The HADES Experiments

Challenges and Observations

Joachim Stroth

Research Retreat, Bensheim, Germany

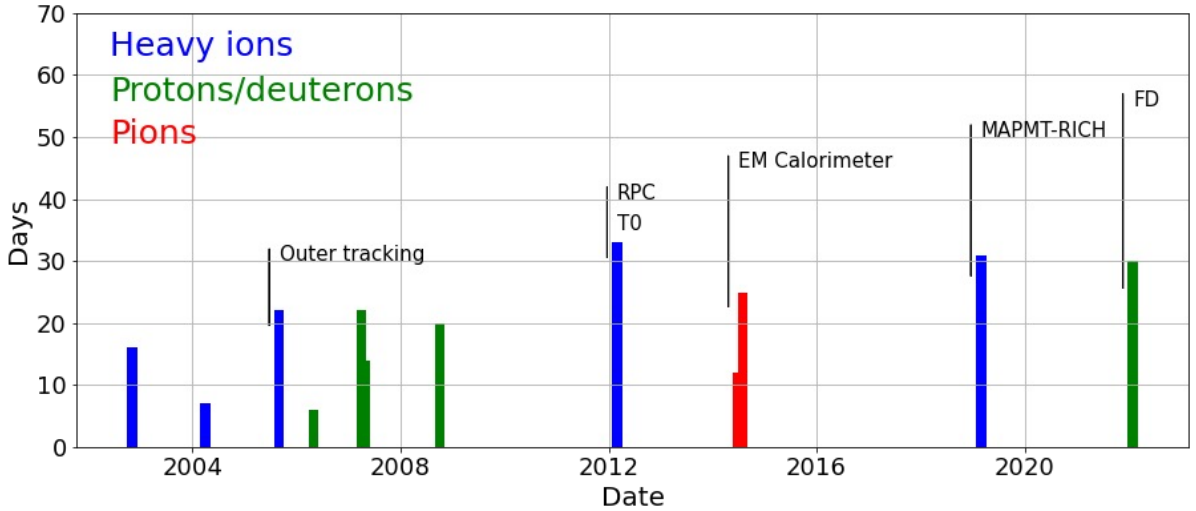
February 13 – 14, 2023

Many greetings to you from the HADES Collaboration!

Coimbra, September 2022

HADES overall run statistics & upgrades

- Ten runs in 20 years
- Continuous upgrade program to improve the performance
- Ready for next campaign



Outer tracking:	High precision momentum reconstruction
RPC:	High multiplicity events (e.g. Au+Au)
EM calorimeter:	Neutral mesons, dielectron purity

T0, iTOF:	Improved particle identification and trigger purity
MAPMT RICH:	Improved dielectron efficiency and conversion rejection
Forward Detectors:	Larger phase space for proton-induced reactions (exclusive channels)

Successfully upgraded HADES

For S518:

Inner TOF (iTOF; FAIR-NRW

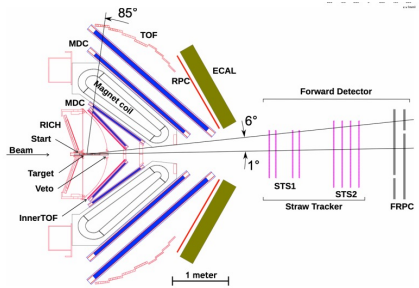
Forward Detector
STS1: FAIR-NRW (Jülich) team
STS2: Cracow team (JU, AGH)
Forward RPC: Coimbra team (LIP)

HADES T0 detector (LGAD)
GSI and TU Darmstadt teams

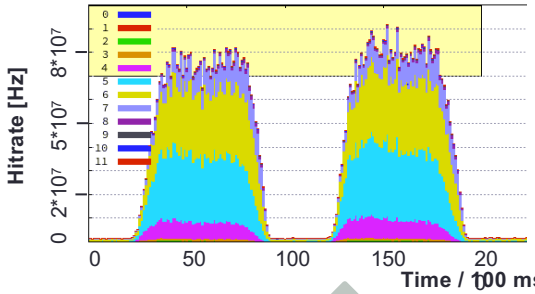
New:

Completion all ECAL sectors 2022
2022 Rez, TU Darmstadt, GSI

MDC FEE replacement
2023-2024 GU and GSI



Online: Spill profile from HADES T0
p+p@4.5GeV 02.2022

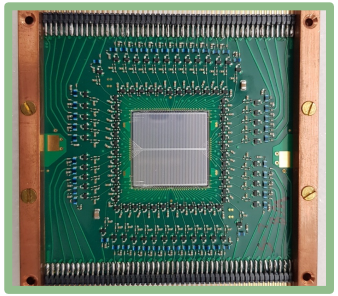


iTOF

Forward RPC *STS2*

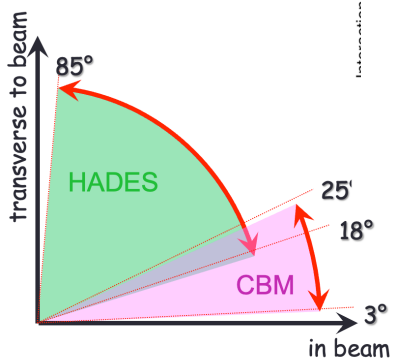
STS2 *STS1*

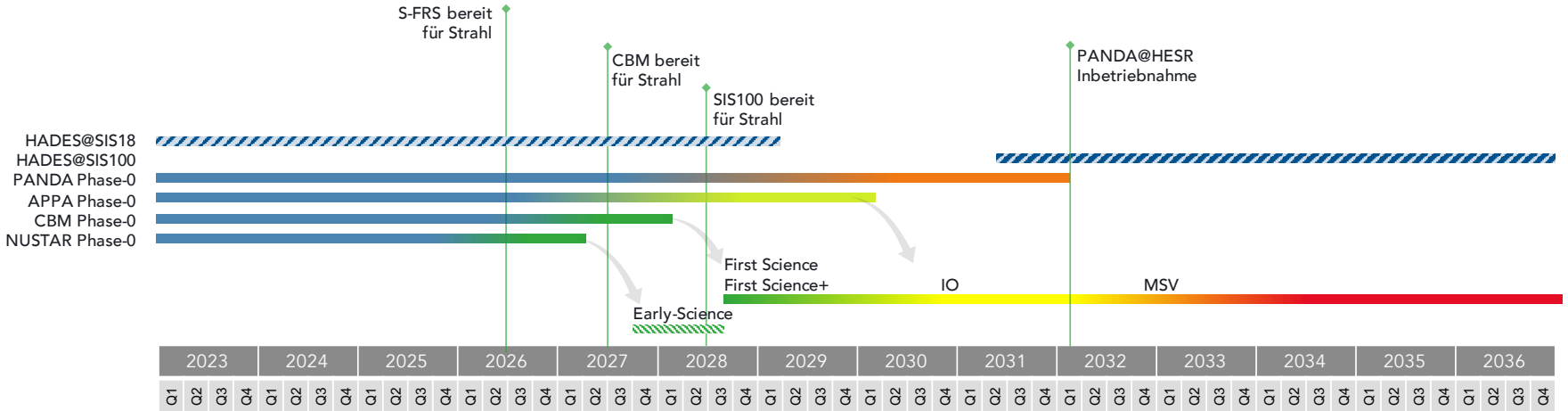
HADES T0:
LGAD sensor on a FEE PCB



HADES in the next 10 years

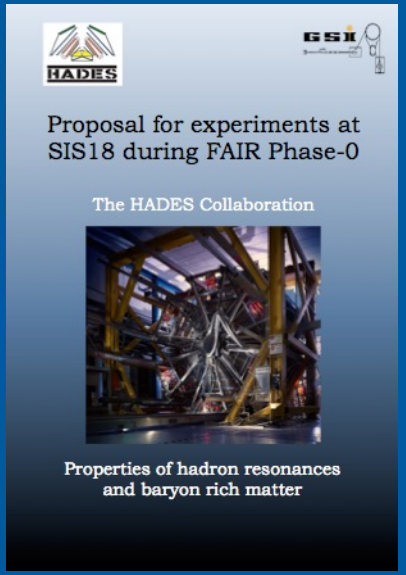
- Original FAIR Phase-0 program (See next slide)
- Extended running with pion and proton beam
- Transfer to CBM cave





PROPOSED PHYSICS

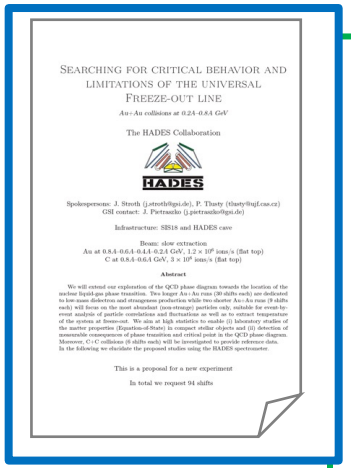
FAIR Phase-0



HADES proposals for FAIR Phase-0

- Proposed program will take at least until 2026 (one 4-weeks run per year), but likely longer.
- Transferring HADES to the new cave is expected to take two years.

Au+Au BES < 1 A GeV



SEARCHING FOR CRITICAL BEHAVIOR AND LIMITATIONS OF THE UNIVERSAL FREEZE-OUT LINE

Au+Au collisions at 0.24–0.8 A 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 and HADES cave

Beam: slow extraction
Au at 0.8,4–0.6,4–0.4,4–0.2,4 GeV, 1.2×10^9 ions/s (flat top)
C at 0.8,4–0.6,4 GeV, 3×10^9 ions/s (flat top)

Abstract

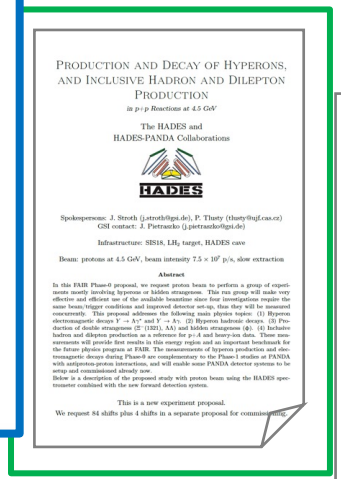
We will extend our exploration of the QCD phase diagram towards the location of the nuclear liquid-gas phase transition. Two longer Au+Au runs (30 shifts each) are dedicated to low-mass dielectron and strangeness production while two shorter Au+Au runs (9 shifts each) will focus on the most abundant (non-strange) particles only, 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 high statistics to enable (i) laboratory studies of the matter properties (Equation-of-State) in compact stellar objects and (ii) detection of measurable consequences of phase transition and critical point in the QCD phase diagram. Moreover, C+C collisions (6 shifts each) will be investigated to provide reference data. In the following we elucidate the proposed studies using the HADES spectrometer.

This is a proposal for a new experiment

In total we request 94 shifts

re-submission to GPAC 2022

EM transition form factors of hyperons



PRODUCTION AND DECAY OF HYPERONS, AND INCLUSIVE HADRON AND DILEPTON PRODUCTION

in p+p Reactions at 4.5 GeV

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, LH_2 target, HADES cave

Beam: protons at 4.5 GeV, beam intensity 7.5×10^7 p/s, slow extraction

Abstract

In this FAIR Phase-0 proposal, we request proton beam to perform a group of experiments mostly involving hyperons or hidden strangeness. This run group will make very effective and efficient use of the available beamtime since four investigations require the same beam/trigger conditions and improved detector set-up, thus they will be measured concurrently. This proposal addresses the following main physics topics: (1) Hyperon electromagnetic decays $Y \to \Lambda\gamma^*$ and $Y \to \Lambda\gamma$, (2) Hyperon hadronic decays, (3) Production of double strangeness (Ξ^- (1321), AA) and hidden strangeness ($\phi\phi$), (4) Inclusive hadron and dilepton production as a reference for p+A and heavy-ion data. These measurements will provide first results in this energy region and an important benchmark for the future physics program at FAIR. The measurements of hyperon production and electromagnetic decays during Phase-0 are complementary to the Phase-1 studies at PANDA with antiproton-proton interactions, and will enable some PANDA detector systems to be setup and commissioned already now.
Below is a description 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 84 shifts plus 4 shifts in a separate proposal for commissioning.

Successfully conducted in Feb./March 2022

Cold matter effects including line shapes and SRC

STUDYING MEDIUM EFFECTS IN PROTON INDUCED REACTIONS

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)
SRC part: T. Aumann (T.Aumann@gsi.de), O. Hen, E. Piasetzki

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

Beam: p at 4.5 GeV, beam intensity 4×10^6 protons/s, slow extraction

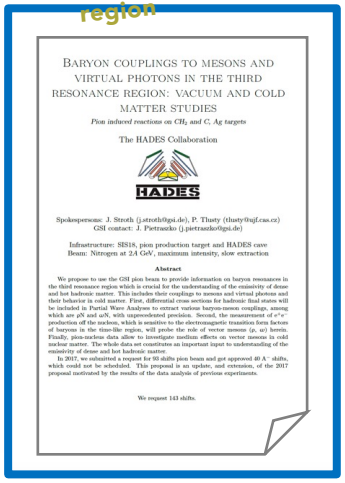
Abstract

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. These results will 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.

Baryon resonances, meson baryon coupling in the 3rd resonance region



BARYON COUPLINGS TO MESONS AND VIRTUAL PHOTONS IN THE THIRD RESONANCE REGION: VACUUM AND COLD MATTER STUDIES

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

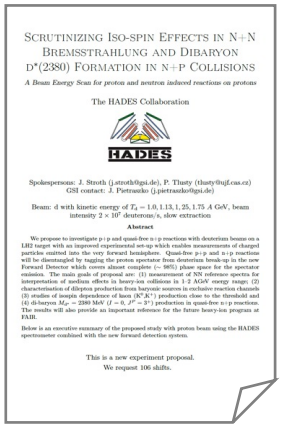
Abstract

We propose to use the GSI pion beam to provide information on baryon resonances in the third resonance region which is crucial for the understanding of the emissivity of dense and hot hadronic matter. This includes their couplings to mesons and virtual photons and their behavior in cold matter. First, differential cross sections for hadronic final states will be included in Partial Wave Analyses to extract various baryon-meson couplings, among which are pN and ωN, with unprecedented precision. Second, the measurement of e^+e^- production off the nucleon, which is sensitive to the electromagnetic transition form factors of baryons in the time-like region, will probe the role of vector mesons (ρ, ω) herein. Finally, pion-nucleus data allow to investigate medium effects on vector mesons in cold nuclear matter. The whole data set constitutes an important input to understanding of the emissivity of dense and hot hadronic matter.
In 2017, we submitted a request for 93 shifts pion beam and got approved 40 A− shifts, which could not be scheduled. This proposal is an update, and extension, of the 2017 proposal motivated by the results of the data analysis of previous experiments.

We request 143 shifts.

re-submission to GPAC 2022

Iso-spin effects in dilepton production



SCRUTINIZING ISO-SPIN EFFECTS IN N+N BREMSSTRAHLUNG AND DIBARYON $D^*(2380)$ FORMATION IN N+P COLLISIONS

A 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)

Beam: d with kinetic energy of $T_d = 1.0, 1.13, 1.25, 1.75$ *A GeV*, beam intensity 2×10^7 deutrons/s, slow extraction

Abstract

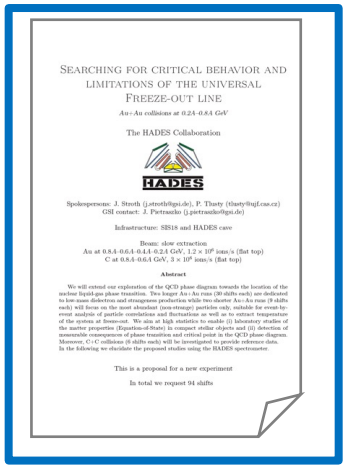
We propose to investigate p+p and quasi-free n+p reactions with deuterium beams on a LH_2 target with an improved experimental set-up which enables measurements of charged particles emitted into the very forward hemisphere. Quasi-free p+p and n+p reactions will be disentangled by tagging the proton spectator from deuterium break-up in the new Forward Detector which covers almost complete ($\sim 98\%$) 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 in 1–2 AGeV energy range; (2) characterisation of dilepton production from baryonic sources in exclusive reaction channels (3) studies of isospin dependence of kaon (K^0, K^+) production close to the threshold and (4) di-baryon $M_{d^*} = 2380$ MeV ($I = 0$, $J^P = 3^+$) production in quasi-free n+p 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 106 shifts.

15 Billion events Ag+Ag taken already in 2019, 35 Billion p+p in 2022.

HADES proposals for FAIR Phase-0

Au+Au BES < 1 A GeV



SEARCHING FOR CRITICAL BEHAVIOR AND LIMITATIONS OF THE UNIVERSAL FREEZE-OUT LINE

Au+Au collisions at 0.24–0.84 GeV

The HADES Collaboration

HADES

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GSI contact: J. Pietraszko (j.pietraszko@gsi.de)

Infrastructure: SIS18 and HADES cave

Beam: slow extraction
Au at 0.8,4–0.6,4–0.4,4–0.2,4 GeV, 1.2×10^9 ions/s (flat top)
C at 0.8,4–0.6,4 GeV, 3×10^9 ions/s (flat top)

Abstract

We will extend our exploration of the QCD phase diagram towards the location of the nuclear liquid-gas phase transition. Two longer Au+Au runs (30 shifts each) are dedicated to low-mass dielectron and strangeness production while two shorter Au+Au runs (9 shifts each) will focus on the most abundant (non-strange) particles only, 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 high statistics to enable (i) laboratory studies of the matter properties (Equation-of-State) in compact stellar objects and (ii) detection of measurable consequences of phase transition and critical point in the QCD phase diagram. Moreover, C+C collisions (6 shifts each) will be investigated to provide reference data. In the following we elucidate the proposed studies using the HADES spectrometer.

This is a proposal for a new experiment

In total we request 94 shifts

S520 (approved)

SEARCHING FOR CRITICAL BEHAVIOR AND LIMITATIONS OF THE UNIVERSAL FREEZE-OUT LINE

Au+Au collisions at 0.2A–0.8A GeV

The HADES Collaboration

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 0.8A–0.6A–0.4A–0.2A GeV, 1.2×10^6 ions/s (flat top)
C at 0.8A–0.6A GeV, 3×10^6 ions/s (flat top)

Abstract

We will extend our exploration of the QCD phase diagram towards the location of the nuclear liquid-gas phase transition. Two longer Au+Au runs (30 shifts each) are dedicated to low-mass dielectron and strangeness production while two shorter Au+Au runs (9 shifts each) will focus on the most abundant (non-strange) particles only, 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 high statistics to enable (i) laboratory studies of the matter properties (Equation-of-State) in compact stellar objects and (ii) detection of measurable consequences of phase transition and critical point in the QCD phase diagram. Moreover, C+C collisions (6 shifts each) will be investigated to provide reference data.

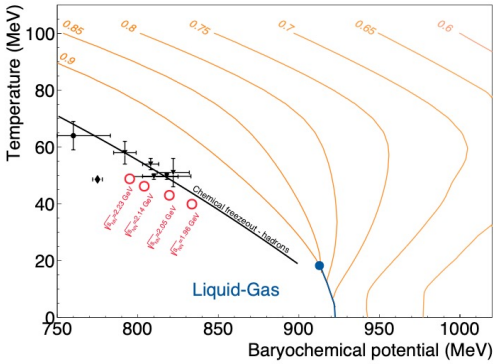
This is a proposal for a new experiment

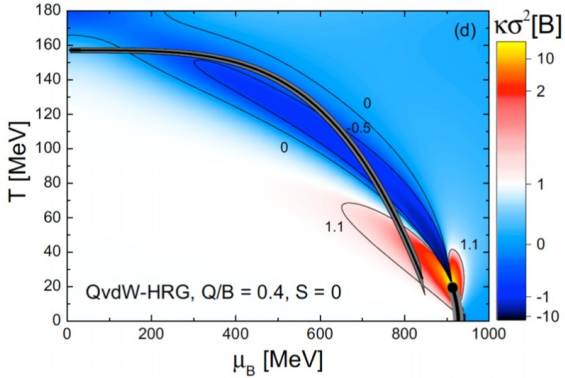
In total we request 100 shifts

Au+Au beam energy scan, C+C for reference

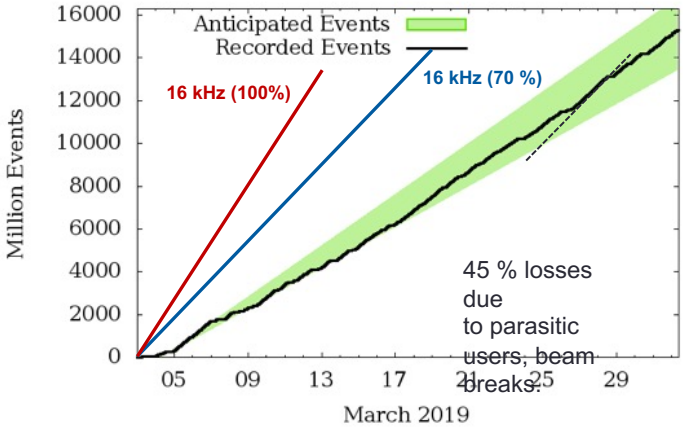
100 shifts Au beam at moderate rigidity

Good micro spill-structure



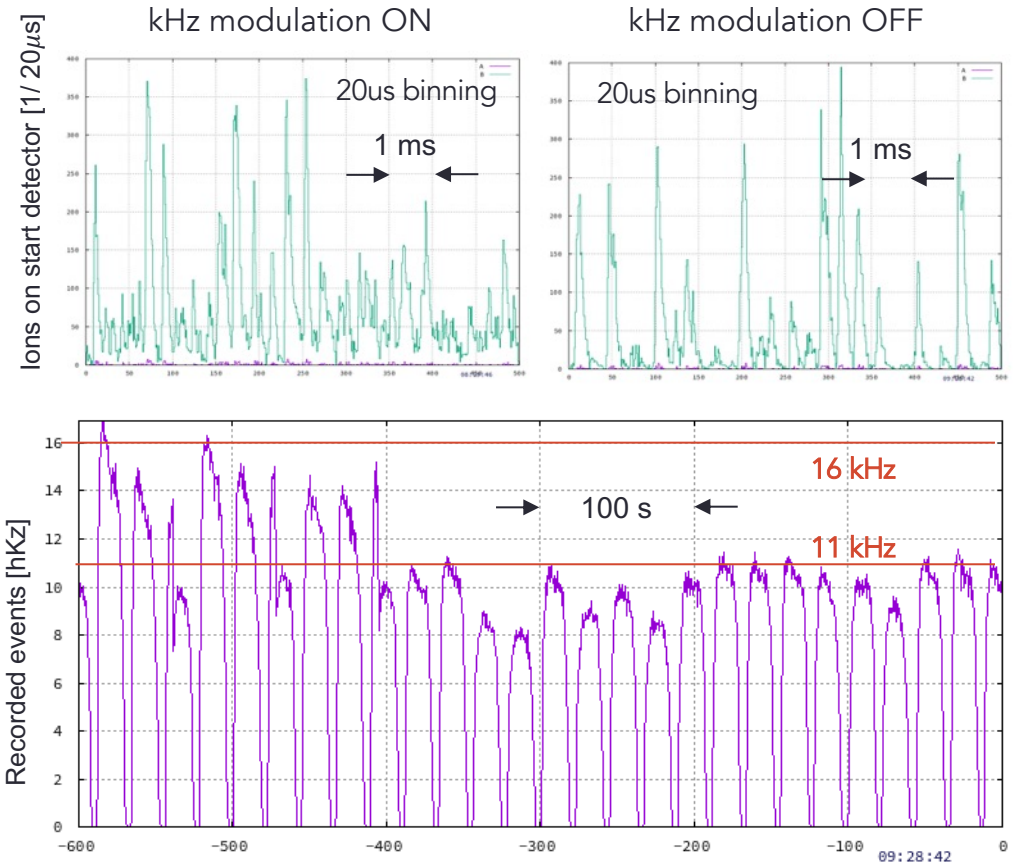


Micro spill-structure



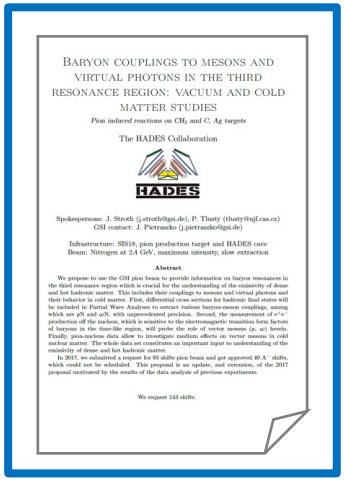
- New high-freq. resonator!?
- Influence of UNILAC beam phase space distribution
- “Wobbler”
- Might be of relevance for SIS100 operation

Quadrupole modulation – influence on HADES event rate



HADES proposals for FAIR Phase-0

Baryon resonances, meson baryon coupling in the 3rd resonance region



BARYON COUPLINGS TO MESONS AND VIRTUAL PHOTONS IN THE THIRD RESONANCE REGION: VACUUM AND COLD MATTER STUDIES

Pion induced reactions on CH_2 and C, Ag targets

The HADES Collaboration

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S517 (approved but not scheduled)

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In 2017, we submitted a request for 93 shifts pion beam and got approved 40 A^- shifts, which could not be scheduled. The present proposal, which is an extension of the 2017 proposal motivated by the results of the data analysis of previous experiments, was submitted to the G-PAC in 2020. Although the scientific interest of the proposed measurements had been recognized by the G-PAC, the experiment was not ranked due to needed improvements of the accelerator to provide the desired beam quality.

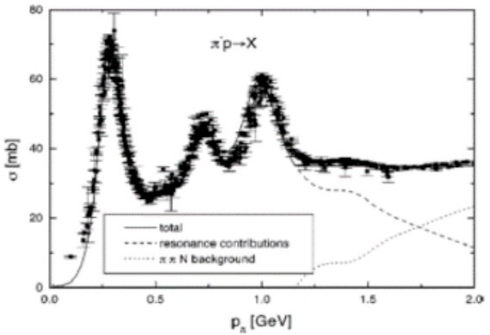
This is a new proposal

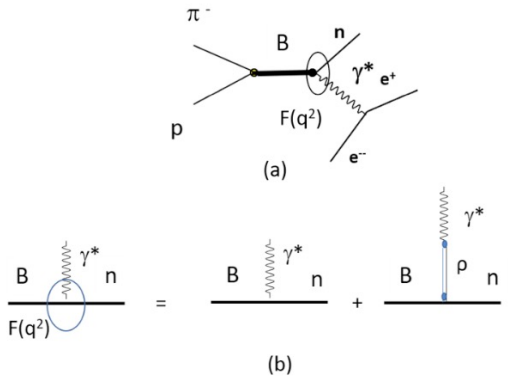
We request 143 shifts.

Baryon resonances in the second resonance region

143 shift with secondary pion beam (π^-)

Highest primary beam intensities at maximum rigidity





Extraction efficiency

Pion beam needs maximum intensity and maximum rigidity ^{14}N (^{12}C) beam

- Several modifications implemented:
  - Enlarged aperture in downstream beam line elements (NE5)
  - Improved diagnostics
  - Optimized beam optics
  - Repaired septum
- Still progress not sufficient
  - New electrostatic septum (SIS100 type)?

HADES proposals for FAIR Phase-0

Cold matter effects including line shapes and SRC

STUDYING MEDIUM EFFECTS IN PROTON INDUCED REACTIONS

p+Ag reactions at 4.5 GeV

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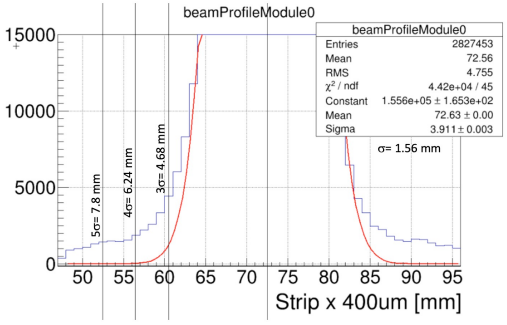
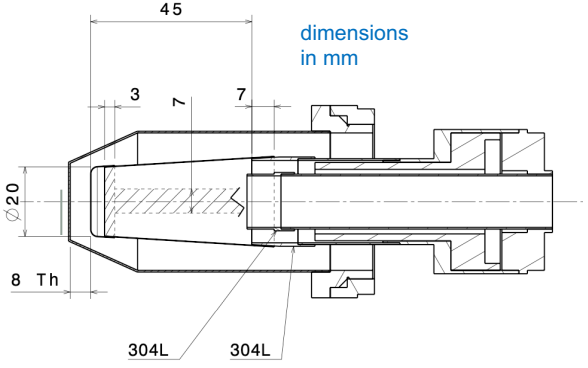
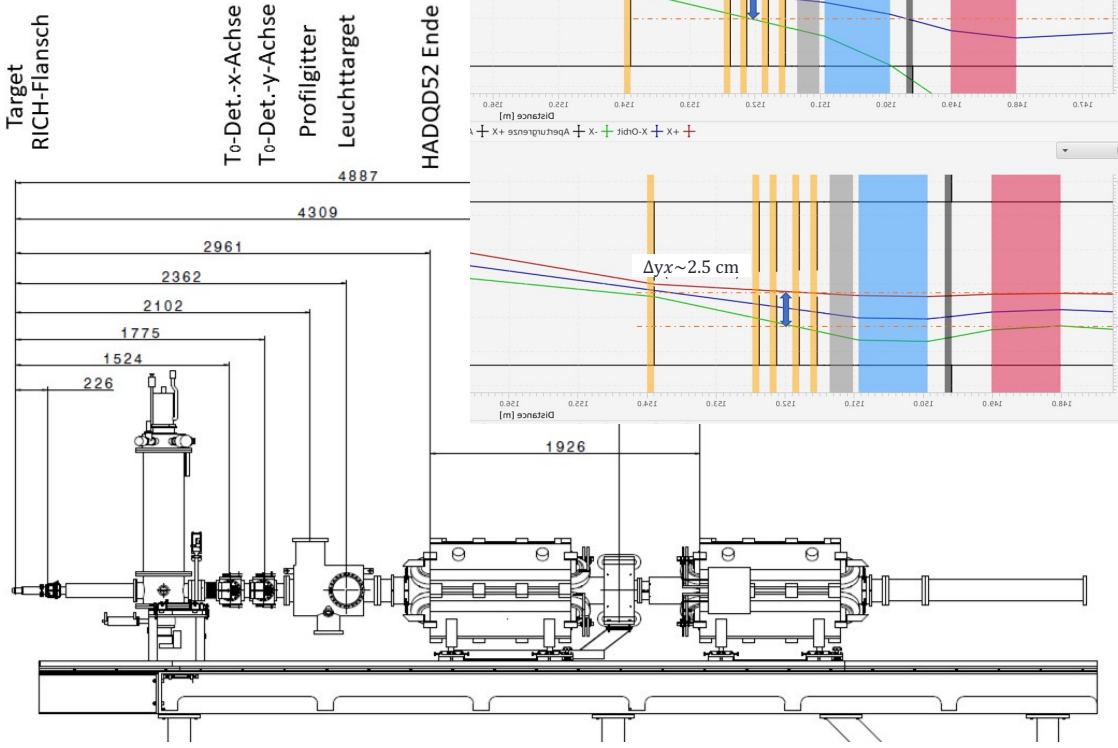
Indication of a beam halo

At ±7 mm away (transverse) from the nominal beam position material introducing 100% interaction probability (target is 1%)







sorry for mirroring "BENNO"