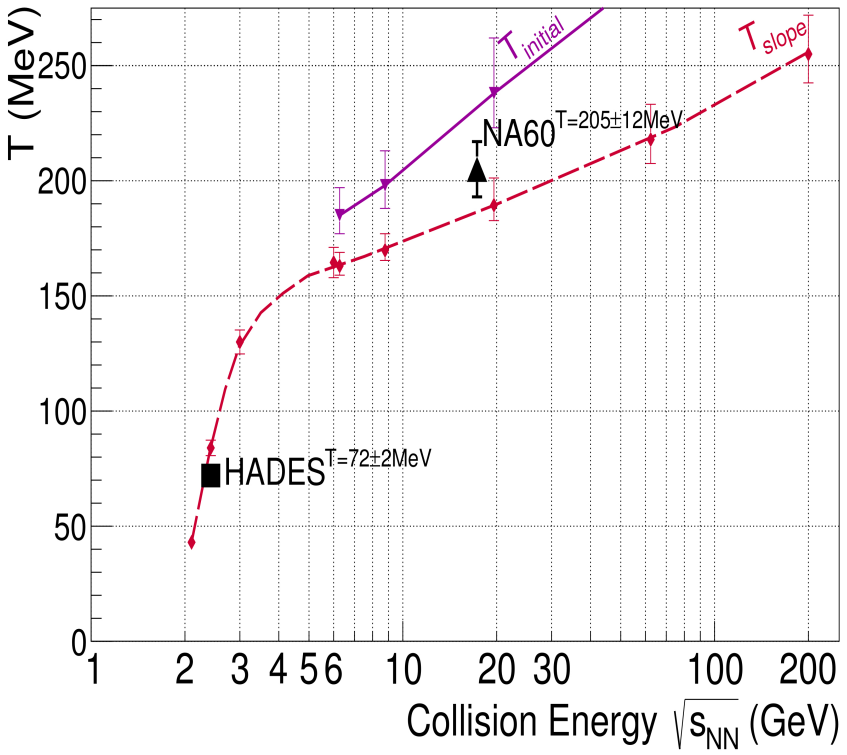






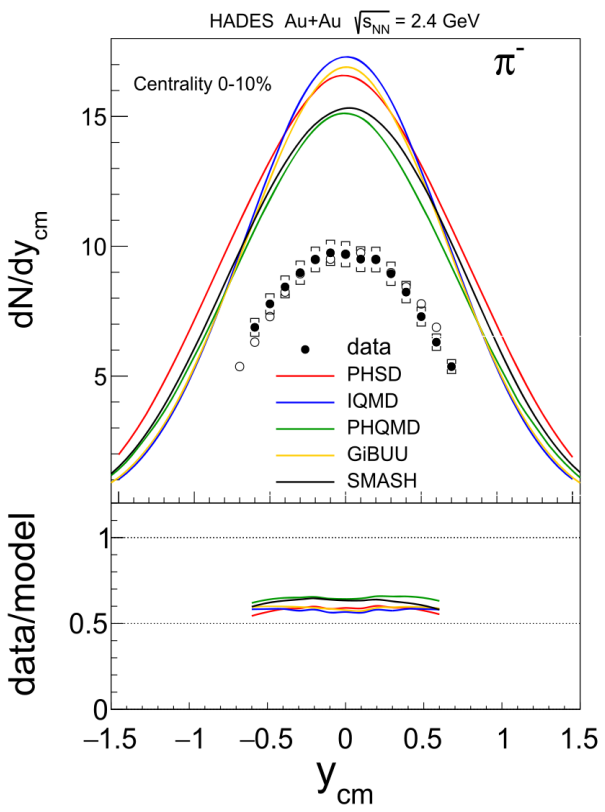
HADES selected results: dileptons

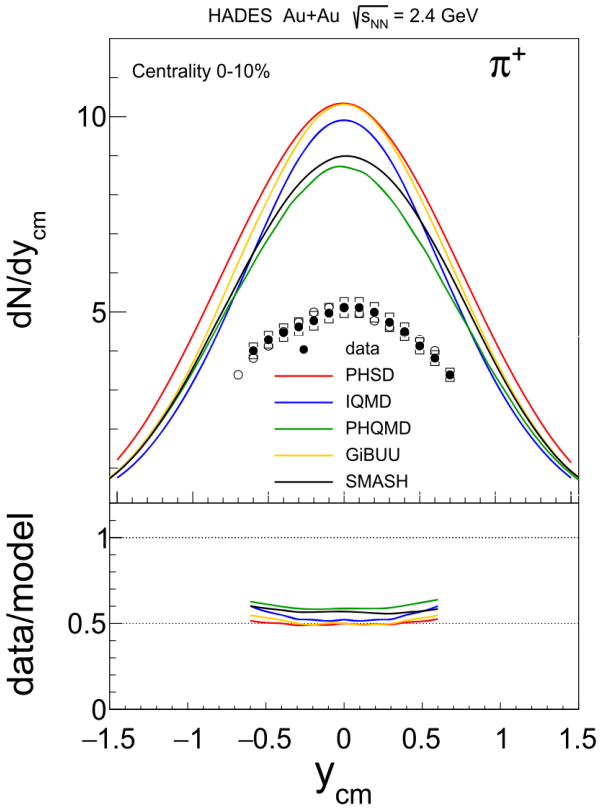




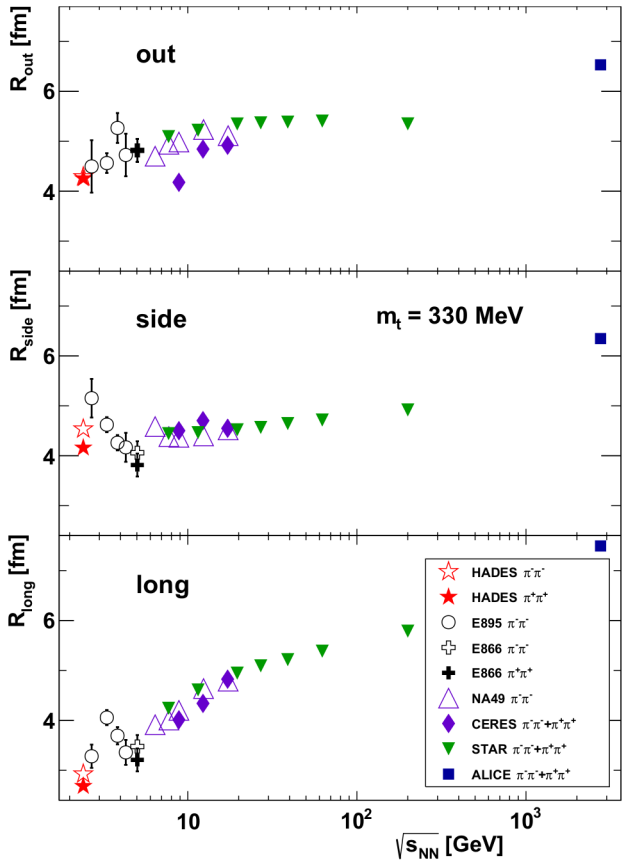
Dilepton paper on Au+Au at 1.23 AGeV is published in Nature Phys.2019

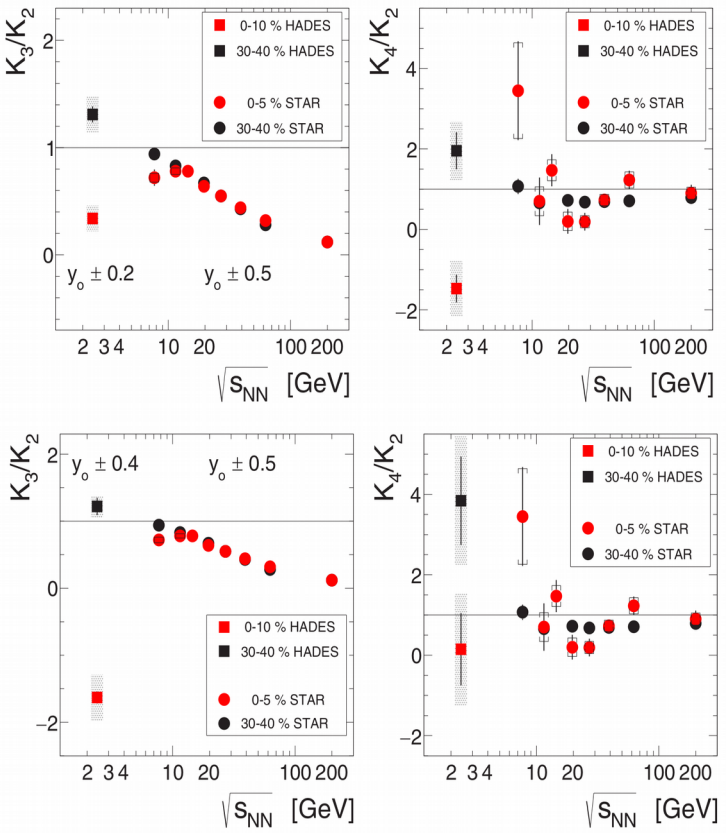
HADES selected results: charged pions



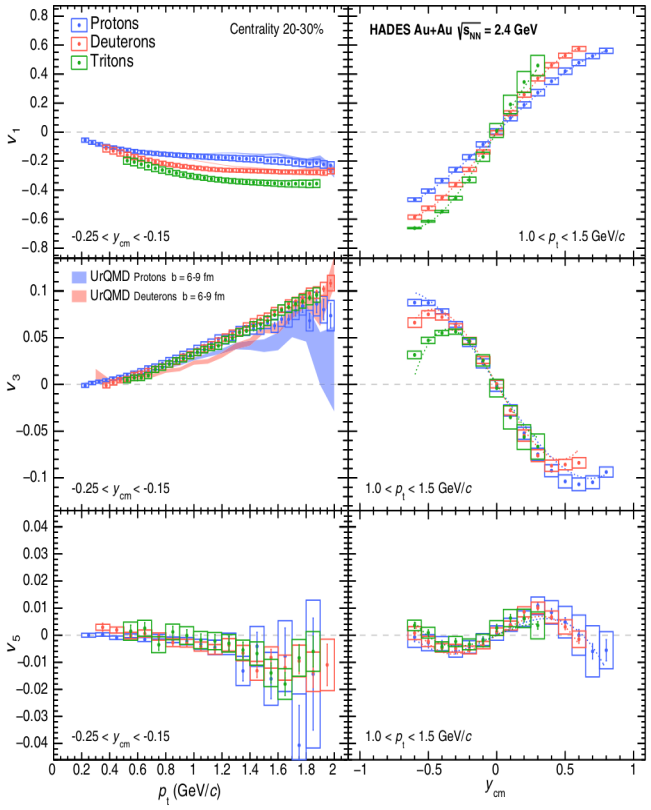


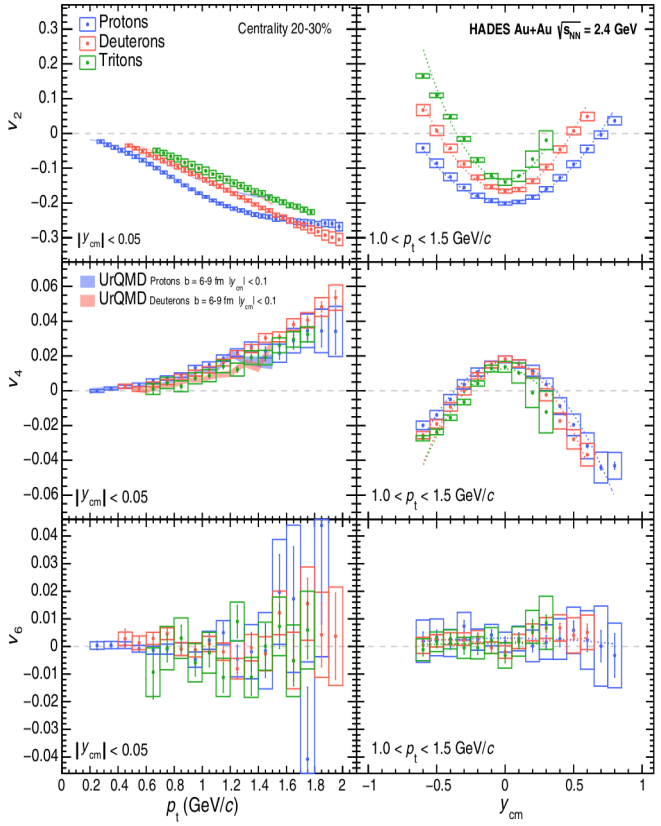
HADES selected results: HBT and fluctuations





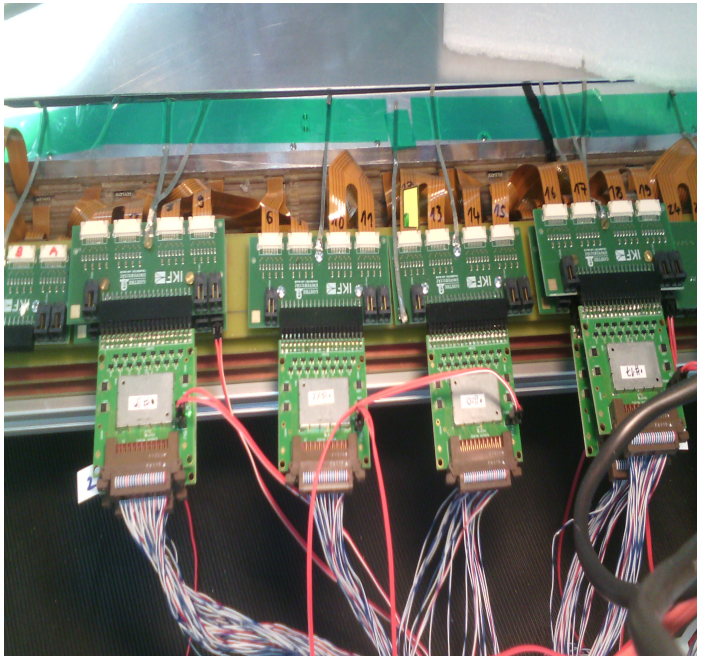
HADES selected results: flows





Flow harmonics 1-6 for protons, deuterons and tritons

HADES MWDCII plane repair and FEE upgrade



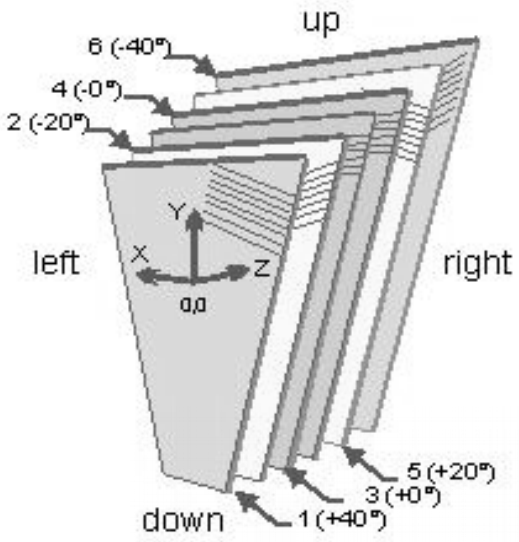
During 2019-2020:

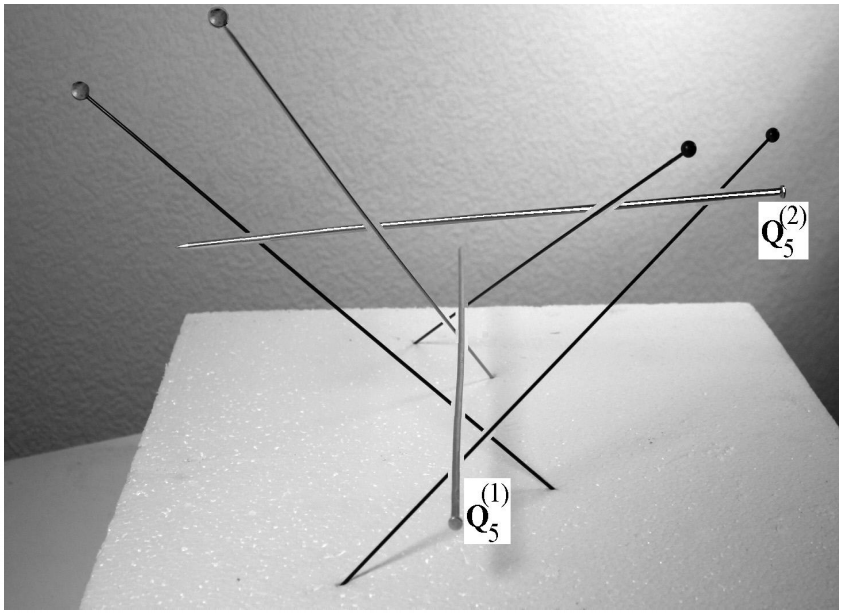
1. Sector #2 is repaired and installed into the plane II of MWDC.

2. Participation in MWDC FEE (based on the use of PASTTRECK chip) upgrade is started.

3. JINR group is planning to create test bench at LHEP to work with new FEE (impact for straw detectors for SPD).

HADES Software development : tracking





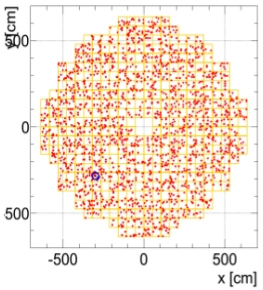
A.Belyaev et al., Nucl.Instrum.Meth. in Phys.Res. A938 (2019) 1.

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.

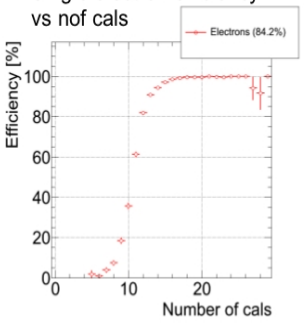
1 paper (CPC) is under preparation

HADES Software development : RICH700

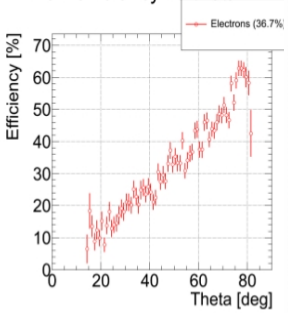
Examples with 2000 noise hits per event (~7,5% of pixels).

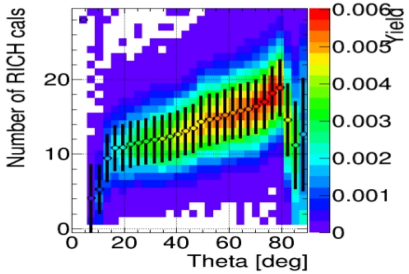


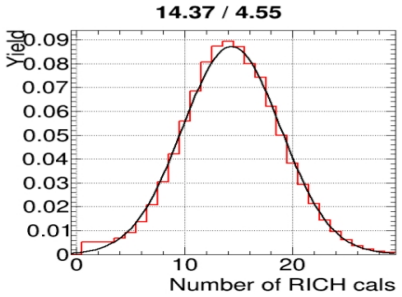
Single electron efficiency vs nof cals

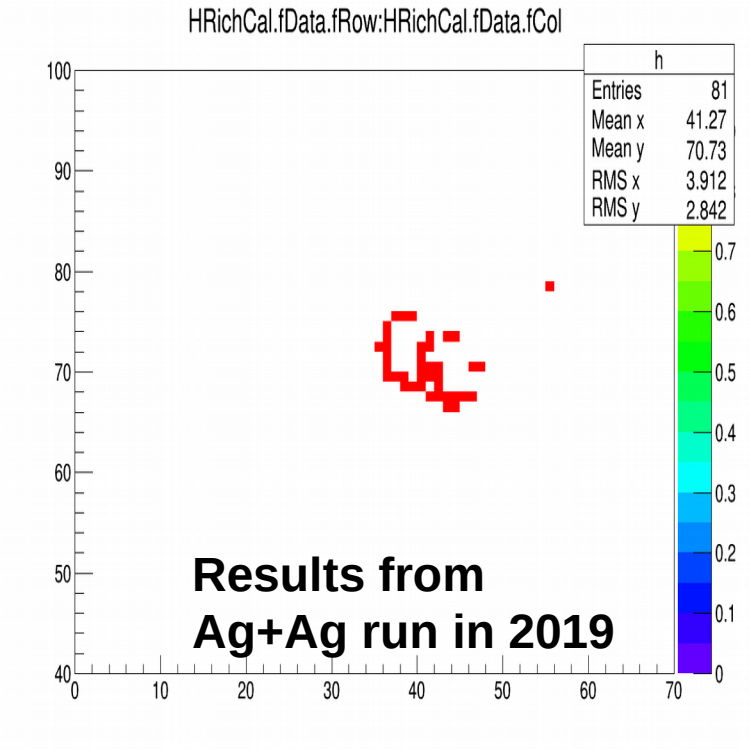


Pair efficiency vs theta



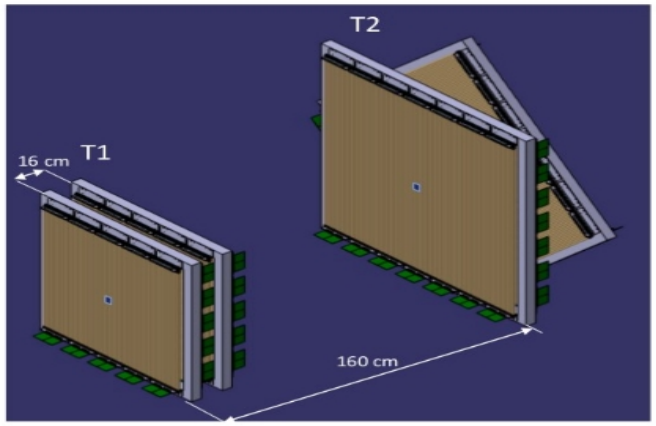


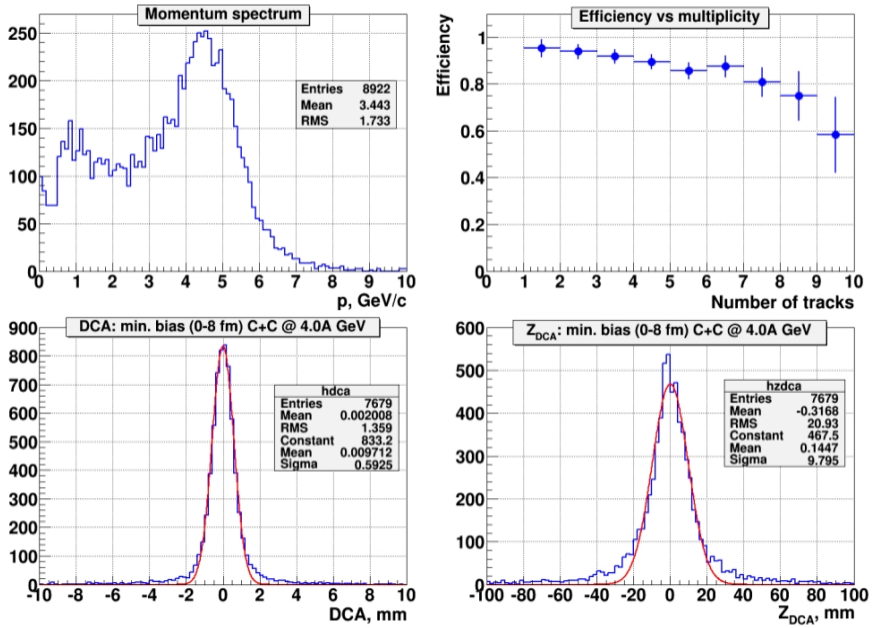




The reconstruction algorithm is based on Hough transformation.
It will be applied for CBM RICH.

HADES Software development : FD





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

D.Zinchenko, A.Zinchenko, E.Nikonov,
Vector Finder—A Toolkit for Track Finding in the MPD Experiment,

Publications, Presentations at the Conferences

Period 2019-2021

Total: 20

Regular Journals — 15 (1 with JINR principal authors)

Electronic preprints — 1 (JINR principal authors)

Conferences - 3 (1 from JINR)

HADES CM talks - 1

HADES proposals for PAC

1 proposal — A priority
1 proposal — A-B priority
3 proposals — B priority
Resubmission in 2022

100% in 2022

Pion induced reactions on CH_2 and C, Ag targets

The HADES Collaboration

HADES

Spokespersons: J. Stroth (j.stroth@gsi.de), P. Tlusty (tlusty@ujf.cas.cz)
GSI contact: J. Pietraszko (j.pietraszko@gsi.de)

Infrastructure: SIS18, pion production target and HADES cave

Beam: Nitrogen at 2.4 GeV, maximum intensity, slow extraction

Abstract

We will study baryon excitation and decay in the third resonance region. Emphasis is on the electromagnetic structure of baryons and the role of intermediate ρ mesons as doorway states in the decay process. The measurement of e^+e^- production off the nucleon is sensitive to the electromagnetic transition form factors of baryons in the time-like region and probes the role of vector mesons (ρ, ω). Differential cross sections for hadronic final states will be included in Partial Wave Analyses to extract various baryon-meson couplings, among which are ρN and ωN, with unprecedented precision. Pion-nucleus data allow to investigate medium effects in cold nuclear matter. The whole data set constitutes an important input to calculations of the emissivity of dense and hot hadronic matter.

Below is an executive summary of the proposed study with π^- beam using the HADES spectrometer.

This is a new experiment proposal.

We request 89 shifts.

p+p reactions at 4.5 GeV on CH_2

The HADES and
HADES-PANDA Collaborations

HADES

Spokespersons: J. Stroth (j.stroth@gsi.de), P. Tlusty (tlusty@ujf.cas.cz)
GSI contact: J. Pietraszko (j.pietraszko@gsi.de)

Infrastructure: SIS18, CH_2 (LH_2) target, HADES cave

Beam: p at 4.5 GeV, beam intensity 2×10^8 protons/s, slow extraction

Abstract

We propose to investigate p+p reactions with an improved experimental set-up which enables measurements of charged particles emitted into the very forward hemisphere. This is achieved by additional tracking stations composed of straw modules build for the PANDA Forward Tracker. This solid angle is not equipped with a magnetic field, rather, particle identification is provided by an excellent time-of-flight measurement with a new RPC detector placed about 6 m downstream of the target. Two main physics topics are addressed: (1) exclusive reconstruction of strangeness production; (2) inclusive measurement of (strange) particle and dielectron production as reference for p+A and heavy-ion data ada (3) $\Lambda - p$ scattering parameters and phase shifts. The former will allow for studies of hyperon production and for first pioneering measurements of the electromagnetic transition form factors of hyperons. These measurements are complementary to the planned studies of hyperon production in proton-antiproton collisions with PANDA. The results will also provide an important reference for the future program at FAIR.
Below is an executive summary of the proposed study with proton beam using the HADES spectrometer combined with the new forward detection system.

This is a new experiment proposal.

We request 88 shifts.

p+Ag reactions at 4.5 GeV

The HADES Collaboration

HADES

Spokespersons: J. Stroth (j.stroth@gsi.de), P. Tlusty (tlusty@ujf.cas.cz)
GSI contact: J. Pietraszko (j.pietraszko@gsi.de)

Infrastructure: SIS18, HADES cave and
part of the NeuLAND detector to measure the recoil neutron

Beam: p at 3.5–4.5 GeV, beam intensity 4×10^8 protons/s, slow extraction

Abstract

We propose to investigate p+Ag reactions with an improved experimental set-up which enables measurements of charged particles emitted into the very forward hemisphere. Main physics topics are addressed: (i) dielectron production in the low and intermediate mass region; (ii) ω disappearance in "cold" nuclear matter; (iii) strangeness production and propagation in "cold" nuclear matter (comparison and constraints for thermal and transport models) (iv) $\Lambda - p$ scattering parameters and phase shifts; (v) understanding short-range correlations in nuclei; (vi) search for a dark photon in the dielectron channel. This results will also provide an important reference for the future program at FAIR.
Below is an executive summary of the proposed study with proton beam using the HADES spectrometer combined with the new forward detection system.

This is a new experiment proposal.

We request 88 shifts.

50% in 2022

Studies of QCD matter with Au+Au collisions at 800–600–400–200A MeV

The HADES Collaboration

HADES

Spokespersons: J. Stroth (j.stroth@gsi.de), P. Tlusty (tlusty@ujf.cas.cz)
GSI contact: J. Pietraszko (j.pietraszko@gsi.de)

Infrastructure: SIS18 and HADES cave

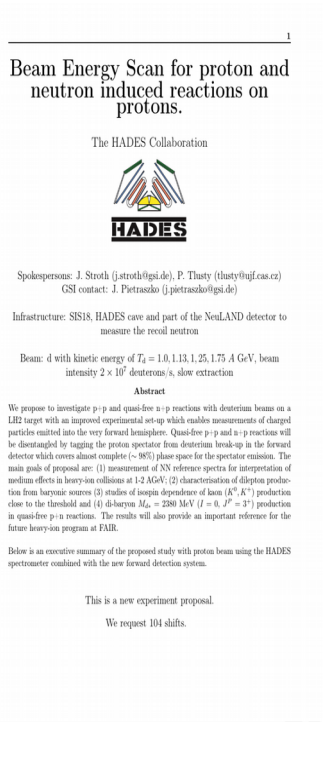
Beam: slow extraction
Au at 800–600–400–200A MeV, beam intensity 1.2×10^9 ions/s (flat top)
C at 800-600A MeV, beam intensity 3×10^9 ions/s (flat top)

Abstract

We will study baryonic matter in the region of highest net-baryon densities close to the nuclear liquid-gas phase transition. The longer Au+Au campaigns (30 shifts for 800A MeV and 30 shifts for 600A MeV) are optimized for abundant low-mass dielectron and strangeness production; the shorter Au+Au campaigns (9 shifts for 400A MeV and 9 shifts for 200A MeV) will allow to collect most abundant particles (π, p, d, t, ^{3}He, Li) in large quantities, *e.g.* suitable for event-by-event analysis of particle correlations and fluctuations as well as to extract temperature of the system at freeze-out. We aim at a high statistics beam energy scan to enable (i) laboratory studies of the matter properties (Equation-of-State) in compact stellar objects; (ii) detection of measurable consequences of phase transition and critical point in the QCD phase diagram. Collisions of C beam on C target (6 shifts for 600A MeV and 6 shifts for 600A MeV) will serve as reference measurements.
Below is an executive summary of the proposed study with Au beam using the HADES spectrometer.

This is a new experiment proposal.

We request 90 shifts.



Beam Energy Scan for proton and neutron induced reactions on protons.

The HADES Collaboration

HADES

Spokespersons: J. Stroth (j.stroth@gsi.de), P. Tlusty (tlusty@ujf.cas.cz)
GSI contact: J. Pietraszko (j.pietraszko@gsi.de)

Infrastructure: SIS18, HADES cave and part of the NeuLAND detector to measure the recoil neutron

Beam: d with kinetic energy of $T_d = 1.0, 1.13, 1, 25, 1.75$ A GeV, beam intensity 2×10^7 deuterons/s, slow extraction

Abstract

We propose to investigate p+p and quasi-free n+p reactions with deuterium beams on a LH_2 target with an improved experimental set-up which enables measurements of charged particles emitted into the very forward hemisphere. Quasi-free p+p and n+p reactions will be disentangled by tagging the proton spectator from deuterium break-up in the forward detector which covers almost complete (~ 98%) phase space for the spectator emission. The main goals of proposal are: (1) measurement of NN reference spectra for interpretation of medium effects in heavy-ion collisions at 1-2 AGeV; (2) characterisation of dilepton production from baryonic sources (3) studies of isospin dependence of kaon (K^0, K^+) production close to the threshold and (4) di-baryon $M_{\Delta\Delta} = 2380$ MeV ($I = 0$, $J^P = 3^+$) production in quasi-free p+n reactions. The results will also provide an important reference for the future heavy-ion program at FAIR.

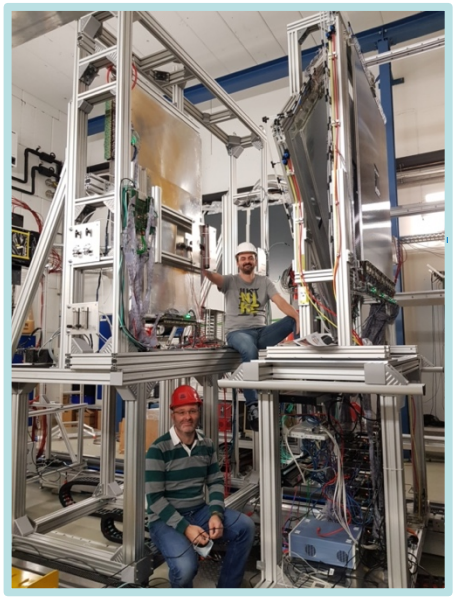
Below is an executive summary of the proposed study with proton beam using the HADES spectrometer combined with the new forward detection system.

This is a new experiment proposal.

We request 104 shifts.

The upgraded HADES detector (five new detector systems) for 2022-2024 campaign

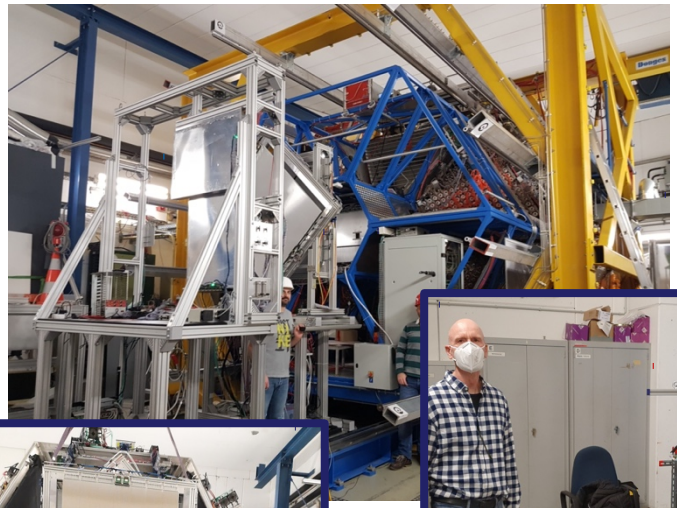
- Improved physics performance through instrumentation of the very forward hemisphere using FAIR technology.
- In particular important for the Hyperon Program.



Forward RPC

LIP Coimbra

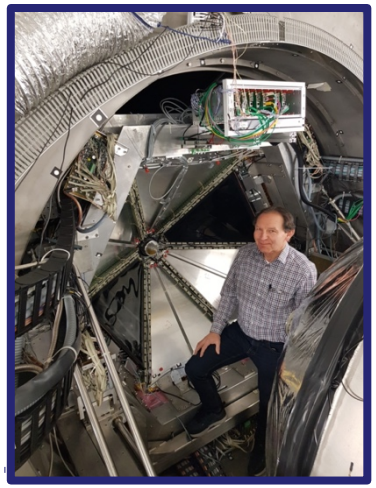
- Based on R&D for neuLAND
- TRB3 read-out

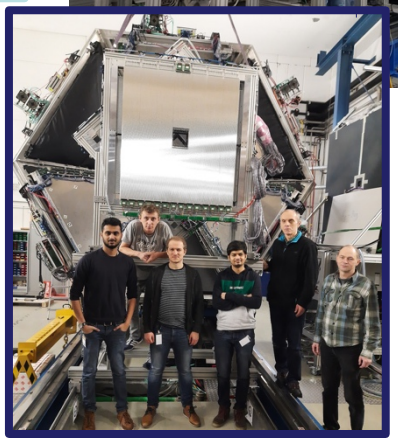


iTOF

TransFAIR, Jülich

- APD read-out
- Enhances trigger purity





STS2

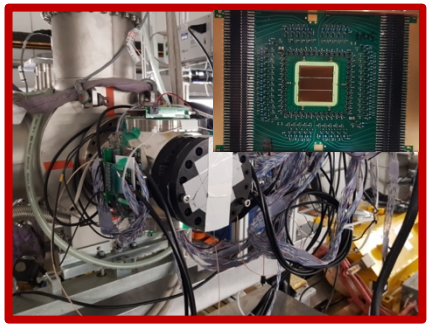
Jagiellonian Univ.

- PANDA straw technology
- PANDA PASTTRECK FEE chip

STS1

TransFAIR, Jülich

- PANDA straw technology
- PANDA PASTTRECK FEE chip



T0

GSI, TU Darmstadt

- LGAD technology
- In-beam detector

Requested resources

Estimated expenditures for the Project HADES:JINR participation

Expenditure items	Full cost*	2022 y.	2023 y.	2024 y.
Direct expenses for the Project				
1. Accelerator, reactor	-	-	-	-
2. Computers	-	-	-	-
3. Computer connection	-	-	-	-
4. Design bureau	-	-	-	-
5. Experimental Workshop	-	-	-	-
6. Materials	24	8	8	8
7. Equipment	21	7	7	7
8. Construction/repair of premises	-	-	-	-
9. Payments for agreement-based research	-	-	-	-
10. Travel allowance, including:	45	15	15	15
a) non-rouble zone countries	45	15	15	15
b) rouble zone countries	-	-	-	-
c) protocol-based				
Total direct expenses	90	30	30	30

* - from JINR-BMBF grant and JINR-Czech Republic Scientific Cooperation Program

PROJECT LEADER

LABORATORY DIRECTOR

LABORATORY CHIEF ENGINEER-ECONOMIST

Human resources

Laboratory	№№	Name, Surname	FTE	Duty
LHEP 2.4 FTE	1	Belyaev A. V.	0.5	Software development: tracking and kin.refit
	2	Fateev O.V.	0.1	MWDC maitenance and upgrade, management
	3	Ierusalimov A.P.	1.0	Software developments in tracking and simulation
	4	Ladygin V.P.	0.1	Physics, management
	5	Reznikov S.G.	0.2	MWDC maitenance, FEE upgrade project
	6	Troyan A.Yu.	0.5	Computing, simulation
	7	Zinchenko A.I.	0.1	Software developments in tracking: vector finding algorithm
LIT	8	Ivanov V.V.	0.1	Software developments for RICH
0.6 FTE	9	Lebedev S.A.	0.5	Software developments for RICH, data taking
LNP	10	Lykasov G.I.	0.1	Theoretical interpretation
0.1 FTE				

Total FTE — 3.1

SWOT analysis

Strengths:
HADES physics program focuses on the high-statistics studies of the rare probes like di-leptops and strangeness, which provide the information on the early stage of the strong interaction in the energy range of 1-4.5 A GeV. The energy range is unique and cannot by covered by BES-II at STAR at the moment, and by MPD and CBM in future.

Weaknesses:
Very high competition for the available SIS18 beam for HADES. Only 1 from 5 proposals obtained full support in 2022, the second one obtained 50% from the requested beam time.

Opportunities:
Synergy between NICA and FAIR/GSI experiments. DAAD and BMBF-JINR grants for young researchers.

Threats:
JINR obligations on the MWDC maintenance and upgrade requires the staying of JINR physicists at GSI, what is impossible in 2020-2021 due to COVID-19 pandemy impact.
Project budget is formed from JINR-BMBF money mostly – they were not distributed in 2018-2019.

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 2022-2024:
   - participation in data taking at SIS -18 - 2022, -
   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 at SIS-18 is interesting for physics program of BM@N and MPD as well. Program with protons, pions and deuterons can have impact on SPD physics program.
5. The 'HADES project at JINR' is supported by grant of BMBF/JINR and JINR-Czech Republic Scientific program.

Thank you very much!

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)

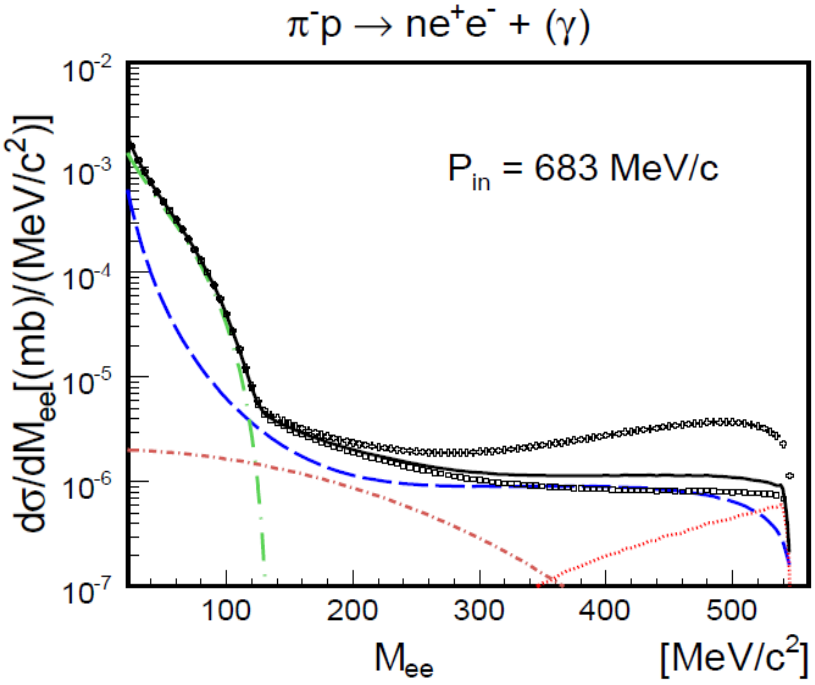
The institute will contribute to all types of experiments performed with HADES. The analysis activities will be focused on the baryonic resonance studies in hadronic and electromagnetic channels and short range correlations in proton/deuteron induced reactions.
The institute will contribute in the R&D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

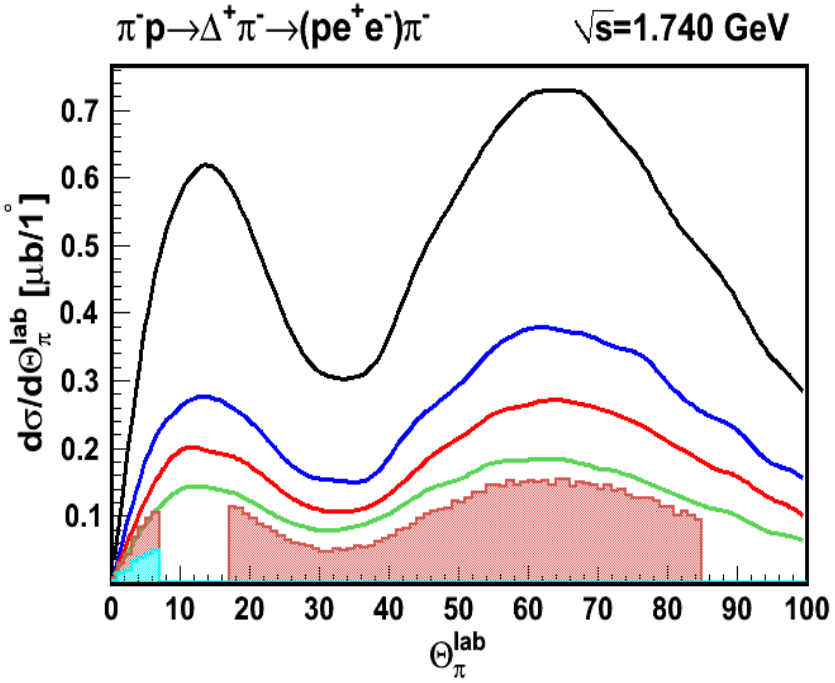
Vladimir Ladygin
Collaboration Board Member

Vladimir Kekelidze
Director LHEP JINR

HADES results : interpretation and new experiments



Calculations for quasi-free $np \rightarrow e^+ e^- X$ and $\pi^- p \rightarrow n e^+ e^-$ reactions: A.P.Jerusalimov, G.Lykasov, arXiv:1907.10298[hep-ph].



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

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:

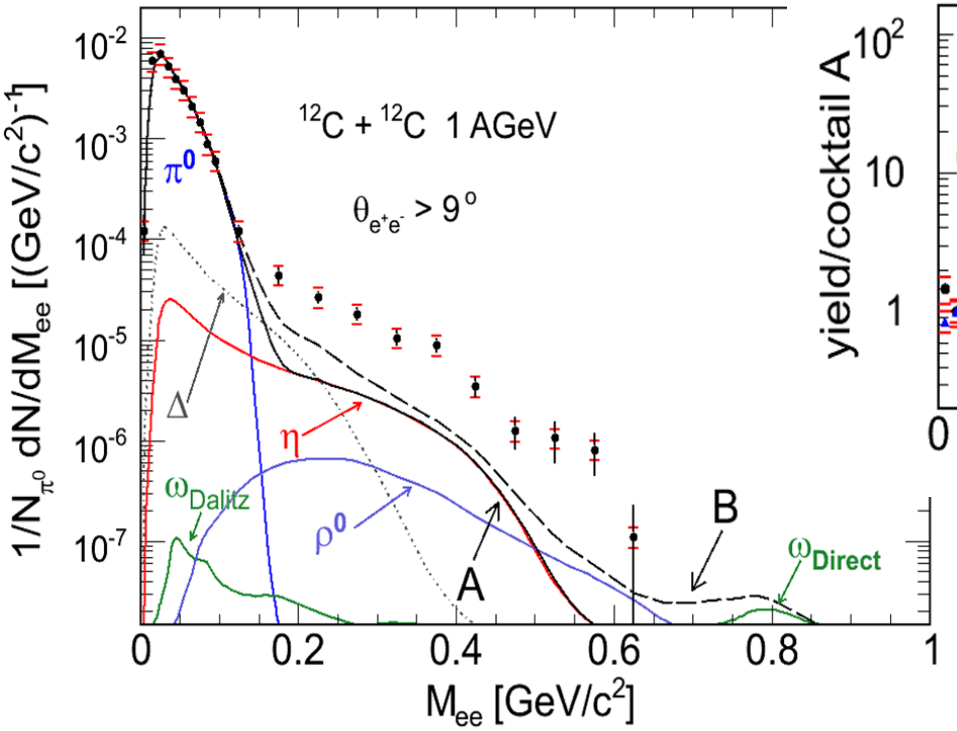
*Participation in the research programs at the **STAR** (RHIC, BNL). **NA61** (SPS, CERN), **ALICE** (LHC, CERN), and **CBM/HADES** (FAIR, GSI).*

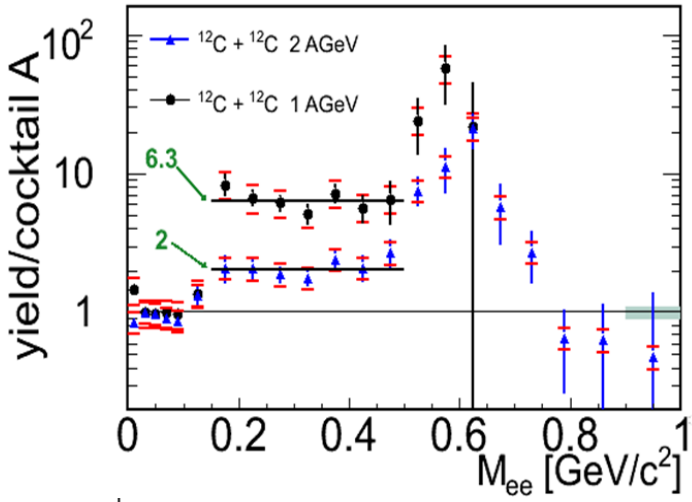
The scale of participation in external projects will be determined by:
- *the consolidation work at the JINR accelerator complex;*
- *the progress in the NICA project realization.*

32

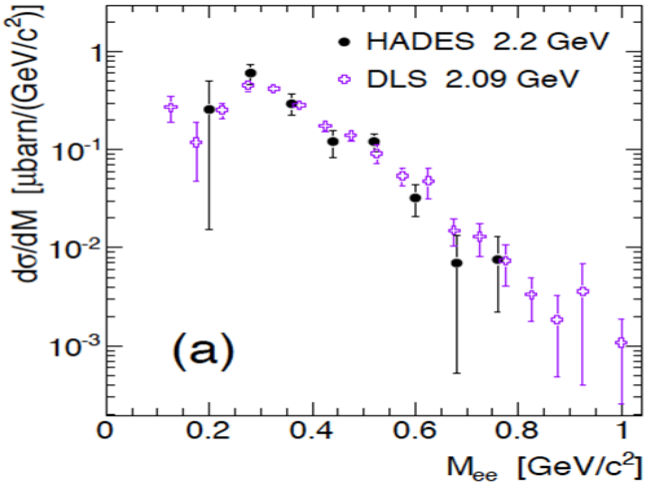
HADES results (DLS puzzle)

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

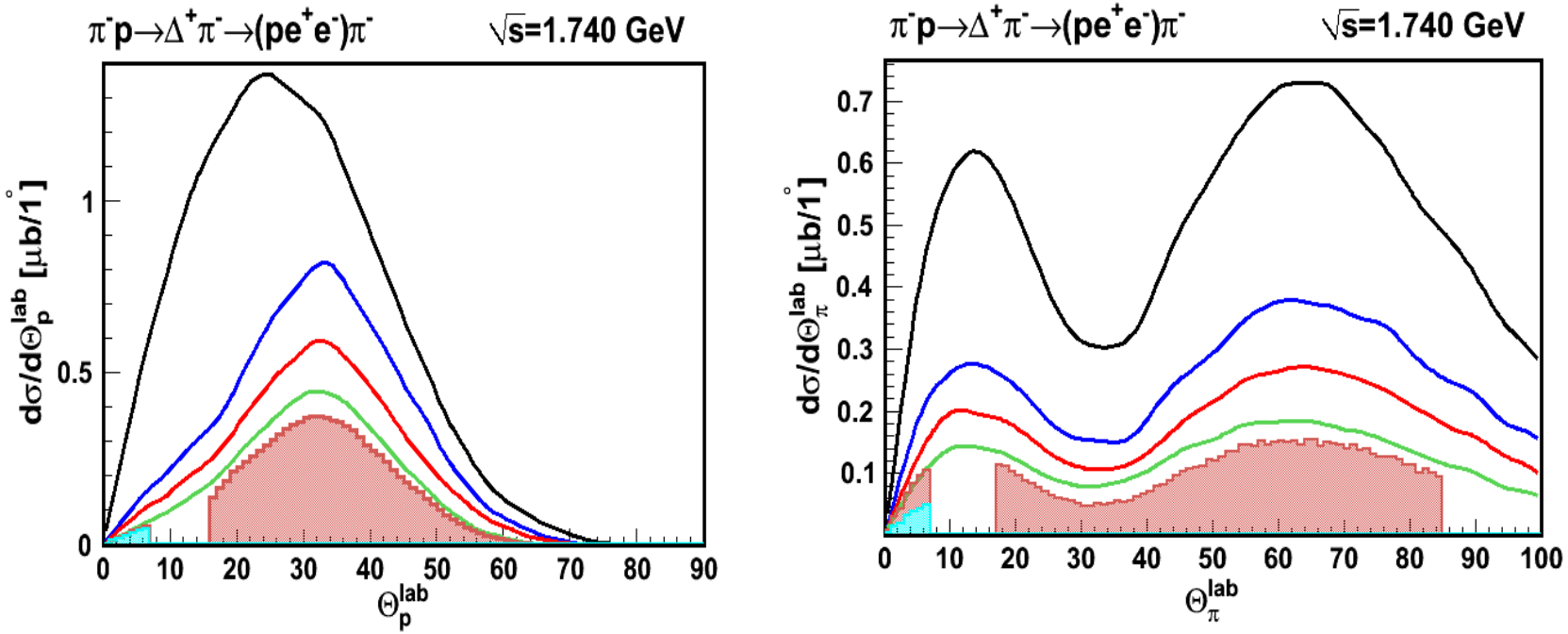
HADES data: PLB 663 (2008) 43,
arXiv:1203.2549, PLB 690 (2010) 118

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 results : baryon formfactors

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