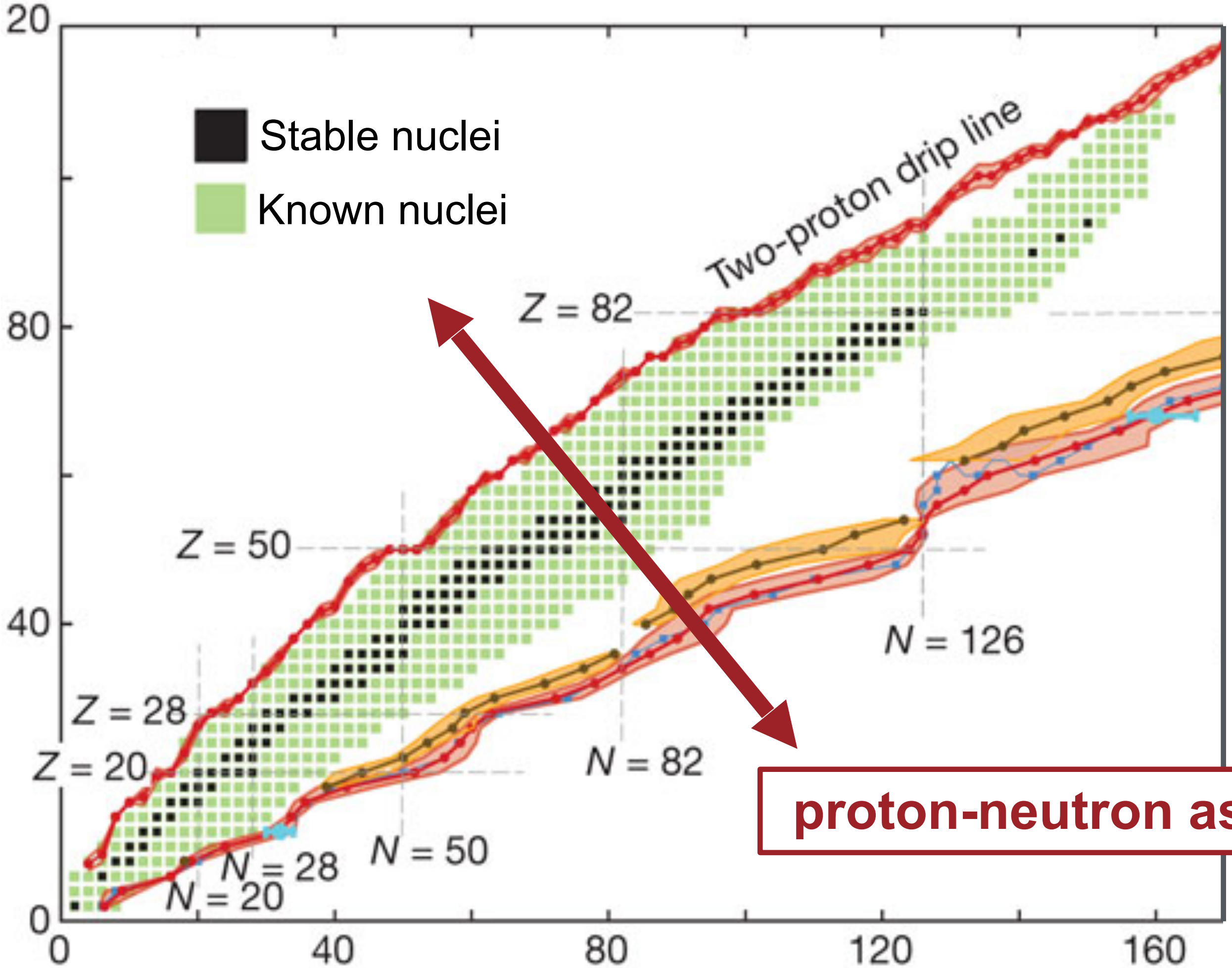
HYDRA, a TPC for hypernuclei studies at R3B

TECHNISCHE UNIVERSITÄT DARMSTADT

Alexandre Obertelli
TU Darmstadt

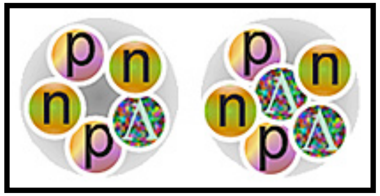
Seminar on R3B-related detector developments, October 20th , 2020

Hypernuclei physics at R3B



proton-neutron asymmetry

hypernuclei



Lifetime against weak decay: about **200 ps**

Hypernuclei physics at R3B

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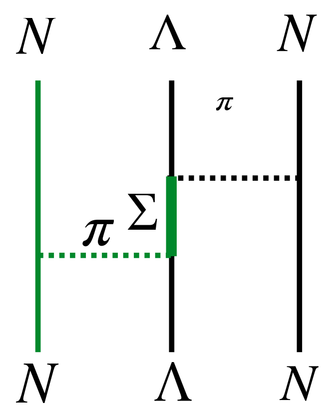
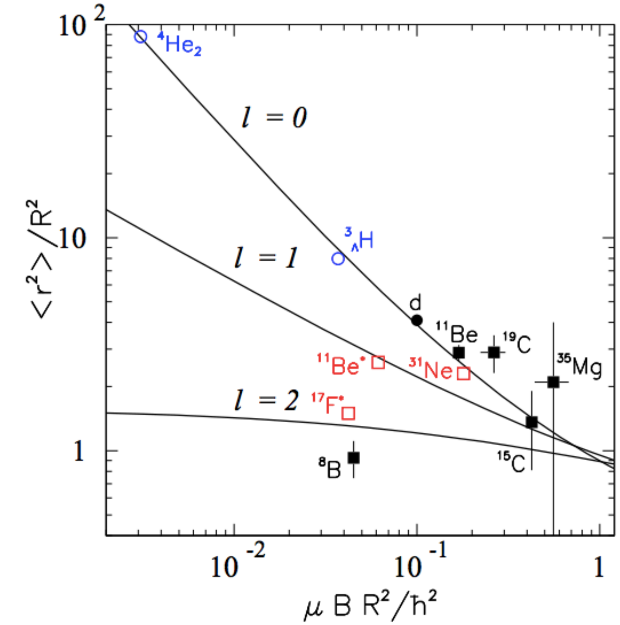
1) Unified understanding of Baryon-Baryon interactions and baryonic bound systems
   - from *u,d* to *u,s,d*

2) Medium effects
   - **three-body forces**
   - in-medium properties of hyperons

3) Many body effects
   - change of size
   - deformation
   - clustering
   - existence of **hyperhalos**

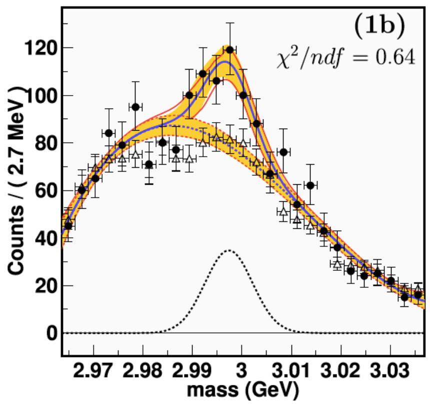


K. Riisager, Phys. Scr. T 152 (2012)



Context at GSI and R3B added value

- **GSI / FAIR one of the few facilities to produce hypernuclei from HI collisions**
- Heavy ion collisions at E > 2 GeV/nucleon, **NN -> Λ K N (thr.: 1.6 GeV)**
- Pioneering work by T. Saito (GSI) / proof of principle performed with HYPHI0, GSI
- Accepted experiment at FRS / WASA (T. Saito, 2017 and 2020 G-PACs)



HyPHI collaboration,
Nucl. Phys. A **913**, 170 (2013)

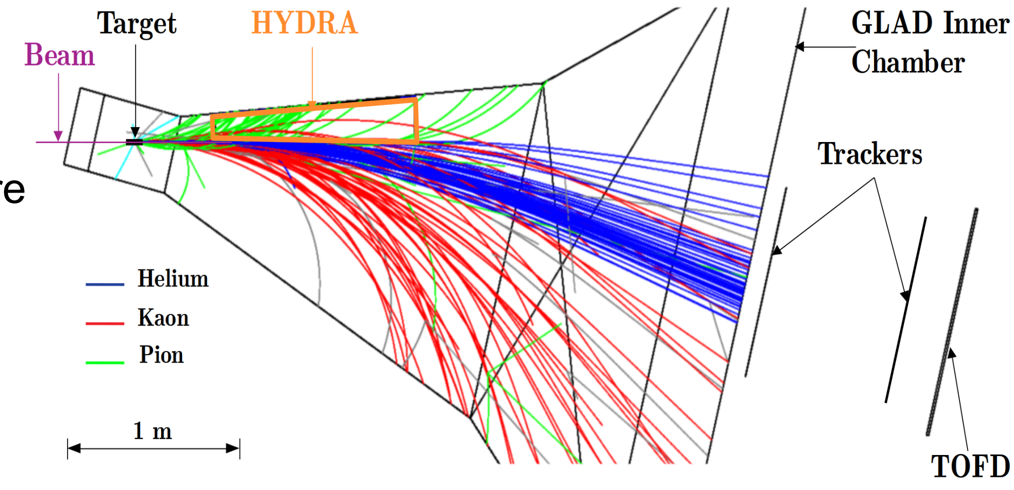
Advantages of HYDRA at R3B (see next slides):
- RIB selected from (Super-)FRS
- improved resolution (< 1.5 MeV sigma)
- improved signal over background
- GLAD: large acceptance spectrometer
- neutron detection
- « simple » addition to R3B standard setup

Challenges:
- number of channels (> 30,000)
- multiplicity of tracks
- space charge effects
- non homogeneity of GLAD magnetic field

HYDRA concept

❑ B-field of GLAD allows:

• separation of π^- from beam and ions
• « zero » straggling tracking
• high-resolution momentum from curvature

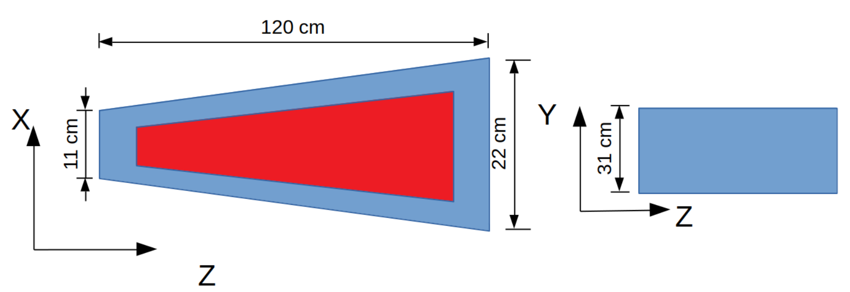


❑ Dimensions

- X→ short base 11 cm
- X→ long base 22 cm,
- Y→ height 31cm,
- Z→ long 120 cm.

❑ Position

- Distance between the GLAD
- entrance and the short base is
- 90 cm (along the beam
- direction (Z))



❑ Pion detection efficiency:30%

Simulations: S. Velardita, TUDa

Main challenges

- ❑ GLAD magnetic field is **not homogeneous**

- ❑ Missing mass at 1.9 GeV/nucleon requires very high resolution
- ❑ Pion emission over 200 ps corresponds to 500 mm of flight distance
- ➡ **large number of electronics channels** with « efficient » energy range and resolution

- ❑ high beam intensity leads to **high counting rate** in TPC, and space charge effects

- ❑ pions are near MIP: **low-threshold electronics** is needed

- ❑ trigger selection

Space charge effects

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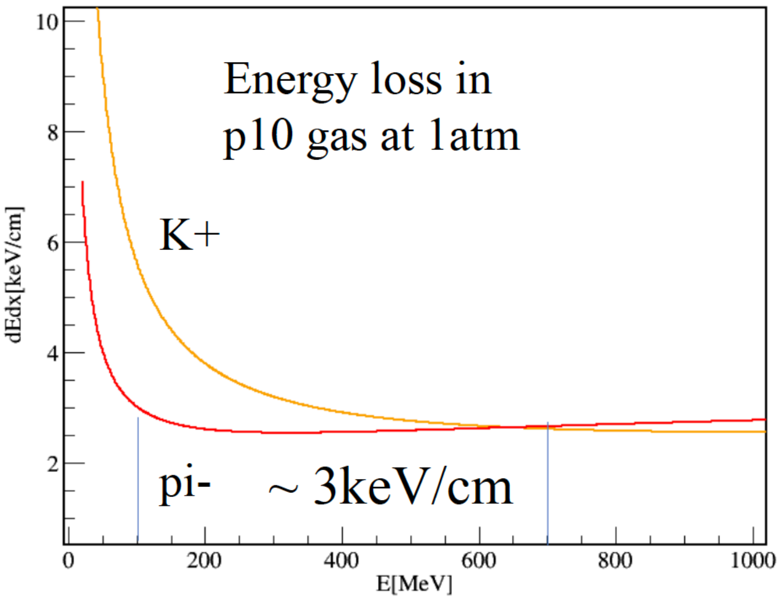
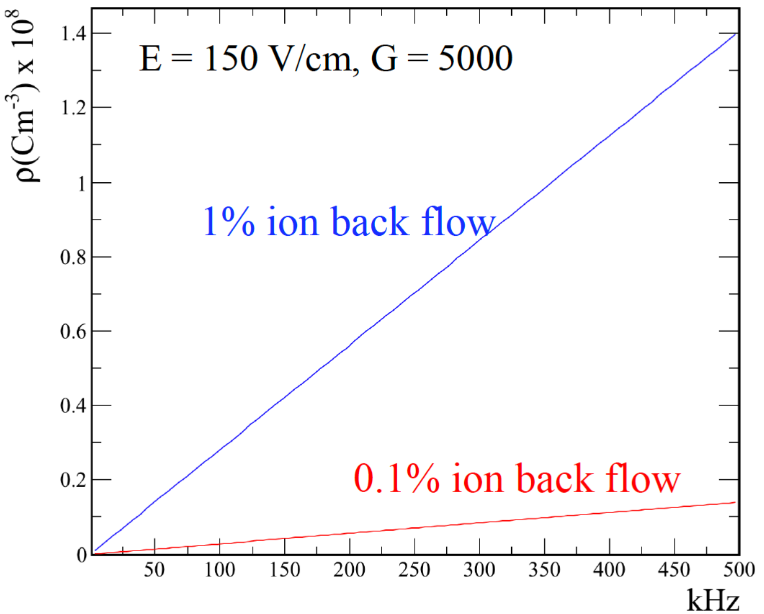


~100 electron-ion pair /cm



- estimated background rate in HYDRA: 200 kHz for 10^6 Hz beam and 50-mm thick target
- pions: 50 kHz, protons:130 kHz
- solution: GEM + Micromegas for the amplification (IBF of 0.2% for gain of 5000)

  Zhang et al., Chinese Phys. C 41, 056003 (2017)

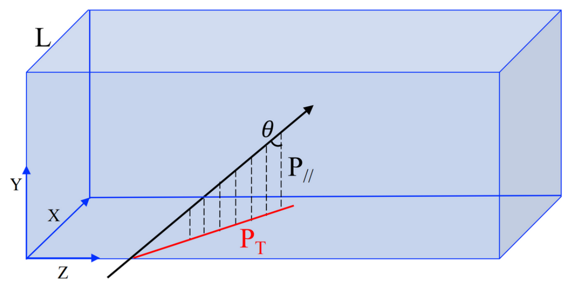
Resolutions

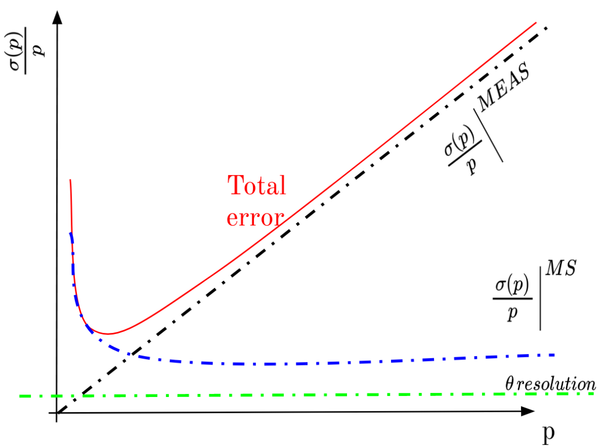
Pad size

$$\left(\frac{\sigma_p}{p}\right)^2 = \left(\sqrt{\frac{720}{N+4}}\,\frac{\sigma_x p\,\sin\theta}{0.3\,B\,L^2}\right)^2 + \left(\frac{0.2}{\beta B\sqrt{L\,X_0}}\left[1+0.038\ln\left(\frac{L}{X_0}\right)\right]\right)^2$$

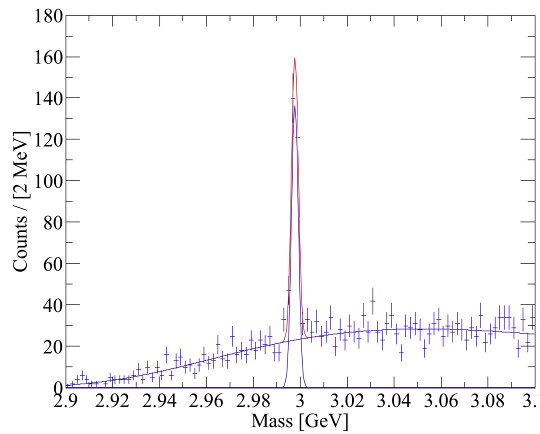
$$+(\cot\theta\sigma_\theta)^2$$

Multiple scattering

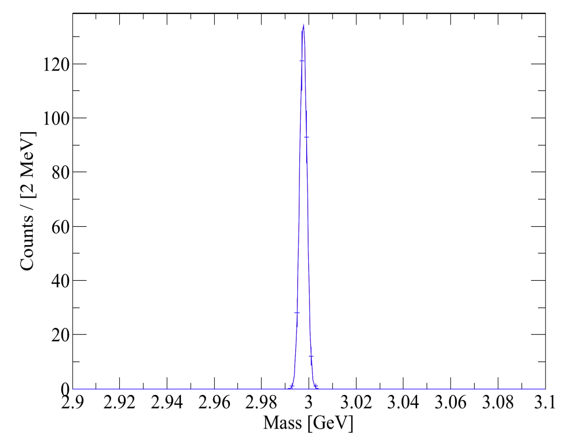




Z > 50 mm with 10 mm vertex resolution



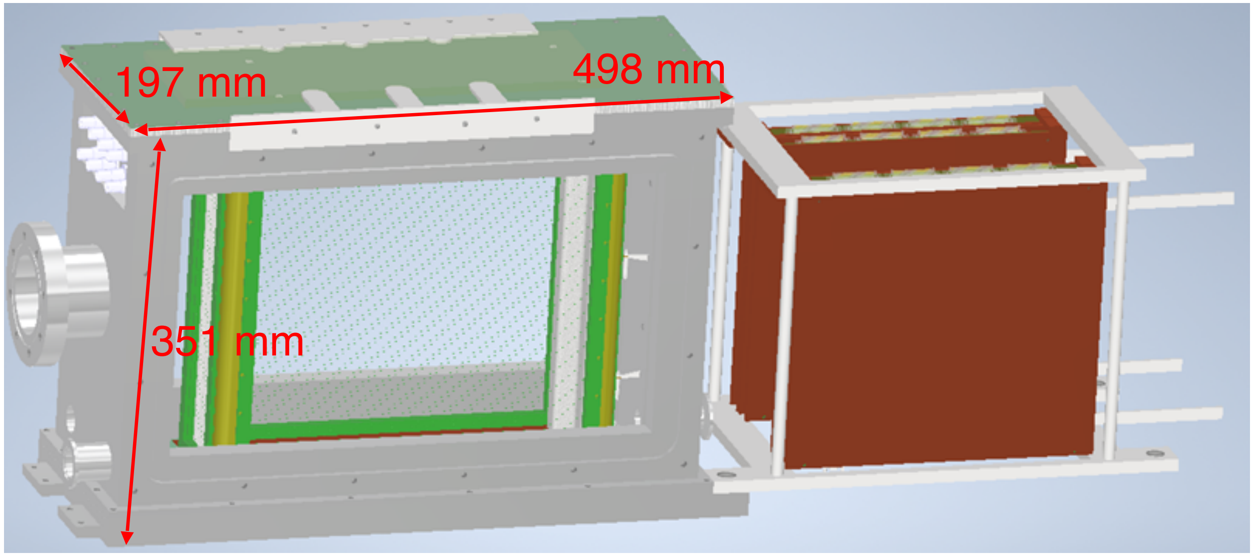
Z > 50 mm with 5 mm vertex resolution



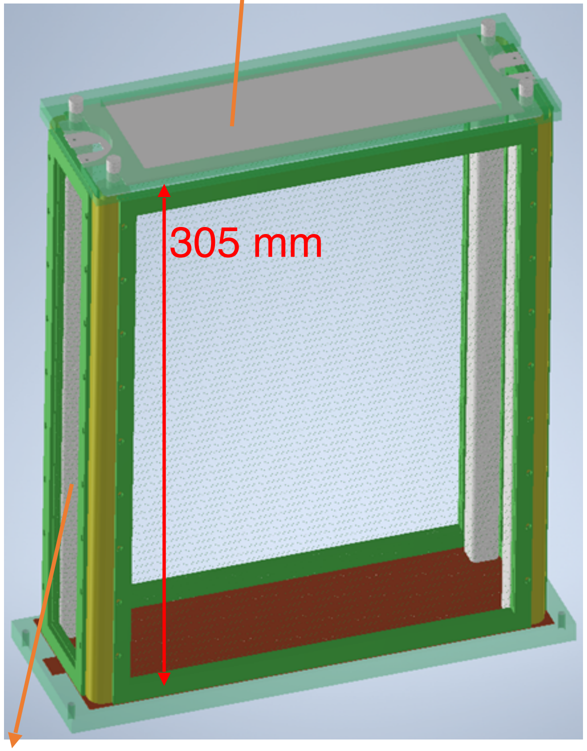
Simulations: Y. Sun and S. Velardita, TUDa

The prototype TPC

- Thin (50-100 microns) Mylar entrance window
- Slight over pressure foreseen (1.1 atm)
- Active region: 300 mm of drift, 100 mm wide, 300 mm long
- double wire field cage
- Integrated laser system (see next)
- GEM + Micromegas amplification
- adaptable electronics scheme



GEM



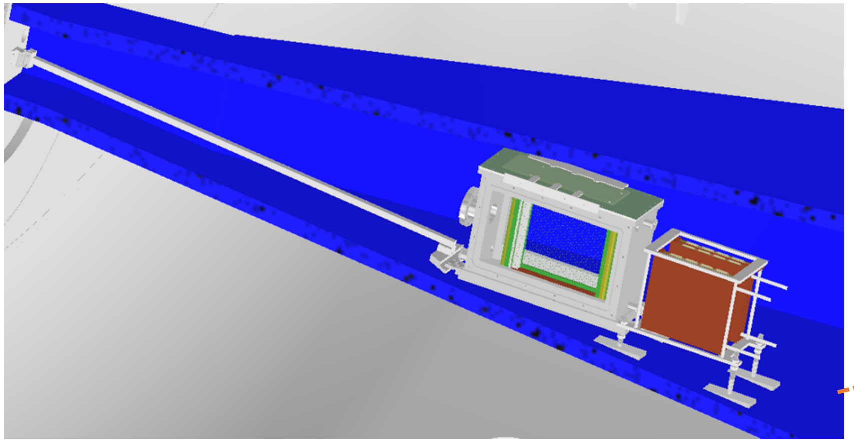
Field cage: double layers

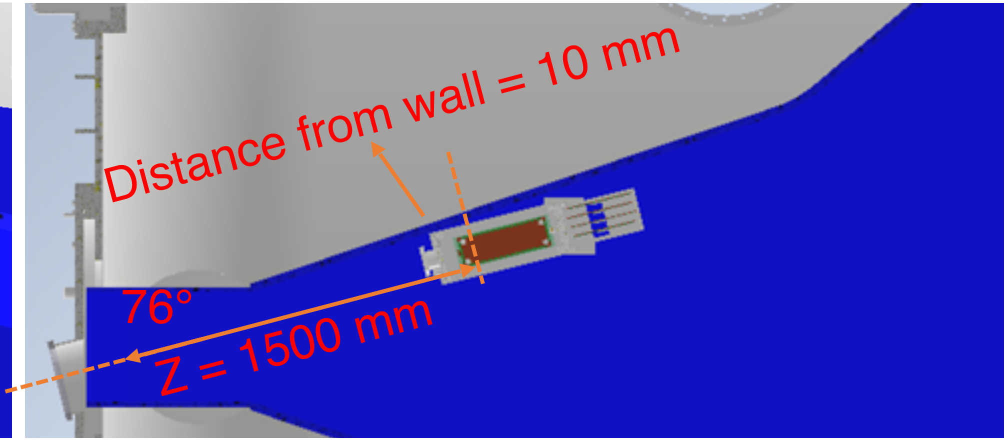
Design: L. Ji, TUDa, in collaboration with: S. Ota, CNS, Univ. of Tokyo

The prototype TPC

- positioning method in discussion
- prototype construction to be submitted to workshop in November 2020
- window and field cage under design
- front-end electronics received, back-end still under discussion
- laser system ordered, first micro-mirrors received
- pad plane ordered / under construction

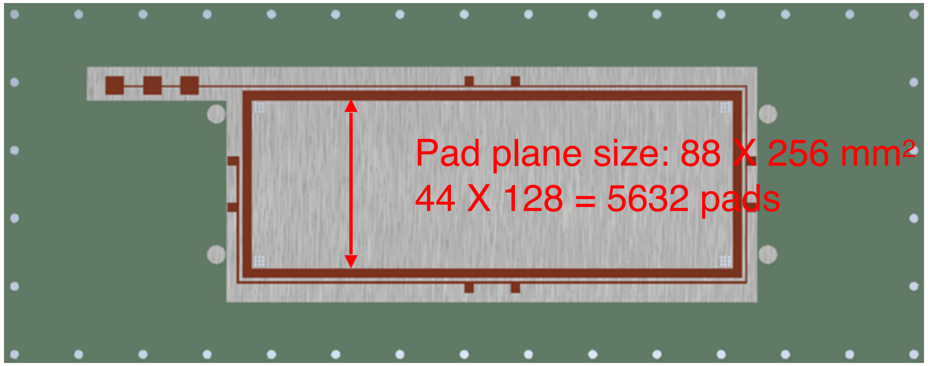
- DAQ under discussion
- Simulations ongoing



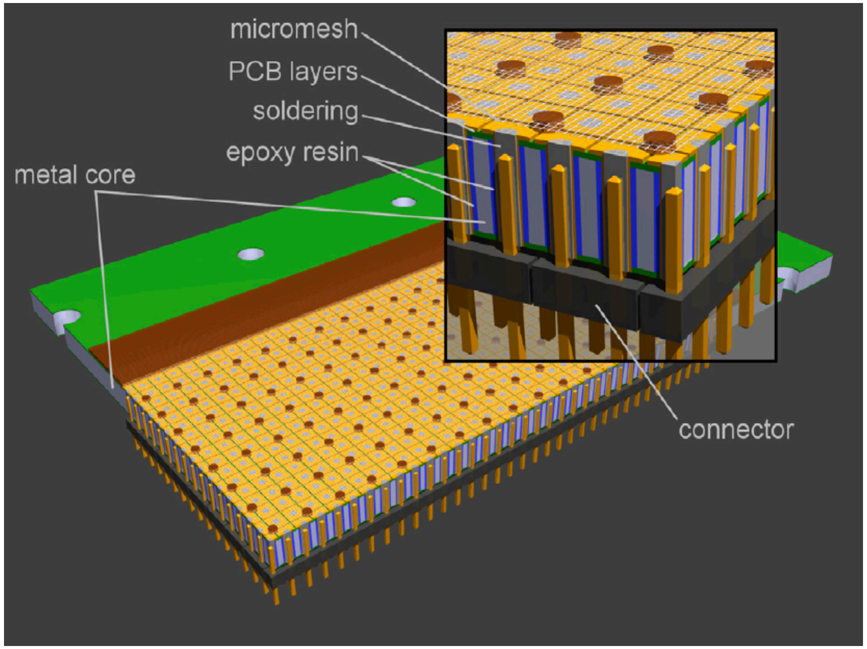


Metal-core pad plane

- 7-mm thick Al metal core (plate)
- the detector is the lid of the vacuum chamber
- mechanical strength allows over pressures
- Micromegas built at CERN (R. de Oliveira)
- resistive Micromegas (improved resolution)



Metal-core pad-plane development for ACTAR TPC
J. Giovinazzo et al., NIMA 892, 114 (2018)

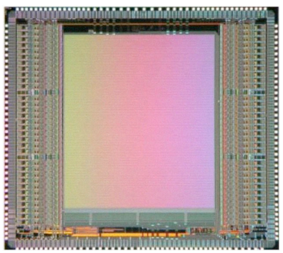


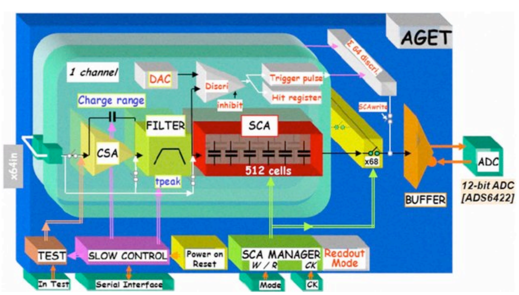
Assistance and design from J. Pibernat, CENBG, IN2P3

Prototype electronics

- AGET chip
- ASAD FE card
- ZAP protection cards
- zCoBo backend from Warsaw university (M. Cwiok, M. Zaremba)

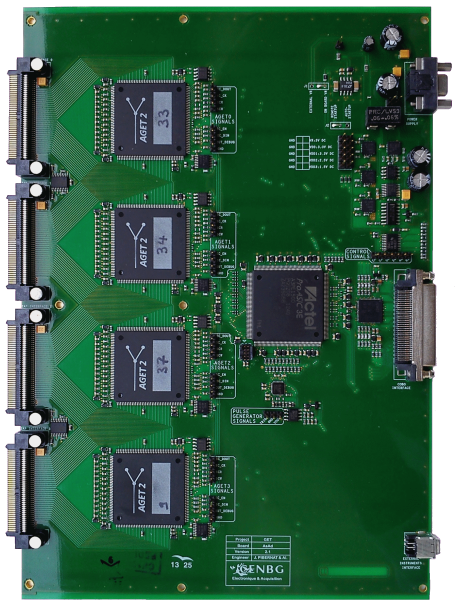
64 channels
512 SCA, 12 bit ADC





AGET

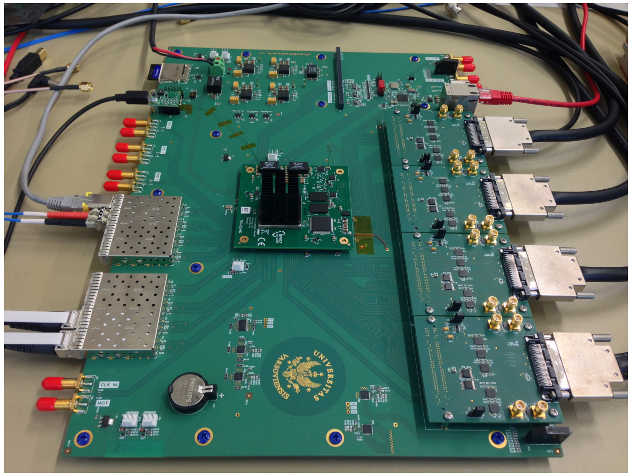
4 AGET, i.e. 256 channels



ASAD

Courtesy: F. Druillole, CENBG

Max 4 ASAD, i.e. 1024 channels

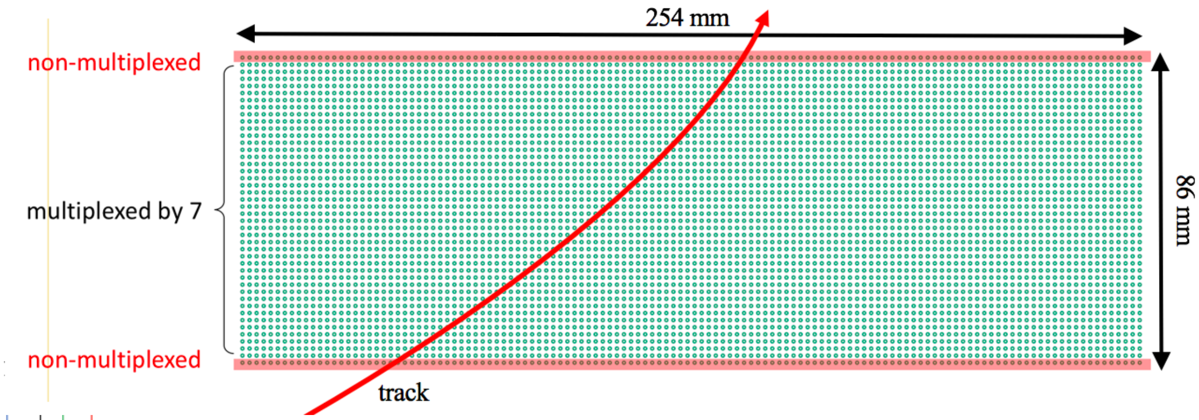


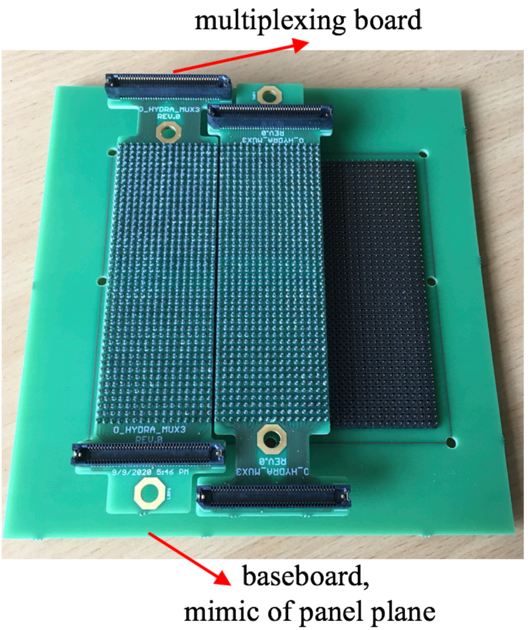
zCoBo

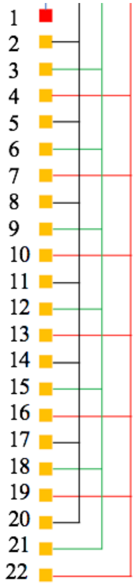
Courtesy: M. Cwiok, Warsaw

Prototype electronics

2mm x 2mm pad







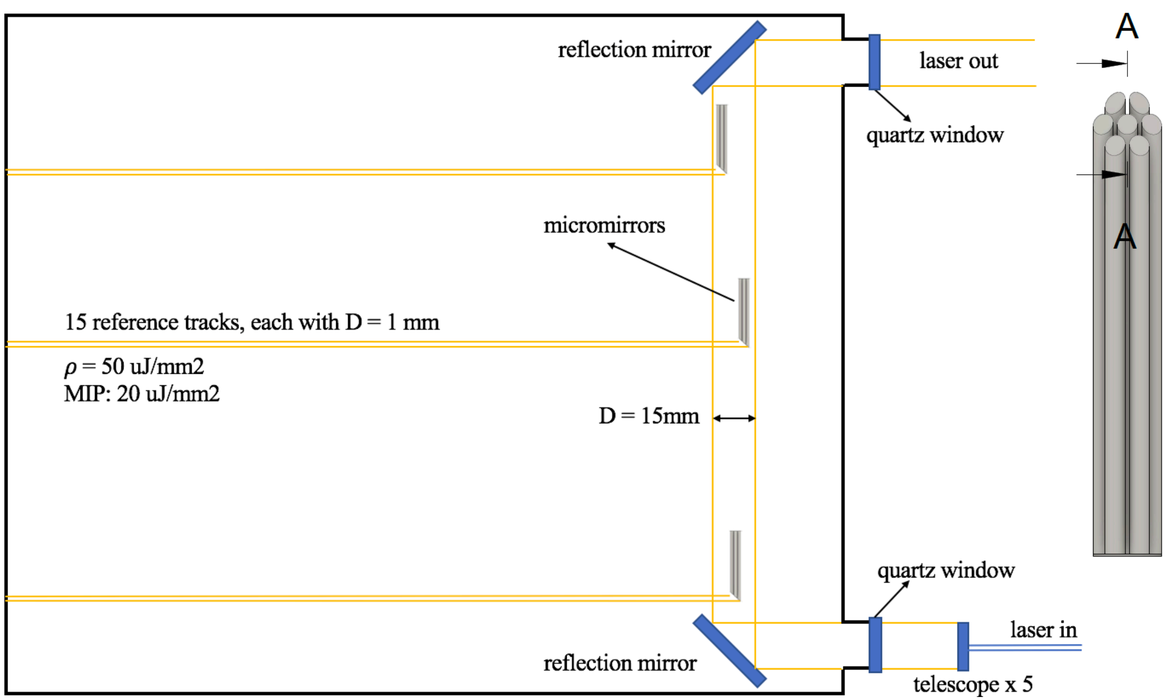
Data: pad plane →multiplexing board→AGET→zCoBo

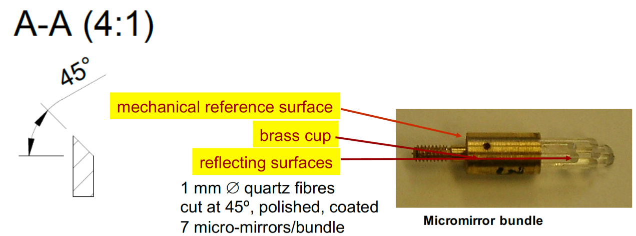
- ❑ Multiplexing factor F = 7
- ❑ reduce the readout channels from 5632 to 1024
- ❑ First and last rows readout directly to solve the ambiguity

Multiplexing scheme: Y. Sun, TUDa
PCB design: U. Bonnes, TUDa

Laser system for reference tracks

- Integrated laser system for reference tracks : two-step ionisation (266 nm) from gas impurities
- Concept from STAR and ALICE experiments

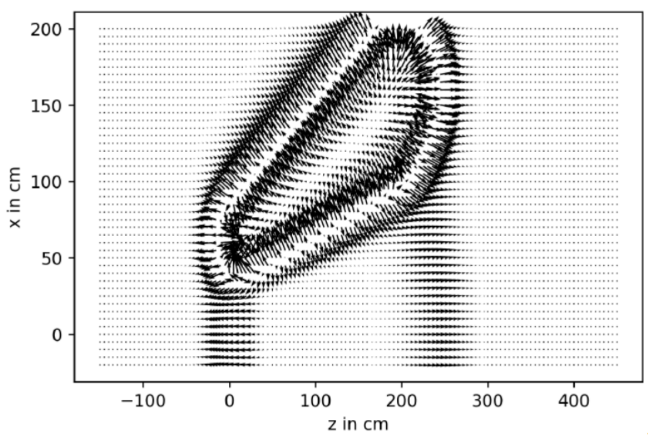


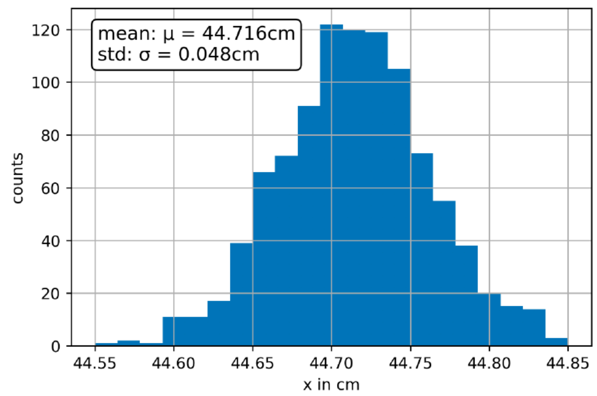


Laser source: 266nm, 20Hz, 9mJ
HFHF funding

Support from A. Lebedev (STAR collaboration)

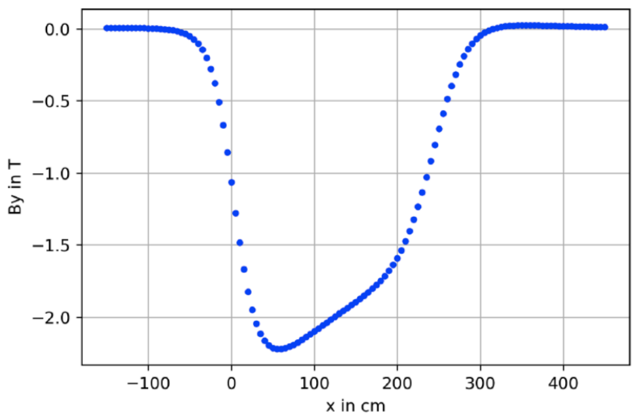
Drift in non-uniform magnetic field





Drift of 1000 electrons in GLAD (Garfield simulation)

$B = (0.011, -1.678, 0.098)$ in Tesla at point (45, 10, 190)



- ❑ E × B deviate the drift of electrons from straight trajectories
- ➢ Methods under development to restore the original 3D track
- ➢ Analyze reference tracks by the laser

- ❑ Non-hom. B field will deviate a track from a helical trajectory
- ➢ Develop specific tool for the track fitting (Ref. Kalman filter track fit tools: GenFit / KalTest)
- ❑ Several groups from R3B involved in this problematics

Options for HYDRA electronics

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Still open. The main point to address. [also from discussion with B. Lörher]

❑ **Evolution of zCoBo or ASAD** to > 1024 channels (GET not available anymore)
- Advantage: ongoing development. Available in 1 year.
- Limitation: acquisition rate limited to 1 kHz.

❑ ALICE 02 framework + **SAMPA asic + GBT output**
- Advantages: High rates. Continuous flow. Low noise. Compact.
- Limitation: 32 channels / asic. No experience within the collaboration.

❑ **STS xyter**
- Advantages: High rates. Continuous flow. Low noise. Compact.
- Limitation: ADC of 5 bits would lead to a loss of position resolution.

❑ **n-xyter**
- Advantages: High rates. Continuous flow. Low noise. Compact.
- Attempt to use the nxyter for GEM TPC (Super-FRS) aborted?

❑ **TRB3** based electronics
- Advantage: high rates. time resolution. Possibility of ADC.
- Limitation: need for front-end (pre-amplifier) on TPC. Prohibitive cabling.

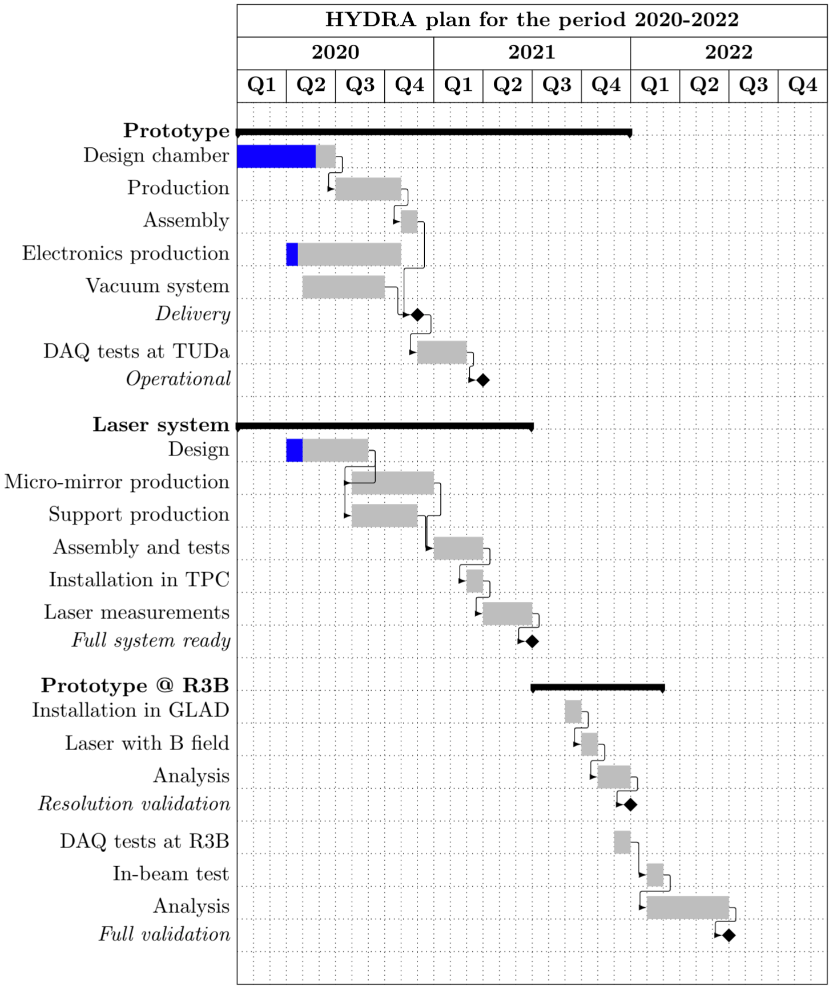
Letter of intent (GPAC 2020)

Hypernuclei studies at R^3B with HYDRA
Letter of Intent, G-PAC, 2020

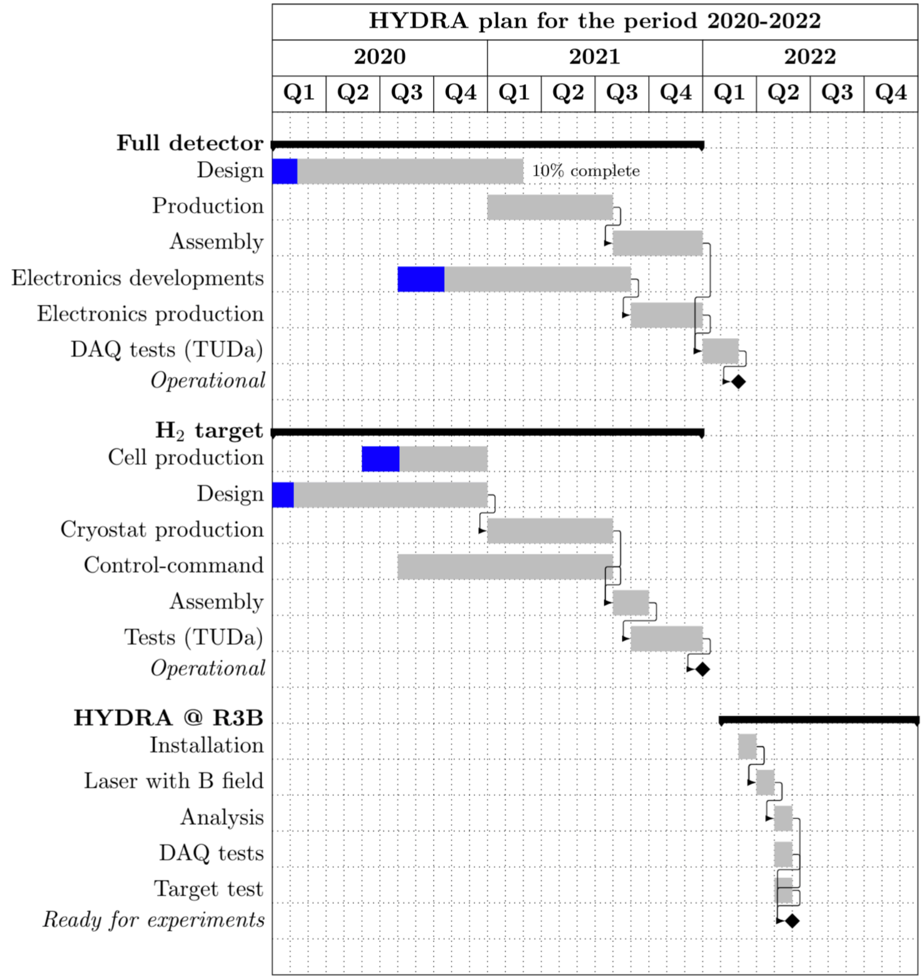
H. Alvarez-Pol,[11] T. Aumann,[5] J. Benlliure,[11] M. Bleicher,[7] A. Botvina,[7], A. Corsi,[8] D. Cortina-Gil,[11] H. Ekawa,[4] L. Fabbietti,[10] R. Gernhaüser,[10] L. Ji,[5] D. Körper,[3] T. Kröll,[5] M. Nakagawa,[4] S. Ota,[1] A. Obertelli,[5] E. C. Pollacco,[8] C. Rappold,[6] J. L. Rodriguez,[11] D. Rossi,[5] R. Roth,[5] T. R. Saito,[4,9,3] H. Scheit,[5] H. Simon,[3] Y. L. Sun,[5] O. Tengblad,[6] S. Velardita,[5] F. Wienholtz,[5] R. Wirth,[2] S. Zacarias,[5] and the R^3B collaboration

[1]Center for Nuclear Studies (CNS), University of Tokyo, Japan
[2]Facility for Rare Isotope Beams, Michigan State University, USA
[3]GSI Helmholtzzentrum für Schwerionenforschung, Germany
[4]High Energy Nuclear Physics Laboratory, Cluster for Pioneering Research, RIKEN, Japan
[5]Institut für Kernphysik, Technische Universität Darmstadt, Germany
[6]Instituto de Estructura de la Materia, CSIC, Spain
[7]Institut für Theoretische Physik, J.W. Goethe Universität, Frankfurt am Mainz, Germany
[8] Irfu, CEA Saclay, France
[9]School of Nuclear Science and Technology, Lanzhou University, China
[10]Technische Universität Munchen, Germany
[11] Universidade de Santiago de Compostela, Spain

Agenda



HYDRA plan for the period 2020-2022
2020
2021
2022
Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4
Prototype
Design chamber
Production
Assembly
Electronics production
Vacuum system
Delivery
DAQ tests at TUDa
Operational
Laser system
Design
Micro-mirror production
Support production
Assembly and tests
Installation in TPC
Laser measurements
Full system ready
Prototype @ R3B
Installation in GLAD
Laser with B field
Analysis
Resolution validation
DAQ tests at R3B
In-beam test
Analysis
Full validation



HYDRA plan for the period 2020-2022
2020
2021
2022
Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4
Full detector
Design
10% complete
Production
Assembly
Electronics developments
Electronics production
DAQ tests (TUDa)
Operational
H_2 target
Cell production
Design
Cryostat production
Control-command
Assembly
Tests (TUDa)
Operational
HYDRA @ R3B
Installation
Laser with B field
Analysis
DAQ tests
Target test
Ready for experiments

Open aspects for collaboration

Detector
- R&D on gas detectors: sparking rate, amplification, IBF
- Simulations of space charge effects and effect on position resolution
- Mechanical & electrical design of the full HYDRA TPC (PANDA Prototype TPC)

Electronics
- Proof of principle and characterisation of STS-XYTER for a TPC
- Benchmark for other electronics solutions (TRB3 based)

Note: on the R3B side, the HYDRA development relies on :
Bastian Löher, DAQ and electronics
Valerii Panin, online and tracking
Haik Simon and Daniel Körper, on-site installation

Physics cases
The technology, know-how and electronics for a TPC inside GLAD at R3B could open new physics cases beyond hypernuclei, from turning GLAD into a high-resolution spectrometer to HIC with RIB.