Baryon resonance studies with HADES at FAIR

B. Ramstein (IPN Orsay)

FAIR-FRANCE meeting, 17 May 2017

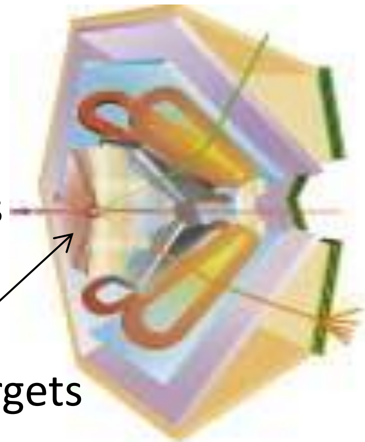
Orsay

HADES : hadronic physics and hadronic matter interplay

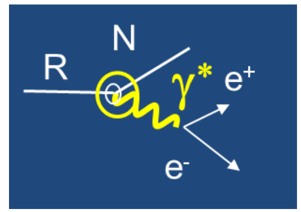
e^+e^- and meson (π, η, ρ, ω, ϕ, K) production in hadronic reactions
SIS18@GSI E/A ~1-3.5 GeV

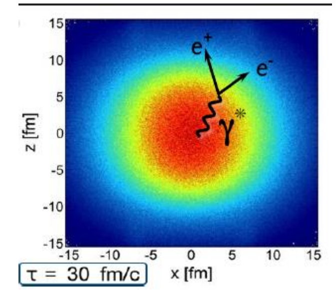
see J. Stroth's talk

proton, pion, light and heavy ion beams



LH2 (p) or nuclear targets





Time-like electromagnetic transitions
$N^*/\Delta \rightarrow Ne^+e^-$
(first meas.)

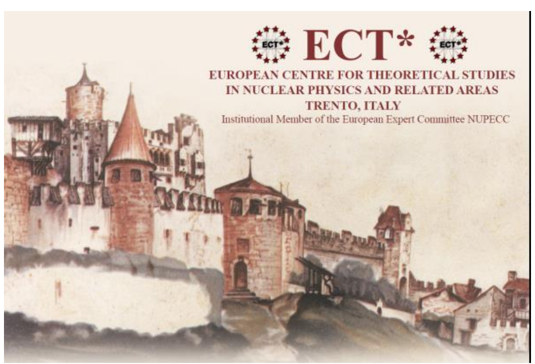
space like transitions
(CLAS N* program)

Hadronic matter studies

HI experiments, RHIC, LHC

Baryon (N^*/ Δ^*) spectroscopy with pion beam
2 PDG entries

photoproduction experiments
(Jlab, Mainz, Bonn,…)

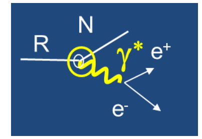


Space-like and time-like electromagnetic baryonic transitions
Trento, May 8 - 12, 2017

40 participants

Organizers
Philip Cole (*Idaho State University - Department of Physics*)
Beatrice Ramstein (*Institut de Physique Nucléaire d'Orsay*)
Andrey Sarantsev (*University of Bonn and NRC KI Gatchina*)

Time like baryon electromagnetic transitions in pp reactions

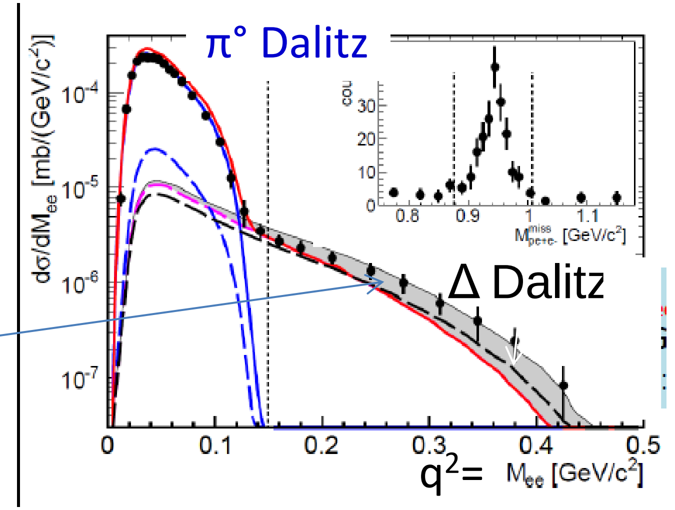


- $pp \rightarrow ppe^+e^-$ E=1.25 GeV

first measurement of **Δ(1232) Dalitz decay**

BR($\Delta^+ \rightarrow pe^+e^-$) = 4.19 $\pm$0.42 (model) $\pm$0.46 (syst.) $\pm$0.34 (stat.) 10^{-5}.

HADES collaboration: arXiv:1703.07840 [nucl-ex](PRC, accepted)



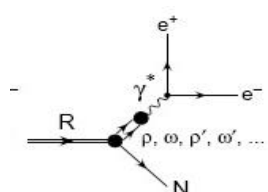
Slight sensitivity to electromagnetic structure (form factor) of the N-Δ transition

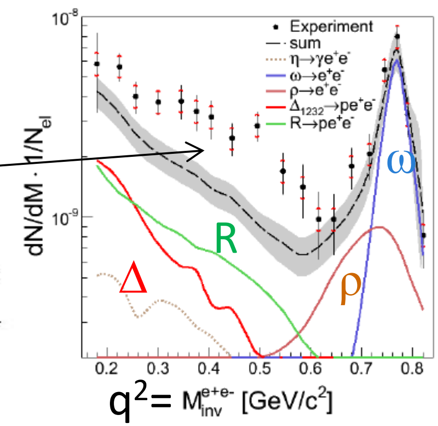
T. Pena and G. Ramalho Phys.Rev. D85 (2012) 113014

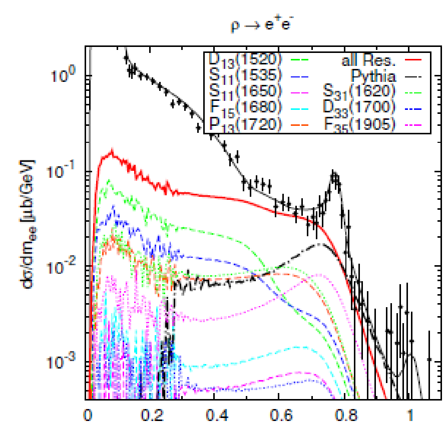
- $pp \rightarrow ppe^+e^-$ E=3.5 GeV

Evidence of form factors of the **Vector Meson Dominance** type (coupling to ρ)

Hades coll. Eur.Phys.J. A50 (2014) 8







Pion production measured in parallell to constrain underlying mechanisms

A. Belounnas on-going PhD

Weil, et al., EPJA 48, 111 (2012)

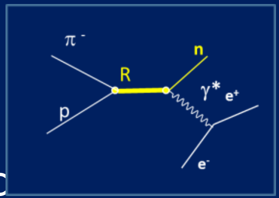
Pion beam experiment with HADES

2014 experiment: N(1520) region

- ✓ Very significant Improvement of database for baryon spectroscopy:

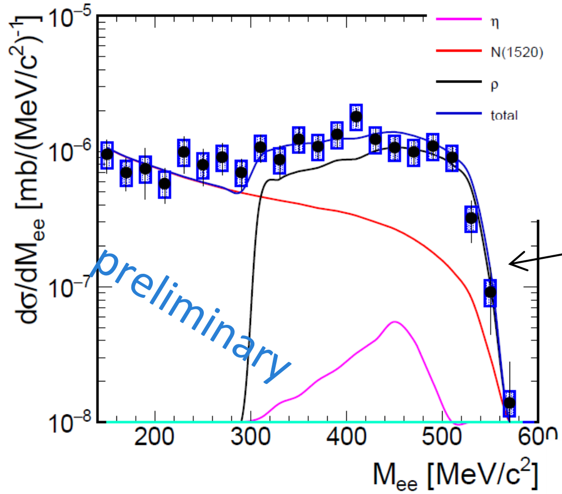
2πN channels N*$\rightarrow\rho$N,σN, $\pi\Delta$ branchings (new PDG entries to be expected…)

- ✓ e^+e^- production : completely new information $\rightarrow$ study of time-like baryonic transitions



Quasi-free $\pi^-p\rightarrow ne^+e^-$ $\sqrt{s}$=1.49 GeV/c²

Total
$\eta\rightarrow e^+e^-\gamma$
N(1520)$\rightarrow ne^+e^-$
$\rho\rightarrow e^+e^-$

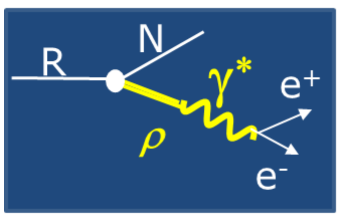


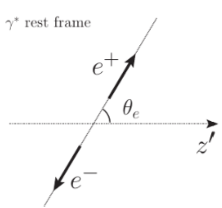
Input from $\pi^-p\rightarrow n\pi^+\pi^-$ (Partial Wave Analysis incl. HADES data)

$\rho\rightarrow\pi^+\pi^-$

$\rho\rightarrow e^+e^-$

Vector Meson Dominance

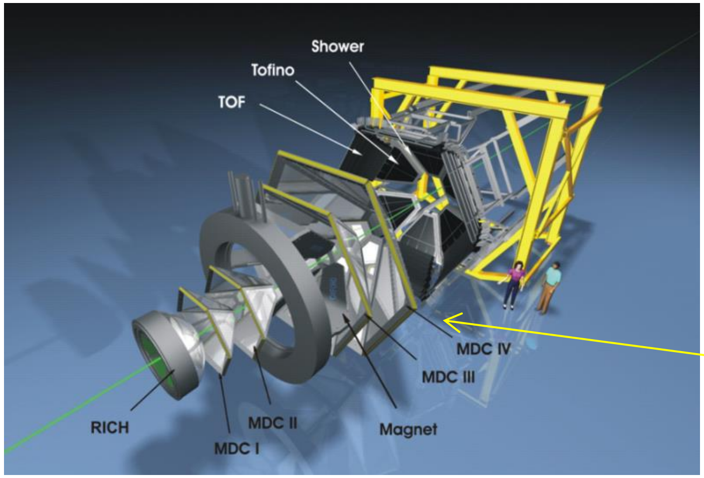




further information
in angular distributions
on the different contributions
(spin density matrix)

Federico Scozzi (PHD IPNO/Darmstadt)
EPJ Web Conf., 137 (2017) 05023

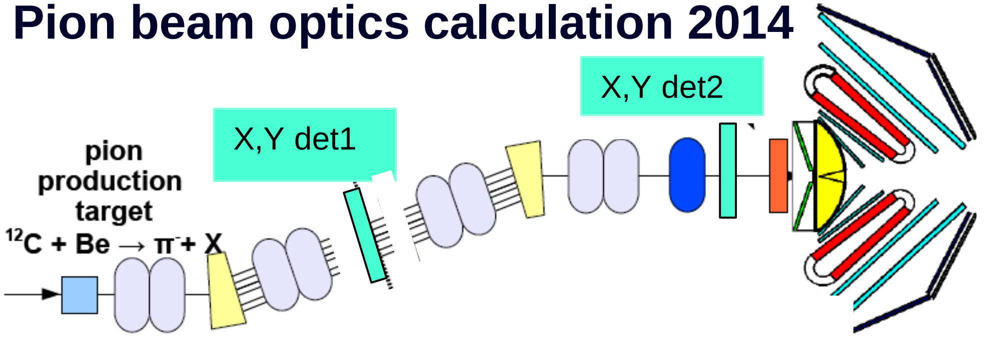
IPN technical contribution in HADES



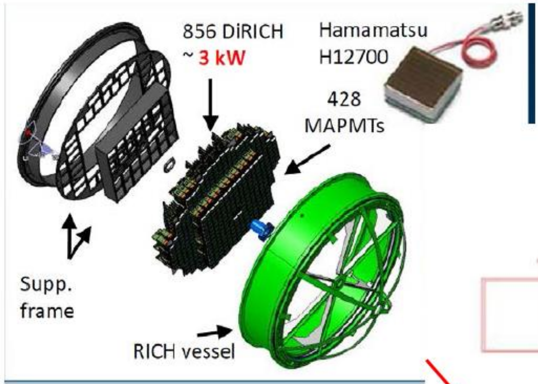
4th station of the tracking system:
6 drift chambers built by IPN R&D group
drift cell (14x10 mm^2)
active area 21 m^2 , 7200 sense wires
last chamber delivered 2006

LH2 target (built in 2000 by IPN Cryogenics group)

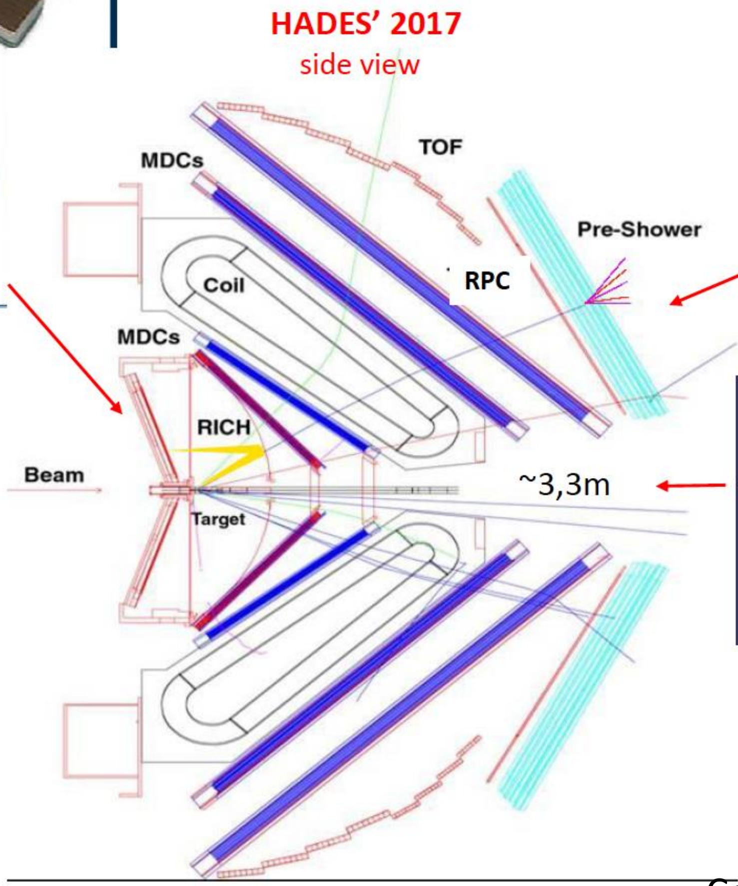
Pion beam optics calculation 2014



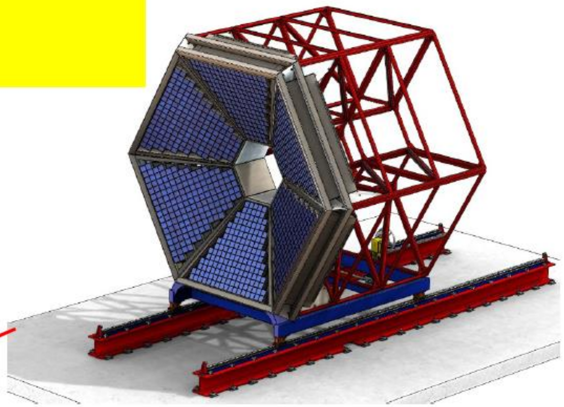
Preparing for FAIR: HADES Upgrade

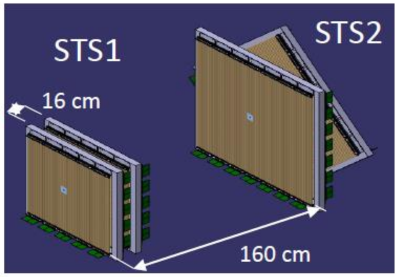


New RICH photon detector
& read-out (CBM @ HADES)
Gain in e+e- eff x 5



New ECAL (lead glass)
γ,e+,e-
$\sigma(E)/\sqrt{E}$ ~ 5.5%



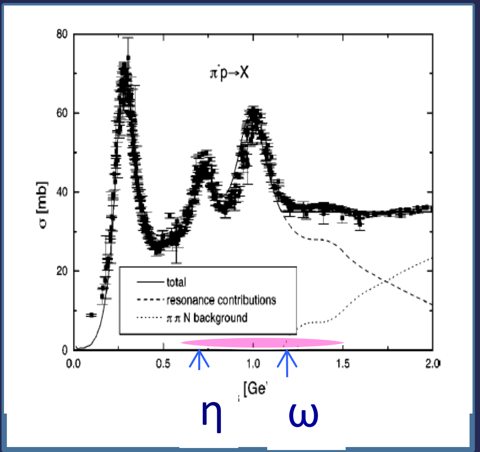


+RPC (5 m distance)

Forward Detector (0.5: 6.5^0)
Panda FT straws + RPC TOF
(HADES@PANDA)
$\sigma(x)$~150µm σ(TOF)~ 70 ps

Contribution of IPNO:
Funds for ½ of STS2 and construction of mechanical frame + support

HADES in the FAIR era: SIS18 experiments =FAIR Phase0 experiments

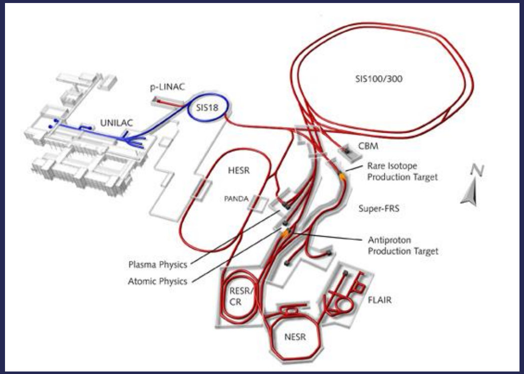


Experimental proposal for beam time in 2018-2019:
dead line June 19 !

- ✓ Exploit **π beam** → investigate heavier resonances Δ(1620), N(1720),… in e^+e^- channels and many hadronic channels e.g. $\pi^- p \to \pi\pi n$, ωn, ηn , ηn , $K^0\Lambda$, $K\Sigma$,….
- ✓ Study of **medium effects** (dilepton+strangeness in Ag+Ag at 1.65 GeV) (see J. Stroth's talk)

Unique at the moment,
But soon JPARC competition
(for hadronic channels only !)

Pave the way for future meson beam facilities at EIC
W. J. Briscoe et al.,
Eur. Phys. J. A51 (2015) no.10, 129



Further measurements at SIS18

- HADES has demonstrated excellent Λ ($\rightarrow p\pi^-$)and e^+e^- meas. capabilities
- Hyperon states are narrow : can be identified in inclusive pp or pA reactions at e.g. T=4.5 GeV

Radiative decays of hyperons $Y \rightarrow \Lambda\gamma$

- e.g. not known for $\Lambda(1405)$,
- Large sensitivity to intrinsic structure (quark correlation)

Dalitz decays of hyperons $Y \rightarrow \Lambda$ e+e- ($BR \sim 10^{-5}$)

no existing measurement, time like transition form factors

- Syst. study of production of $\Xi^-(1321)$ (S= - 2)

Feasibility studies on-going in Krakow

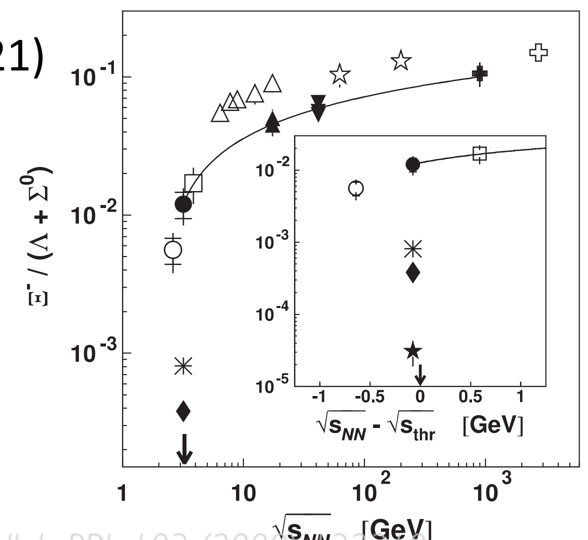
Λ (1520) yields (σ=40 μb at T=5 GeV)

10^8 p/s $5*10^5$ π/s

	Proton Beam	Pion Beam
HADES only		
Carbon Target	52/day	0.2/day
Hydrogen Target	13.2/day	0.2/day
HADES and FW		
Carbon Target	128.3/day	0.5/day
Hydrogen Target	32.6/day	0.7/day

HADES collab. PRL 103 (2009) 132310
HADES collab. PRL 114 (2015) 212301

production of $\Xi^-(1321)$
unexpectedly large
In AA and pA



HADES collab. PRL 103 (2009) 132310
HADES collab. PRL 114 (2015) 212301

HADES collab PRL103(2009)132310
HADES collab PRL114(2015) 212301

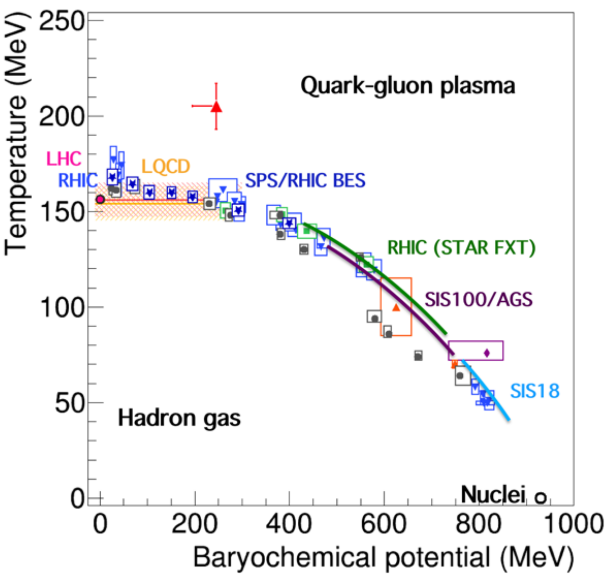
HADES @SIS100 (I) hadronic matter studies

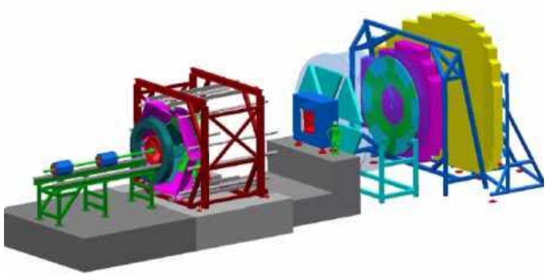
- 2022 (or later ?) :

HADES will move to the CBM cave → HADES experiments with SIS100

p and ion beams, possibly pions in future….

A+A and p+A (cold matter): acceptance complementary to CBM





Observables:
Emissivity of matter (dielectrons)
Flavor production (multistrange, charm)
correlations and fluctuations (photons,hadrons)

HADES @SIS100 (II) hadronic physics studies

■ pp at a few GeV: no LH2 target in CBM

■ *reference for hadronic matter studies* (A+A,p+A)

M<1 GeV/c^2 vector mesons melting

M>1 GeV/c^2 ρ-a1 mixing, radiation from multipion states

But also intrinsic interest:ideal tool for hadronic physics (E<29 GeV)

■ inclusive meson cross sections:

$\pi^\pm$, $K^\pm$, π^0 /$\eta\rightarrow\gamma\gamma$, $\omega \rightarrow \pi^0\pi^+\pi^-$, $\rho \rightarrow \pi^+\pi^-$, $\phi \rightarrow K^+K^-$, $\eta' \rightarrow \pi^0\pi^+\pi$, J/psi $\rightarrow e^+e^-$

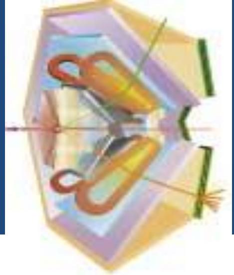
■ Neutral meson Dalitz decays (EM transition form factor):

$\eta \rightarrow \gamma e^+e^-$, $\omega \rightarrow \pi^0 e^+e^-$, $\eta' \rightarrow \gamma e^+e^-$, $\phi \rightarrow \eta e^+e^-$

■ Dalitz decays of Hyperons tagged by K^+ (or Λ) (EM transition form factor): $pp \rightarrow pK^+Y$ (any hyperon)$X \rightarrow pK^+e^+e^-\Lambda$ higher cross-sections than at SIS18 synergy with PANDA

■ Transition from hadron (resonance decays) to quark degrees of freedom in e^+e^- production (Drell-Yan) (access to nucleon structure functions: TMD) ? synergy with PANDA

Conclusion



- HADES is a very productive experiment
  - on-going experimental programme at SIS18 (π, p, A beams) + (p, A targets)
  - future plans at SIS100 (A+A E<8 AGeV; p+p, p+A E<29 GeV)

- Versatile set-up: contribution to studies of hadronic matter, baryon spectroscopy, but also dark matter (heavy photon), probably also Short Range Correlations in near future

- Urgent! Strengthen the involvment of IN2P3 in HADES
  - SIS18: Exploit the π beam (unique tool for baryon spectroscopy and reference measurements for medium effects)
  - SIS100: hyperon studies
  - Joint HADES-PANDA activities at SIS18 (GSI)

    $\rightarrow$ Capitalize on strong IN2P3 involvment in HADES (and PANDA)

    $\rightarrow$ Keep open the possibility of French hadronic physics activities at PANDA

Man-power and collaborations (HADES)

- **Post-doc (HADES/PANDA)**

  Malgorzata Gumberidze(Sudol): 30% HADES from 2010 to 2012
  Ermias Atomssa (Oct. 2013-Oct. 2016, 20% HADES)

- **PhD Thesis: T. Liu: Dec 2010**
  - **H. Kuc (French embassy+IPN+ParisXI, co-direction with Cracow/P. Salabura, Dec. 2014)**
  - **F. Scozzi (P2IO Labex + TU Darmstadt, co-direction with T. Galatyuk, Oct.2014-Oct. 2017)**
  - **A. Belounnas (ED Pheniics grant, Oct. 2016-Oct.2019)**

- **Permanent : B.R.**

with contributions from R. Kunne (Tests of liquid hydrogen target, data analysis), J. Van de Wiele (phenomenology) and T.Hennino (former active participant, now retired)

- **Collaborations :**

  HADES groups Krakow, GSI/Darmstadt
  Theory groups: Bonn-Gatchina (A. Sarantsev), Giessen (V. Shklyar,C. Fischer), IST Lisbon (T.Pena), M. Zetenyi (Budapest), B.Friman(GSI)
  Collaboration agreement: IN2P3/GSI and IN2P3/Poland

Responsibilities and Scientific Output

✓ **Construction → transfer of responsibility to GSI in 2014-2015**

- 6 largest HADES drift chambers
- Liquid Hydrogen target

✓ **Data analysis** (analysis coordination, publication as main author or internal review committees) dilepton, one pion, two-pion production in pp/pn/πp reactions

✓ **Pion Beam optics calculations**

✓ **Organization of meetings**

- Pion beam experiments meeting Orsay (2009)
- Collaboration meetings (Seillac 2011 and fall 2016)
- Joint HADES-WASA meeting in Orsay (April 2013)
- Session on electromagnetic form factors at a RRTF meeting in GSI
- Organization of an ECT* meeting in 2017
- Labex funds for a meeting in 2018

✓ **Chairs of Collaboration Board** (T. Hennino (2001-2007), B.R (2015-2018))

Scientific Output

✓ 25 publications, significant contribution of IPNO to 8 publications (3 with full responsibility)

✓ 10 conference proceedings (IPNO speakers)

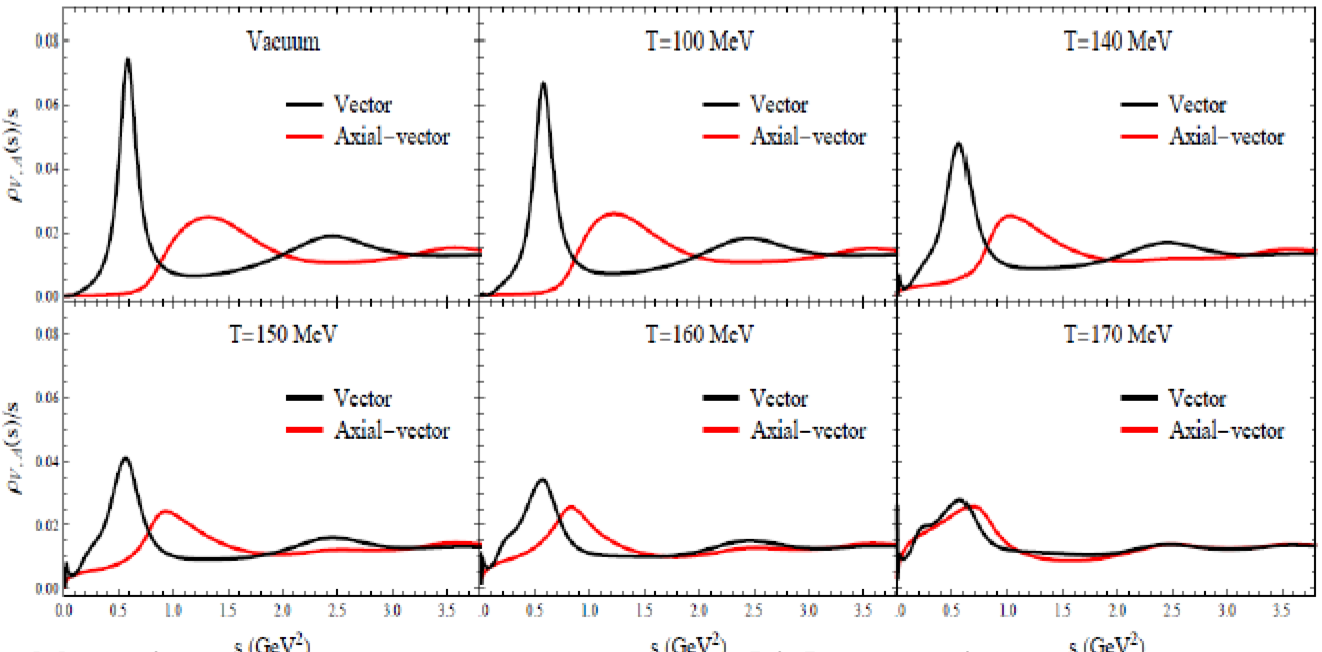
✓ 14 talks at conferences and workshops (7 invited) + 5 seminars

✓ ~ 8 talks/year at collaboration meetings, GDR, Mesonnet

Consistency of hadronic description of Chiral Symmetry Restoration – removal of ρ/a_1 mass splitting

M. Holher & R.Rapp

- Use spectral functions of ρ constrained by e+e- data
- Use (μ_b=0) results on evolution of quark/gluon condensates with T from lattice QCD
- Use QCD sum rules (spectral functions $\leftrightarrow$ quark and gluon condensates) and Weinberg sum rules (spectra functions of Vector (ρ) $\leftrightarrow$ Axial vector (a_1) states)
- Predict evolution of a_1 spectral function in T up to T_c



- Compatible with chiral restoration :

ρ and a_1 becomes degenerate around T_c !