The R^{3}B experiment (at GSI, RIKEN) and FAIR

R^{3}B

FAIR Seminar,

JU & IFJ-PAN Krakow, Poland, 2022-11-25

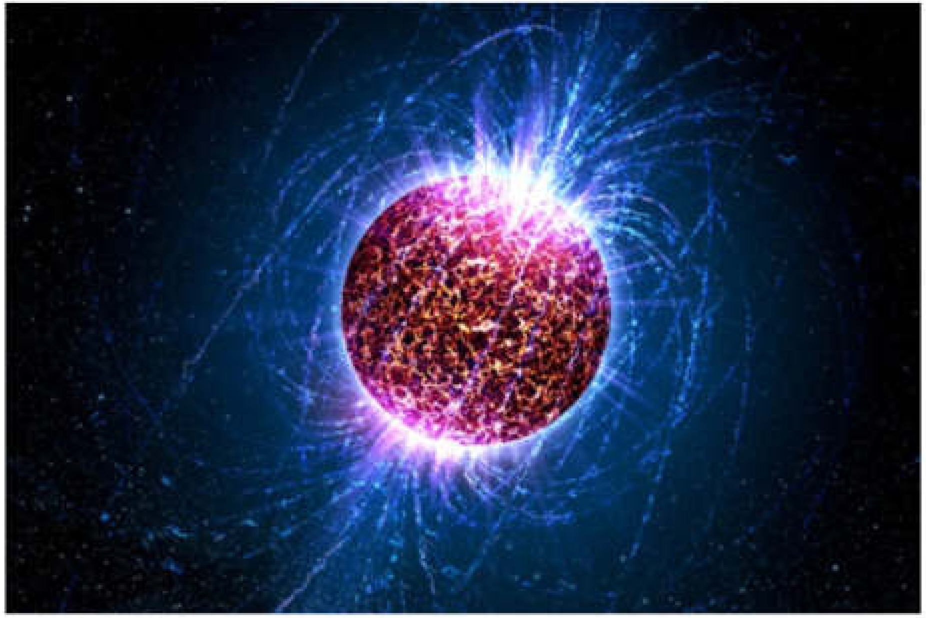
Haik Simon – GSI Darmstadt

Outline

R^{3}B: Reactions with Relativistic Radioactive Beams.

- Versatile Reaction setup with multi particle (gamma) coincidences
- Relativistic energies: internal motion “frozen” (eikonal approx.)
- Radioactive Species: Isospin degree of freedom, exotic systems

- Some R^{3}B physics cases
- R^{3}B experiment an evolving setup
- Enabling technologies
- Evolving to FAIR



An artist's illustration of a neutron star

Casey Reed (Penn State University)/Wikimedia Commons

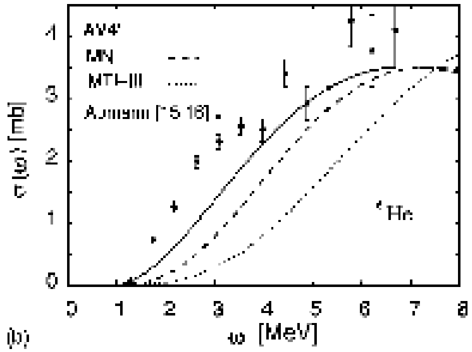
Dipole strength distributions
in neutron-rich nuclei at sizeable energy

GSI

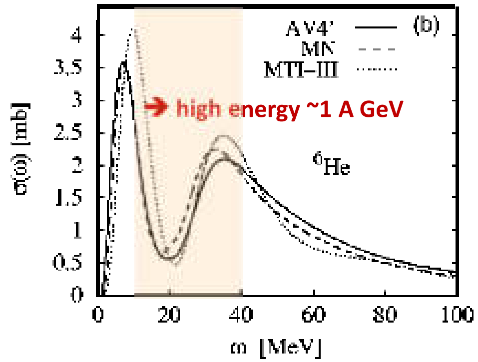
FAIR

Access to the Equation of State in neutron-rich nuclear matter

- Soft E1 excitation in ^{6}He : Core vs. neutron skins & halos → density / asymmetry

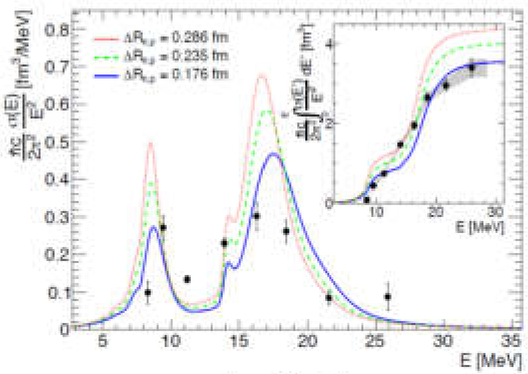


@ 240 A MeV



S. Bacca et al.
PRL **89** (2002) 052502
PRC **69** (2004) 057001

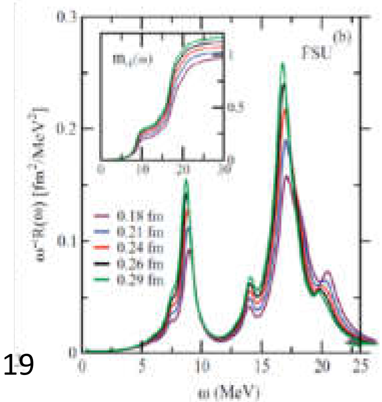
- low lying E1 strength in heavy neutron-rich nuclei (relevant for r-process cross sections)



$$\alpha_D = \frac{\hbar c}{2\pi^2} \int_0^{\infty} \frac{\sigma(E)}{E^2} dE$$

D. Rossi et al.
PRL **111** (2013) 242503

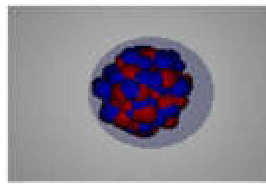
skin thickness **^{68}Ni**
0.175(21) fm

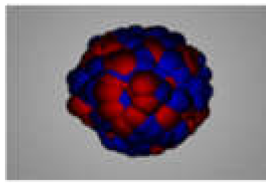


J. Piekarewiczz, PRC **83** (2011) 034319

208+x Pb & N=126 isotones

~1 A GeV →
bare ions
Fragment identification





T. Aumann et al.

EOS via flow or cross section measurements

Nuclear Equation of State (EOS)

EOS for Energy per nucleon

$$\frac{E}{A}(\rho,\delta)=\frac{E}{A}(\rho,0)+S(\rho)\delta^2+\ldots$$

$$\rho(r)=\rho_n(r)+\rho_p(r)$$

$$\delta(r)=\frac{\rho_n(r)-\rho_p(r)}{\rho_n(r)+\rho_p(r)}$$

Symmetry energy

Saturation Density ~0.16 fm^{-3} ρ_0

$$S(\rho)=J+\frac{L}{3\rho_0}(\rho-\rho_0)+\frac{K_{sym}}{18\rho_0^2}(\rho-\rho_0)^2+\ldots$$

Determination of L is becoming important.

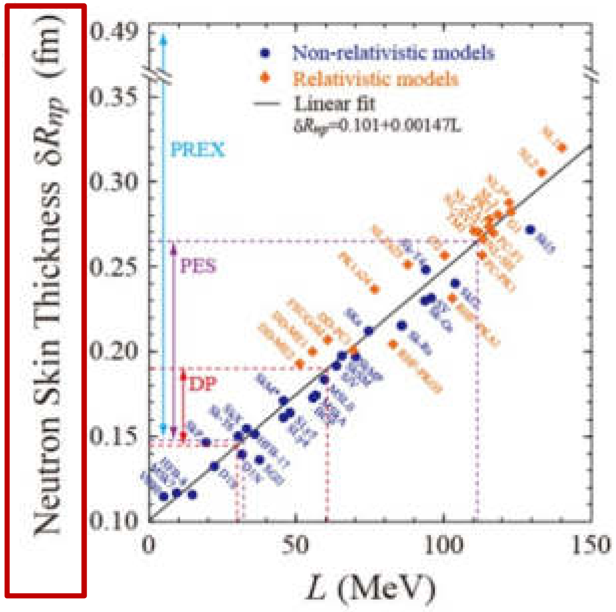
L: Slope Parameter

A. Tami

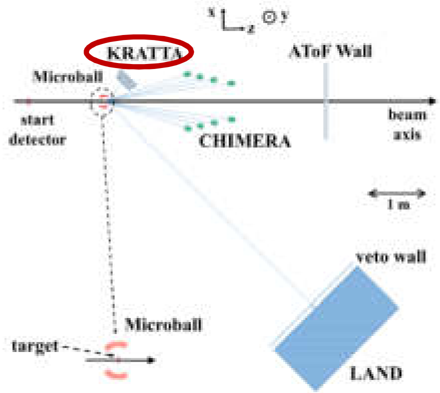
$\alpha_D J$ and L are linear dependend

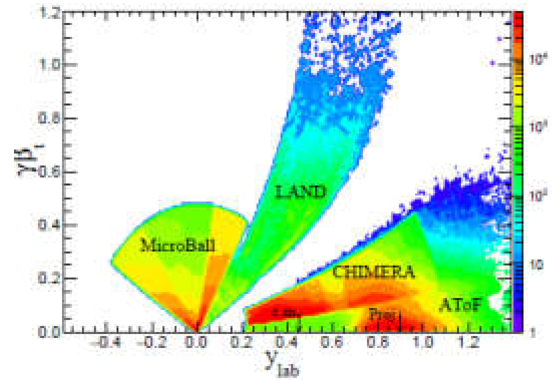
T. Aumann et al.

P. Rusotto et al. ASY-EOS



X. Roca-Maza et al, PRL106, 252501 (2011)

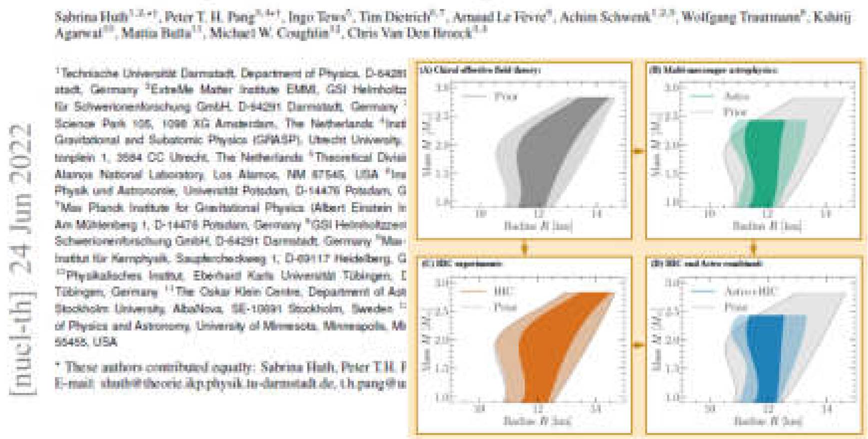




Phys. Rev. C 94, 034608 (2016)

Accepted proposal with improved setup 2023+

S. Huth et al.



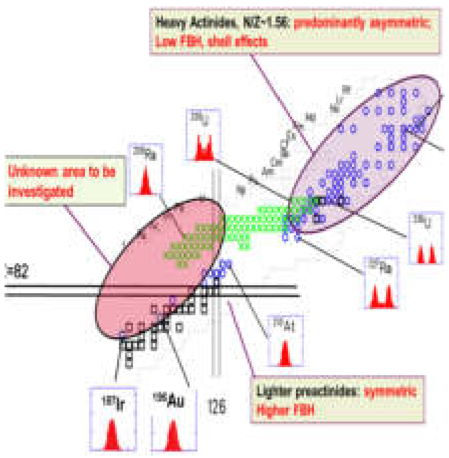
Constraining Neutron-Star Matter with Microscopic and Macroscopic Collisions

[nucl-th] 24 Jun 2022

Fission studies @R3B: detection of both fission fragments

The combination of FAIR beams (High intensity 1.A GeV ^{238}U beam, the worldwide unique production and clean identification of actinides and preactinides) and the R3B setup provide access to new observables to

- Characterize fission yields in the transition between symmetric/asymmetric fission in n-deficient A=180-210 nuclides **Coulex Fission** → E* ~ Coulomb barrier
- Control the temperature dependence of shell effects in the potential-surface energy and energy sharing between fission fragments **(p,2pf)**
  → control the E* from barrier up to 80 MeV
- Determination of Fission barriers N=126 **(p,2pf)**
  → unique possibility to scan E* for short live species



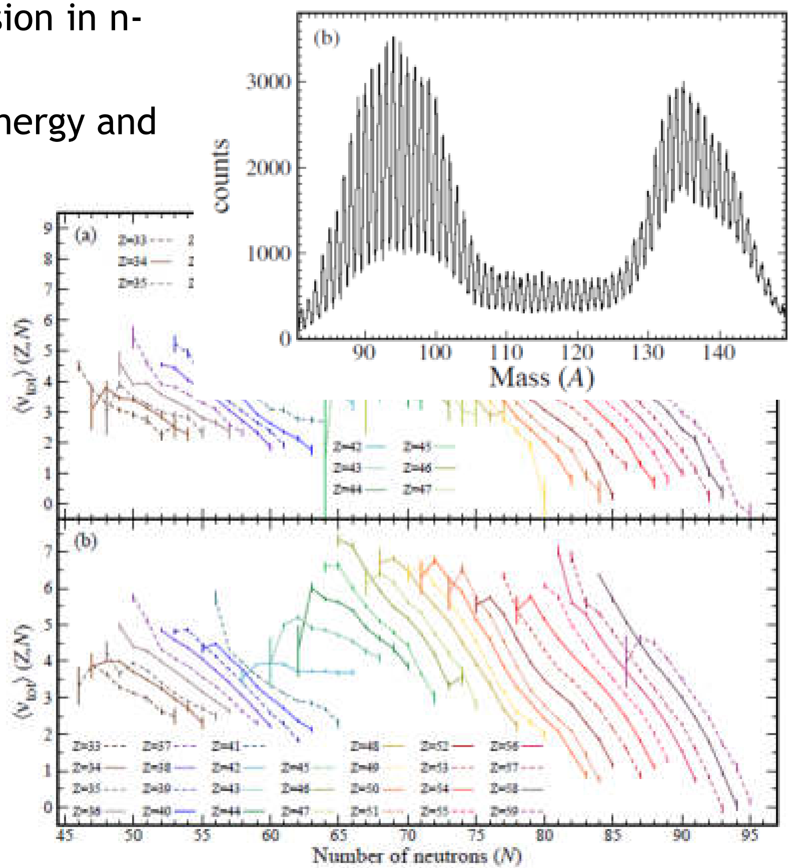
J. Taieb, A. Chatillon et al.

- Fission barriers are important for the description of the r-process. They are expected to evolve with n-excess

→ They also determine the role played by fission in the r-process yields and reaction rates (recycling)

Giuliani, Martinez-Pinedo arXiv 1904.03733

J.-F. Martin *et al.*
Phys. Rev. C 104, 044602 (2022)

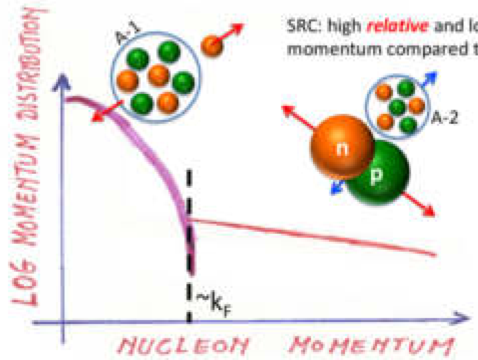


FAIR

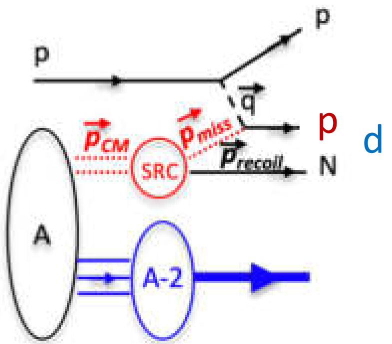
Short Range Correlations in asymmetric matter

Characterization of Short Range correlated pairs of exotic nuclei
Use of inverse kinematics → introduce the isospin depence
Detection of the exotic A-2 Fragment → background supression
Complete kinematics → measure of 4-fold coincidences
Determine the high energy tail of the momentum distribution

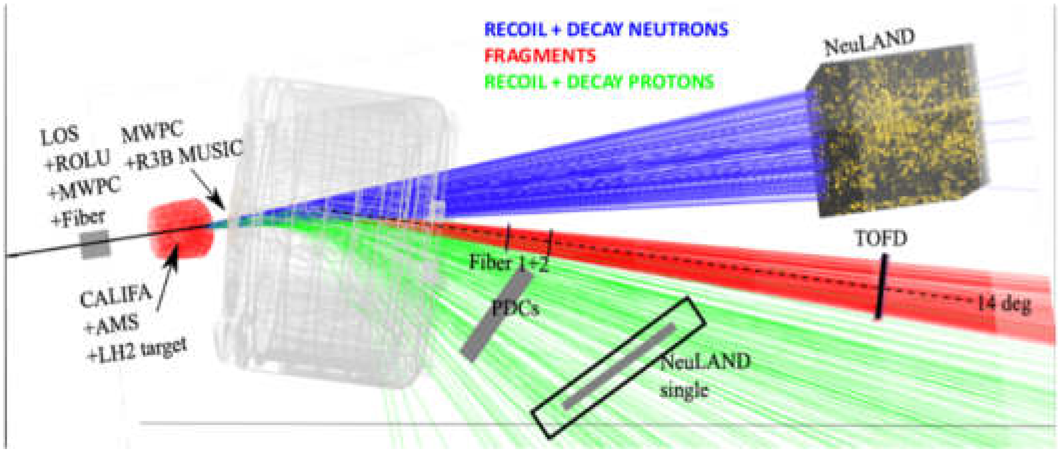
Relevant to carachterize the NN interaction
Complement the single-particle picture of nuclear models



Accepted proposal 2023+



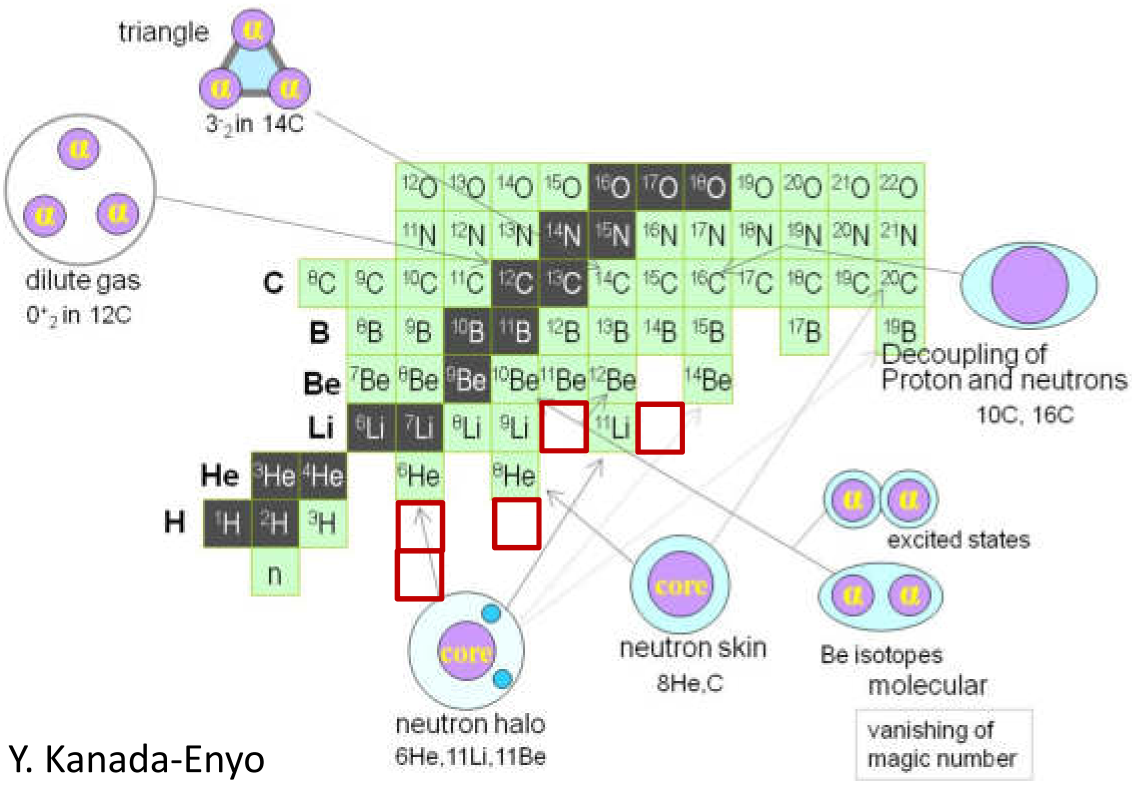
direct access to correlated pairs



The isospin dependence of SRC will have an impact in the Neutron Stars cooling.
The NS crust will present a relative depopulation of p with energies below Fermi level
→ Speed up the star cooling through a modified URCA neutrino cooling process.

A. Corsi, O. Hen et al.
M. Petri et al.

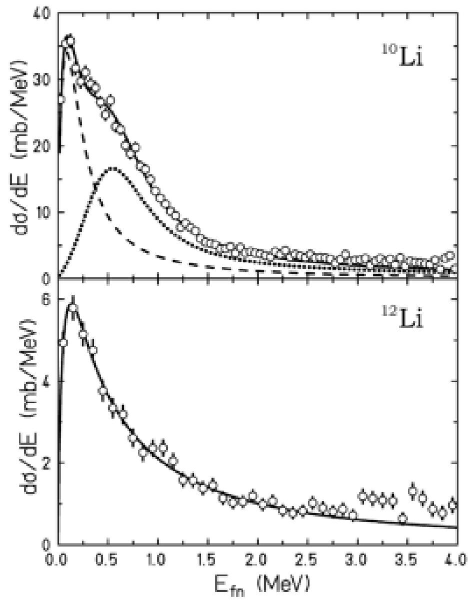
Exotic Nuclei



Y. Kanada-Enyo

O. Tengblad, H.S. et al.

- Production by proton, neutron, … removal
- Particle spectroscopy
  including unbound systems
- Threshold effects coupling to continuum
  (e.g. N. Michel, W. Nazarewicz, M. Płoszajczak
  Phys. Rev. C 75, 031301 ...)



^{11}Li S_{2n}=369(1) keV

Yu. Aksyutina et al
Phys.Lett.B 666 (2008) 430-434

Study the isospin properties of Λ hypernuclei

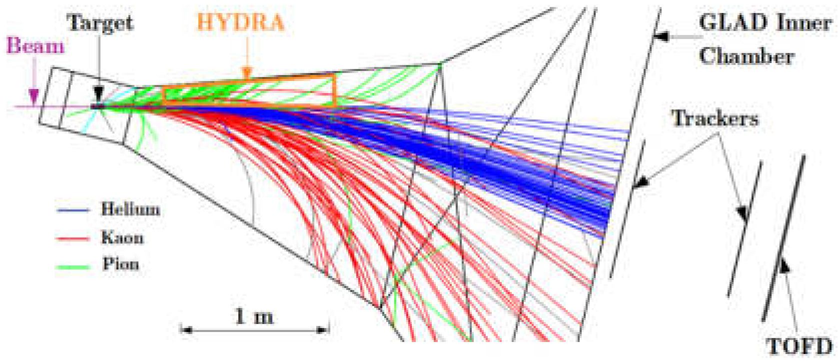
Accepted proposal 2023+

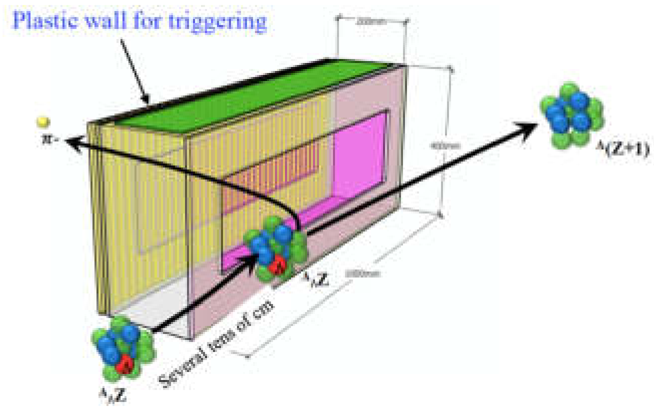
Study of Hyperhalos, determination of binding energies and lifetimes

Program at R3B based on a new high-resolution pion tracker (TPC) , HYDRA, inside GLAD

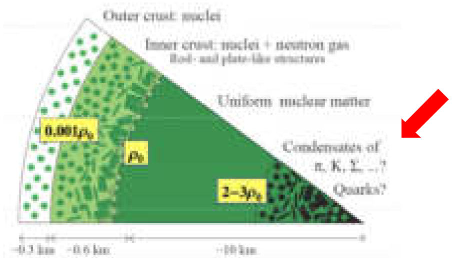
Uniqueness:

Exotic hypernuclei from Heavy Ion collisions (RIB above 1.6 GeV/nucleon) is only possible at GSI/FAIR





The knowledge of EoS in n-rich matter is of interest to understand basic properties of Neutron Stars.
Hypernuclei could be present in the inner part of the NS



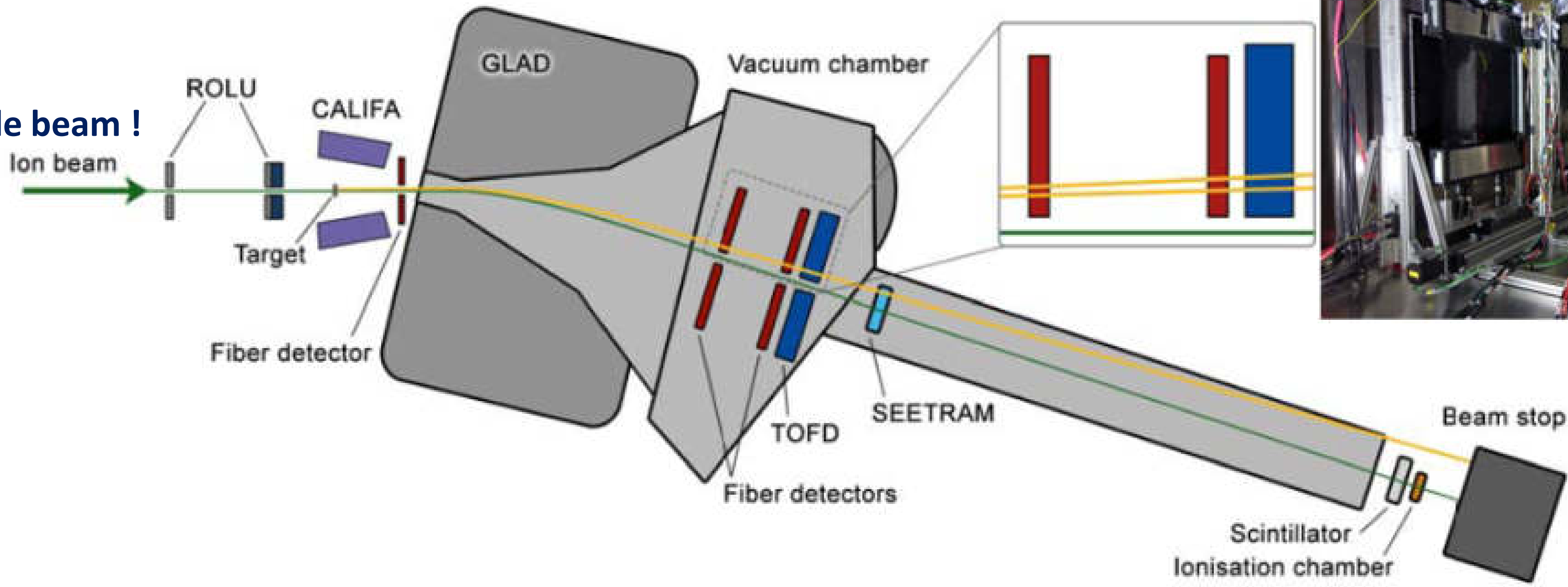
A. Obertelli et al.

$^{12}C(\alpha,\gamma)$ in inverse kinematics

Nuclear Physics in Astrophysics IX (NPA-IX) IOP Publishin
Journal of Physics: Conference Series **1668** (2020) 012016 doi:10.1088/1742-6596/1668/1/01201

Coulomb dissociation of ^{16}O into ^{4}He and ^{12}C

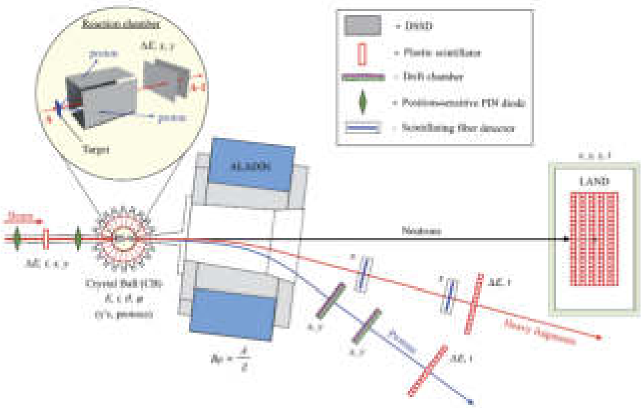
Stable beam !

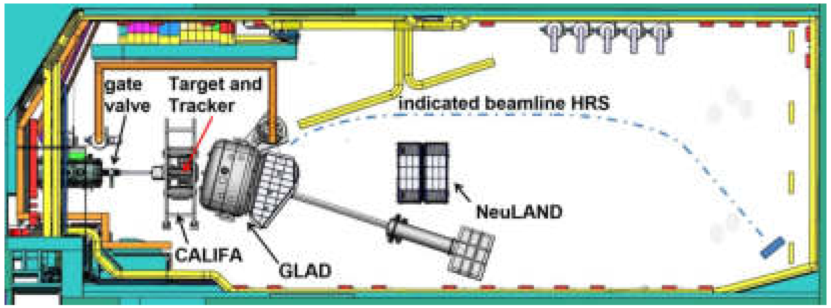


R. Reifarth, K. Göbel, M. Heil et al.

Menu

- From Past experiments (FRS + ALADiN-LAND setup 1990+) to future (Super-FRS – R³B setup)

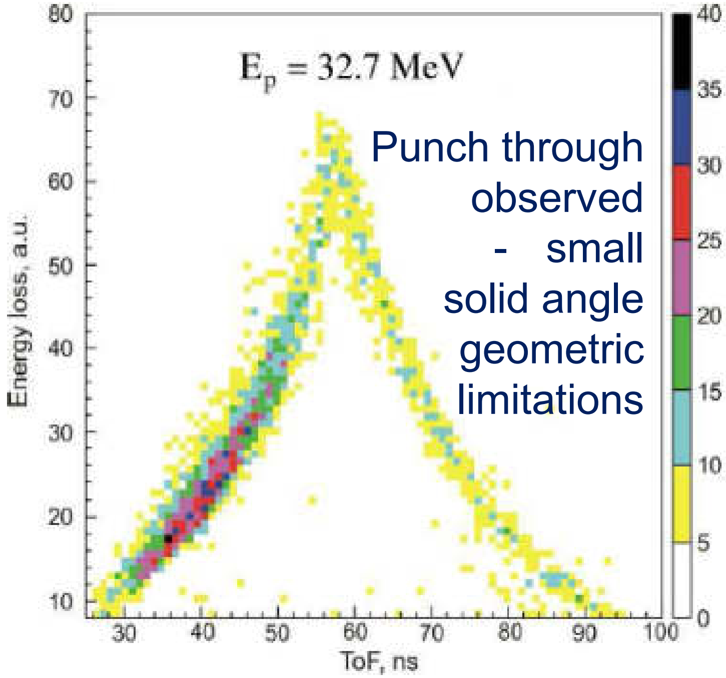




- Evolutionary steps towards R³B setup

Nuclear breakup Reaction studies:
Target dependence C,Be vs. pure p scattering
- first attempts of a proton recoil detection

From diffraction dissociation and „knock-out" to quasi free proton scattering

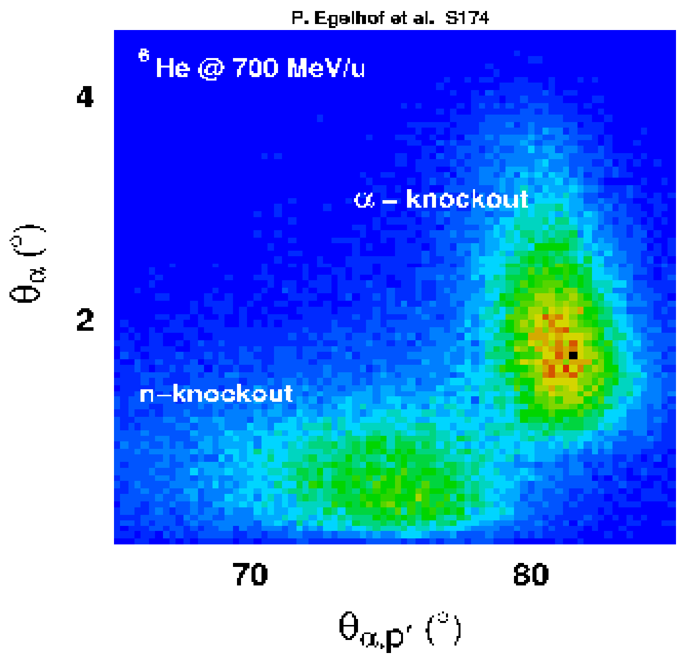


➔ Decision to build a dedicated proton recoil detection system

First attempt during ALADiN/LAND experiment 2001…

Reactions with target recoil detection

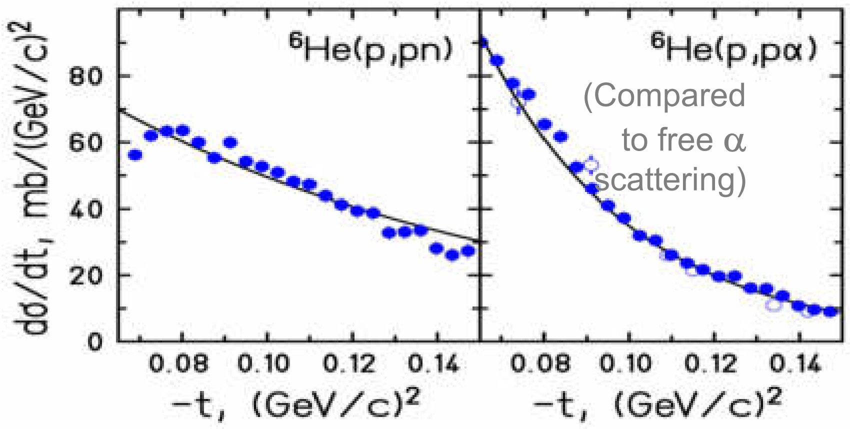
- Active target: IKAR (p,p'f) 10bar hydrogen gas



- Kinematically incomplete
- no gamma detection
- restricted fragment charge

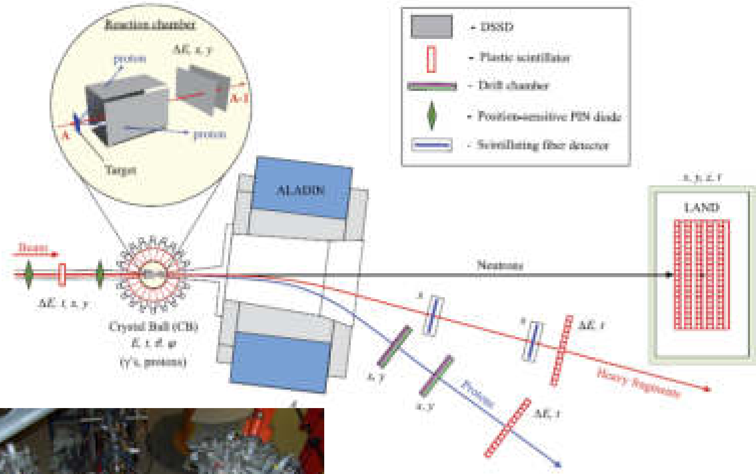
^{6}He: Very simple 2n Halo:
Direct observation of kinematical correlations
- channel can be identified

(Cluster) spectroscopic factors ?



L.V. Chulkov et al., Nucl. Phys. **A759**(2005)43

First ^{12}C(p,2p) experiment @ 400AMeV - „R³B prototype setup"



Physics Letters B 753 (2016) 204–210

Contents lists available at ScienceDirect

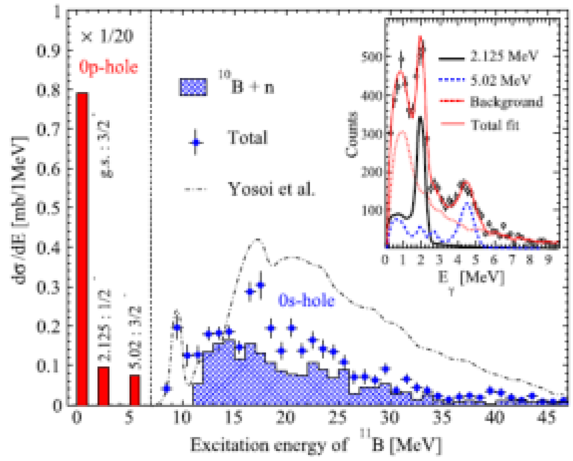
Physics Letters B

www.elsevier.com/locate/physletb

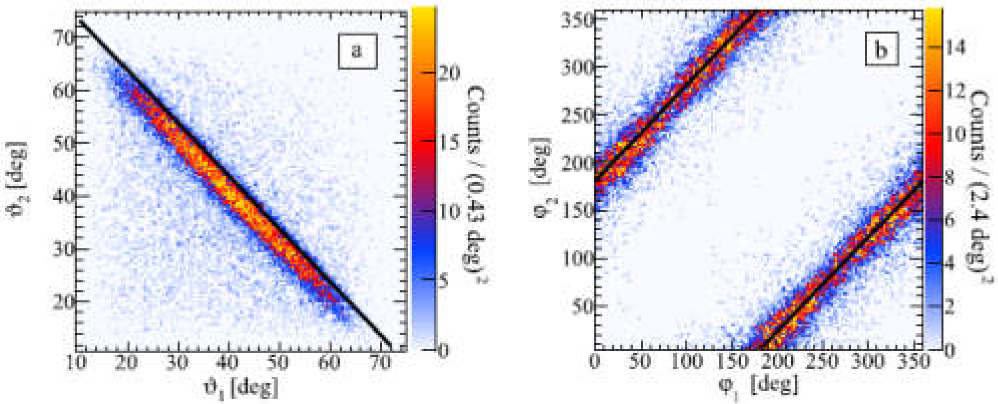
ELSEVIER

Exclusive measurements of quasi-free proton scattering reactions in inverse and complete kinematics

V. Panin, J.T. Taylor, S. Paschalis, F. Wamers, Y. Aksyutina, H. Alvarez-Pol, T. Aumann, C.A. Bertulani, K. Boretzky, C. Caesar, M. Chartier, L.V. Chulkov, D. Cortina-Gil, J. Enders, O. Ershova, H. Geissel, R. Gernhäuser, M. Heil, H.T. Johansson, B. Jonson, A. Kelić-Heil, C. Langer, T. Le Bleis, R. Lemmon, T. Nilsson, M. Petri, R. Plag, R. Reifarth, D. Rossi, H. Scheit, H. Simon, H. Weick, C. Wimmer



V. Panin et al. / Physics Letters B 753 (2016) 204–210



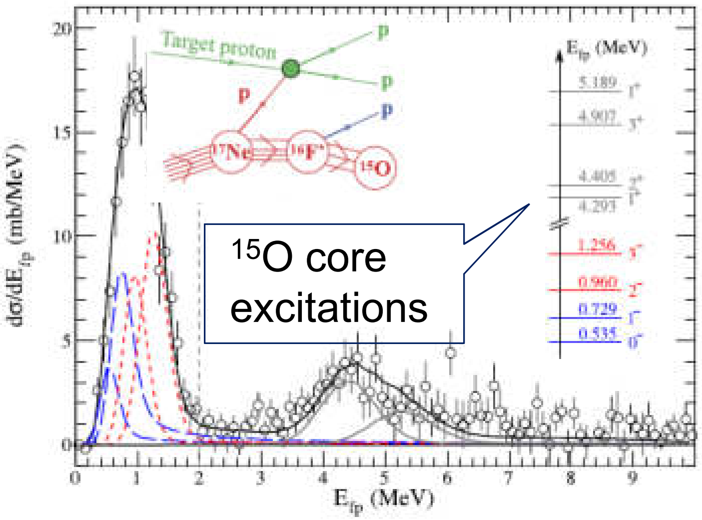
The ^{17}Ne 2p halo quest (@500 AMeV)

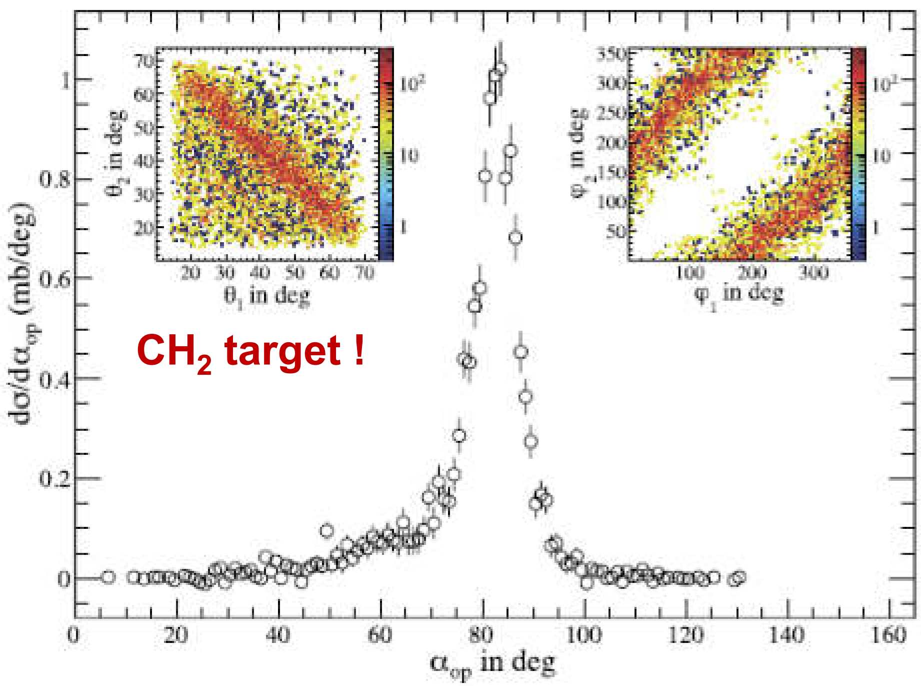
ELSEVIER

Unveiling the two-proton halo character of ^{17}Ne: Exclusive measurement of quasi-free proton-knockout reactions

C. Lehr, F. Wamers, F. Aksouh, Yu. Aksyutina, H. Álvarez-Pol, L. Atar, T. Aumann, S. Beceiro-Novo, C.A. Bertulani, K. Boretzky, M.J.G. Borge, C. Caesar, M. Chartier, A. Chatillon, L.V. Chulkov, D. Cortina-Gil, …

Physics Letters B 827 (2022) 136957

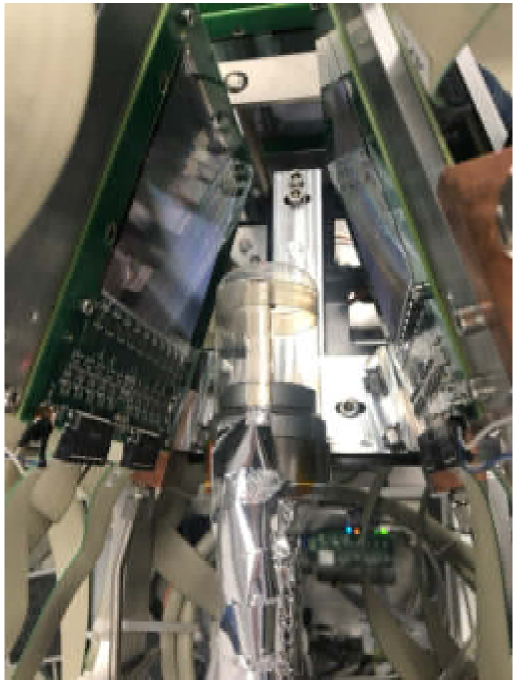




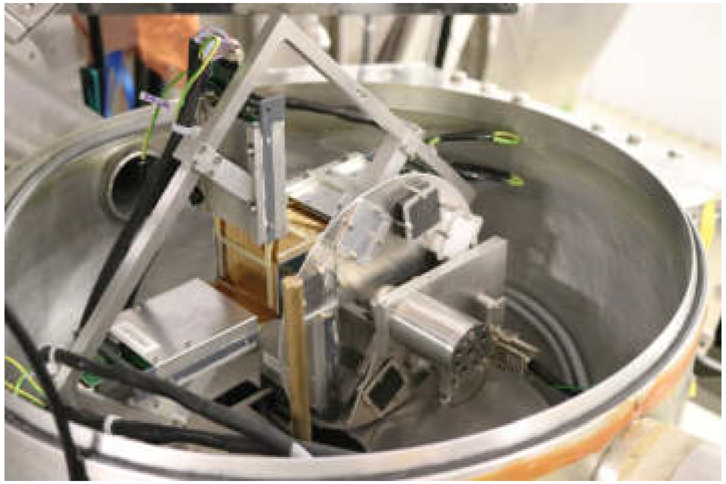
Rather small
2s² - contribution 35(3) %

➔ Suppressed halo

Enabling technologies
- from Space to medical applications



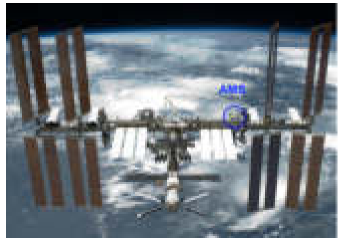
Cocotier LH2 target with
FOOT Si-trackers
as subsystem of the
CALIFA calorimeter



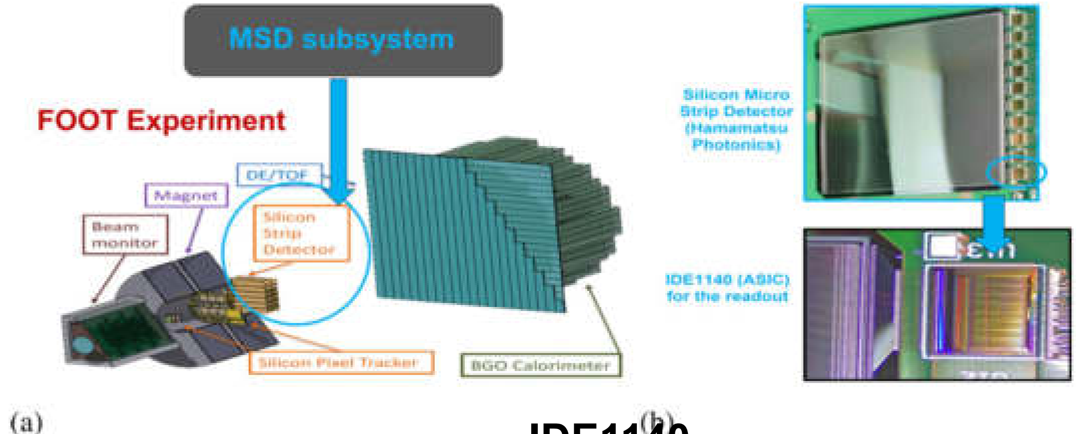
VA64.hdr

AMS-02
Detectors in Vacuum
low power (!)
Box geometry
CH2 target

https://ams02.space/detector/silicon-tracker



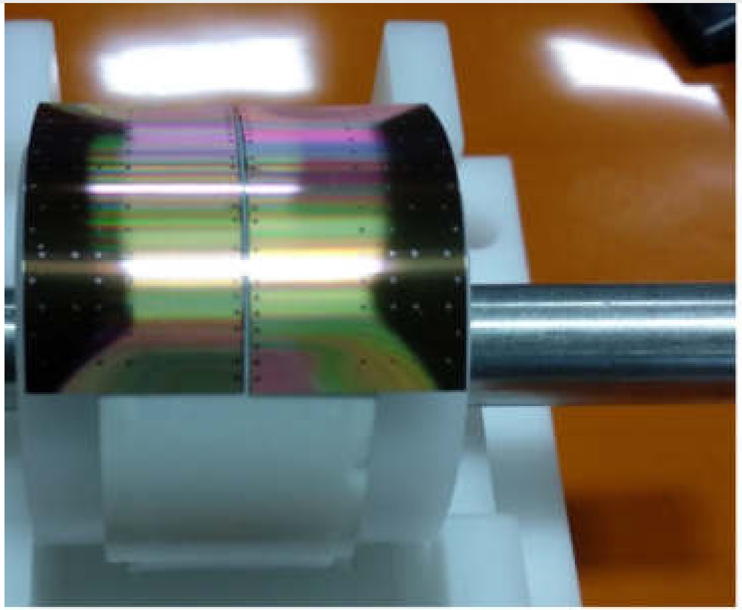
Physics Reports 894 (2021) 1-116



IDE1140

K. Kanxheri *et al* 2022 *JINST* **17** C03035

Enabling technologies
- ALICE Alpide

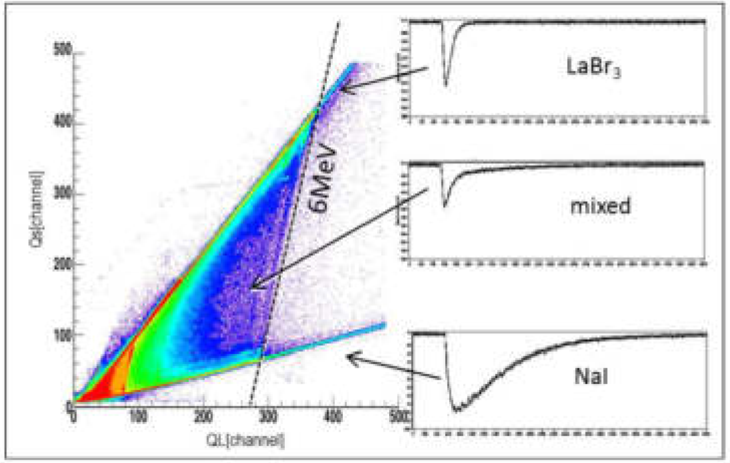


M. Mager | ITS3 | TREDI 2020 | 18.02.2020 |

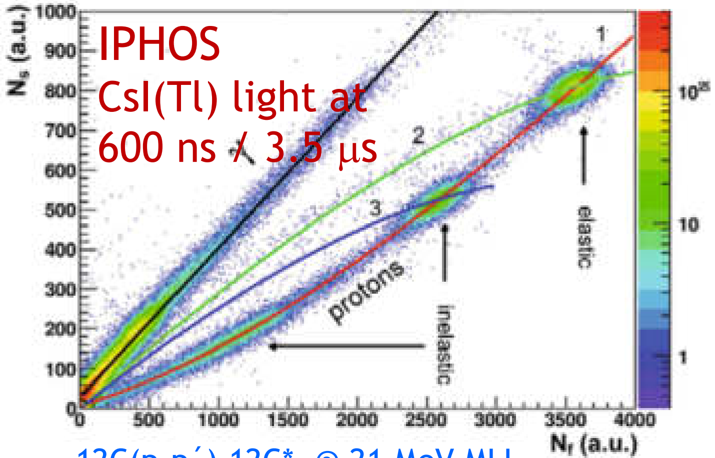
Test system at GSI

- Geometry adaptation to the limit (‚surrounding the target‘)
- Pixel detectors
  - suppression of delta rays
  - noise environment / noise reduction & selective trigger/selection schemes
  - option for inner tracker in front of Calorimeter

Enabling technologies
- Phoswitch/IPHOS (Dual Readout)

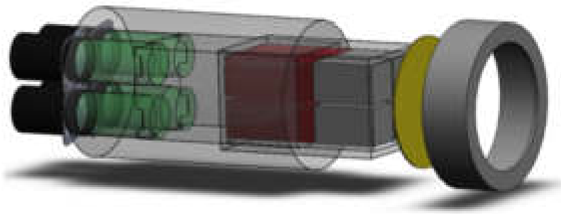


PARIS White Book – 03/2021



12C(p.p´) 12C* @ 21 MeV MLL

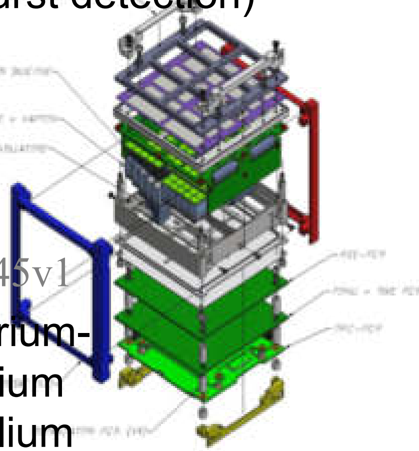
CEPA: 4x 4cm $LaBr_3$(Ce) + 6cm $LaCl_3$(Ce)



?

HERMES nano satellit GAGG:Ce
(Gamme ray burst detection)

3U platform
Available Payload volume:
97 x 97 x 150 mm
Available Mass:
0.5 to 1.5 kg
Data rate in the air:
up to 150 Mbps



arXiv:2101.03945v1

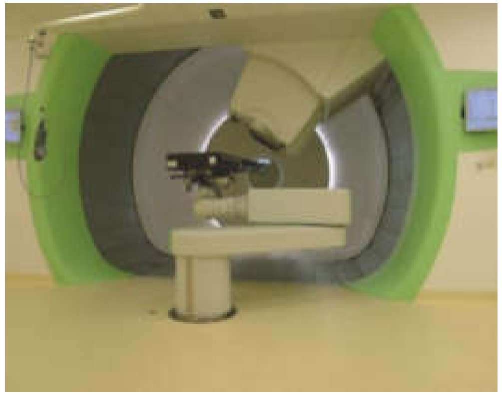
GAGG:Ce (Cerium-doped Gadolinium Aluminium Gallium Garnet)

R&D: Test experiments
Bronowice Cyclotron Center Krakow

Beam Diameter : 4mm FWHM

200 MeV

80 MeV

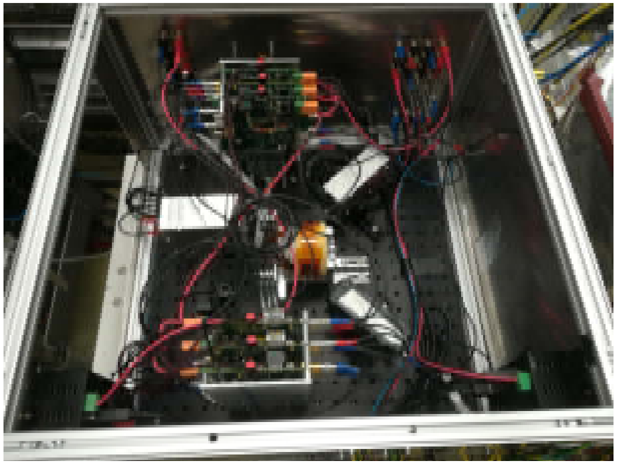


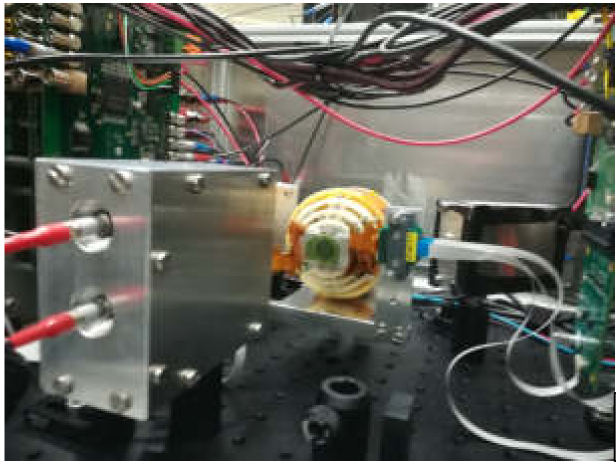
- Proteus C-235 Cyclotron
- E = 70 – **235 MeV** mono-energetic protons, I= 1 – 500 nA
- Medical and scientific facility (2 medical, 1 scientific cave)
- Cancer therapy with special rotating gantry
- Experiment scheduled in 04-14.11.2022 (just weekends)

Several systems tested in parallel at Bronowice - courtesy: R. Gernhäuser -TUM

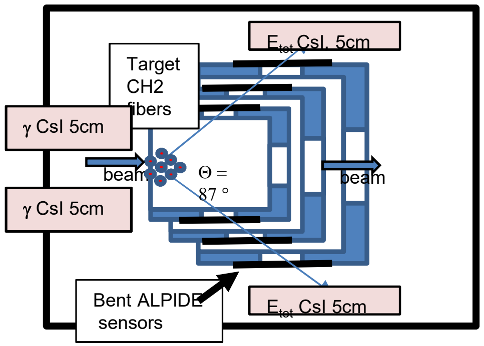
Selected tasks:

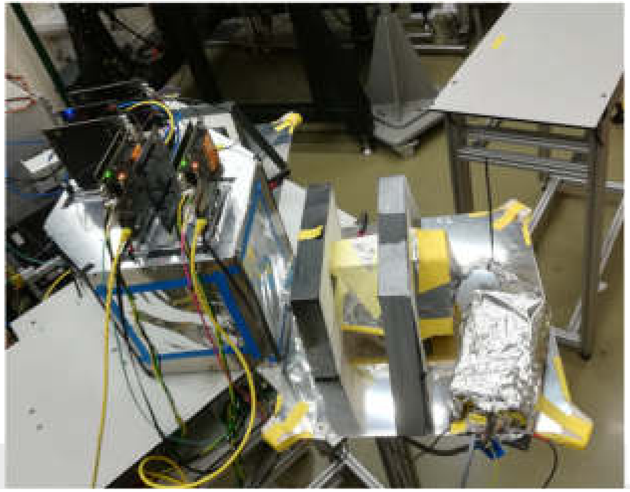
- R3B Target tracker in realistic geometry
- Full 4 momentum reconstruction in $^{12}C(p,2p)$
- DSSD silicon tracker with self triggering
- First two clusters of CEPA-CsI
- Prototype test of GAGG Phoswich
- Alpides @ different angles of incidence

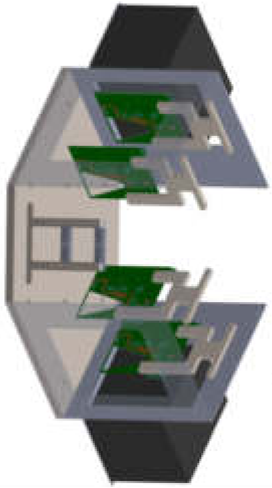




CsI Cluster

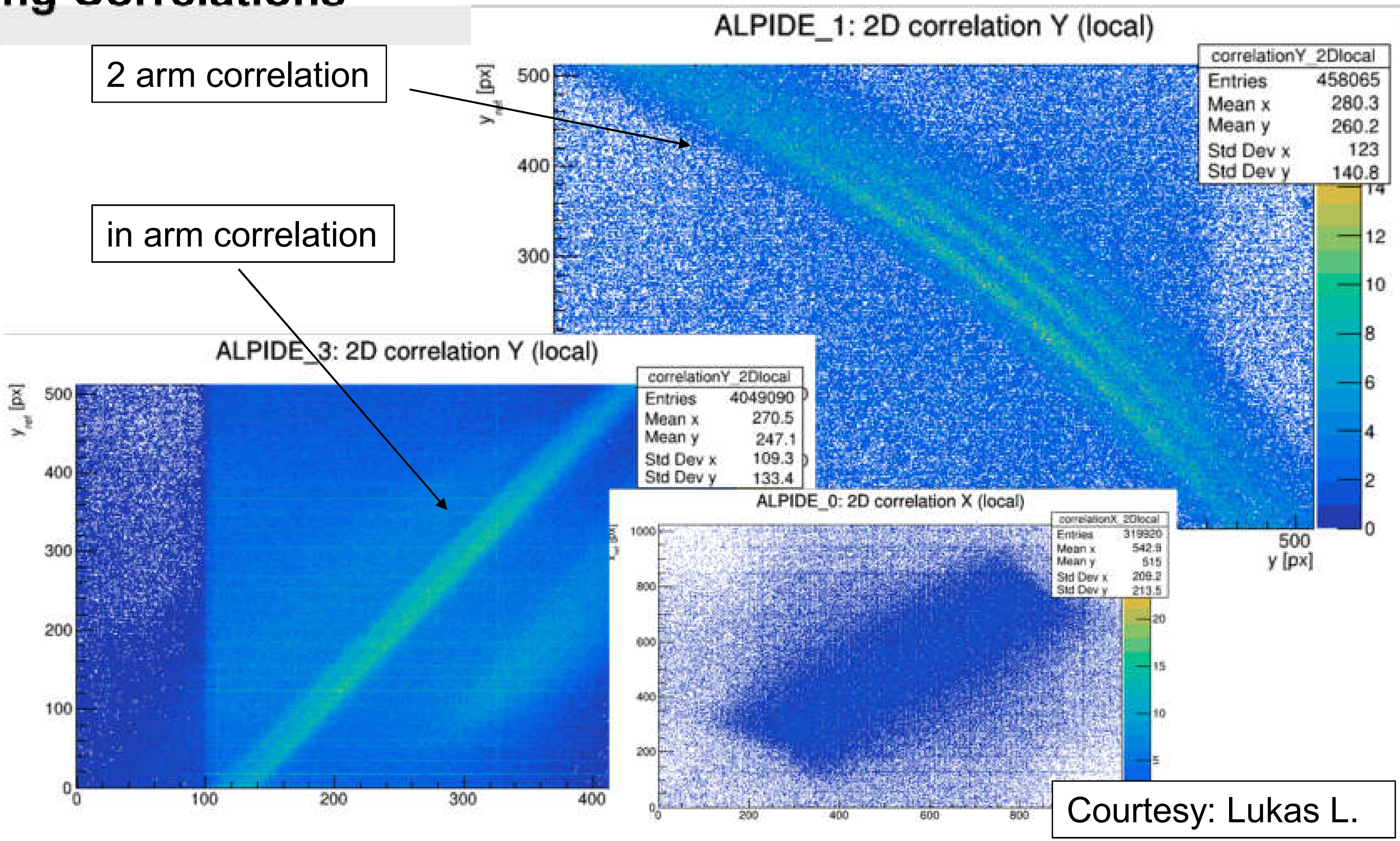






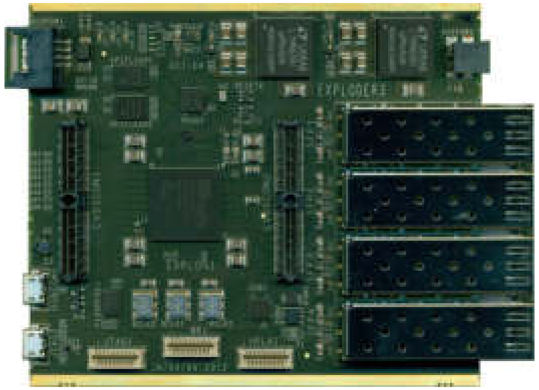
CsI / GAGG Cluster

Tracking Correlations



Enabling technologies
- Precision timing (few...100 ps)

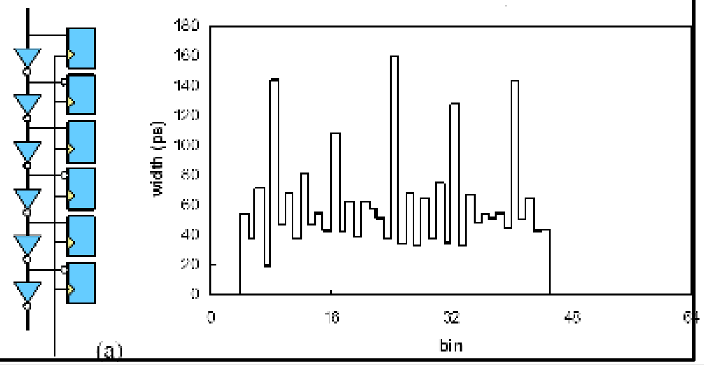




- Time distribution systems
  - e.g. Based on WR network (… KM3NeT)
  - https://white-rabbit.web.cern.ch/
  - CAMPUS wide (e,g, ToF: Separator – Exp.)
- FPGA TDCs down to 7ps resolution
- Precise position measurement
- Amplitude information via time over threshold
- E.g. ToF Wall based on plastic scintillator
  σ_t=14ps, σ_E/E=1%

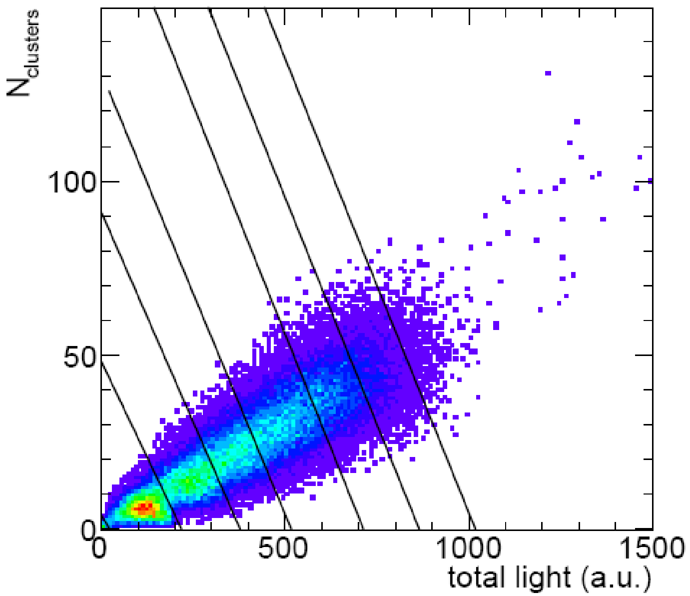
The 10-ps Wave Union TDC:
Improving FPGA TDC Resolution
beyond Its Cell Delay
Jinyuan Wu and Zonghan Shi

IEEE Nucl. Sci. Symp. Conf. Rec. (2008)



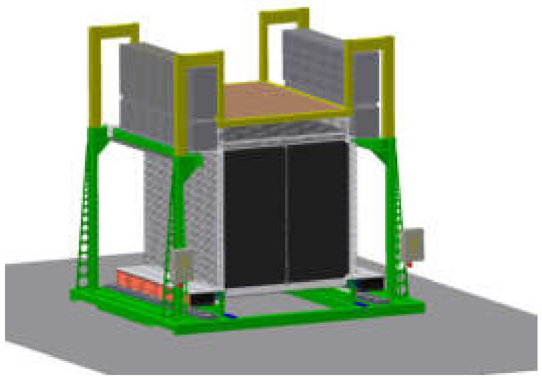
Novel Neutron Detector: NeuLAND

Fully active neutron detector based on scintillators (calorimetry & tracking)



Previously < 50%

Previously <5% !



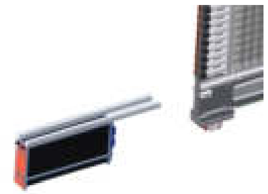
		1000 MeV generated				
	%	1n	2n	3n	4n	5n
detected	1n	**89**	12	1	0	0
	2n	7	**78**	23	3	0
	3n	0	8	**63**	26	5
	4n	0	0	12	**63**	40
	5n	0	0	0	7	**46**
	6n	0	0	0	0	8

ELSEVIER journal homepage: www.elsevier.com/locate/nima

NeuLAND: The high-resolution neutron time-of-flight spectrometer for R^{3}B at FAIR

K. Boretzky, I. Gašparić, M. Heil, J. Mayer, A. Heinz, C. Caesar, D. Kresan, H. Simon, H.T. Törnqvist, D. Körper, G. Alkhazov, L. Atar, T. Aumann, D. Bemmerer, ...

NIMA **1014** (2021) 165701



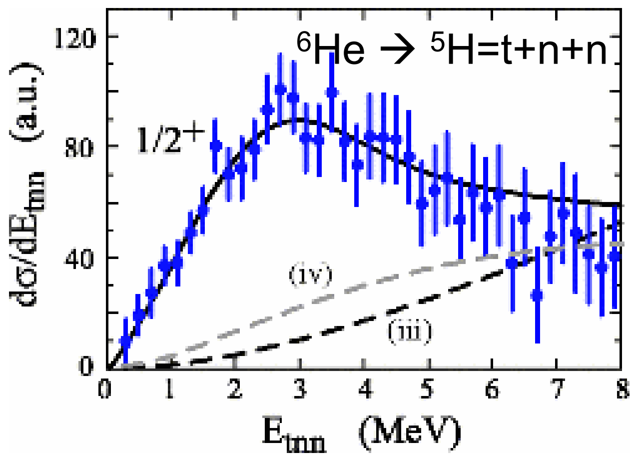
30 double planes
2 x 50 paddles each
5 x 5 x 250 cm^3
RP408 / R8619ASSY

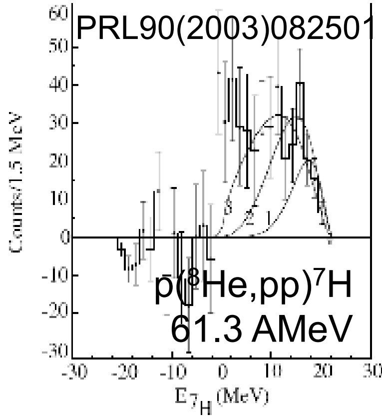
FPGA TDC readout

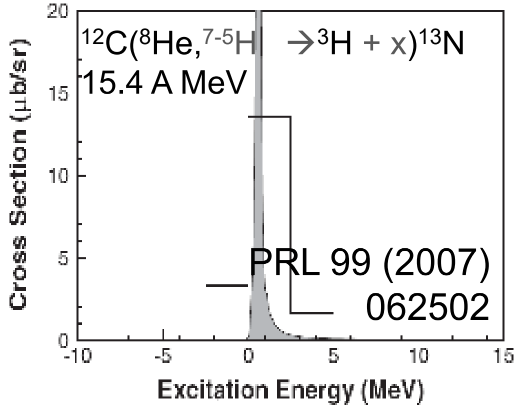
➔ 4n coincident four-momentum detection
1st time with good precision

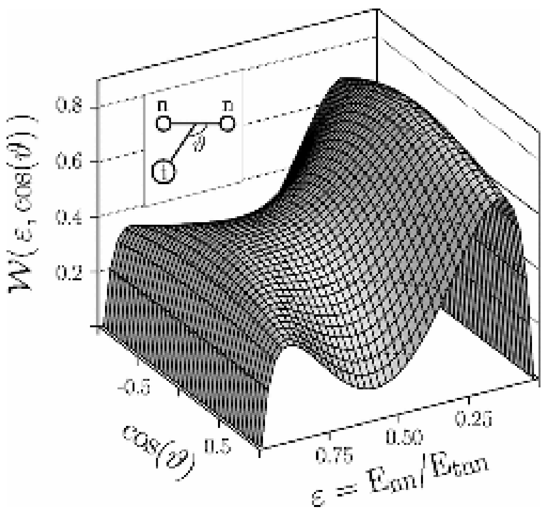
Very exotic systems $^{5,7}H$

- Invariant mas vs. Missing mass analysis

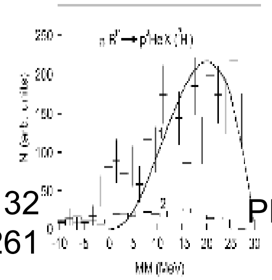




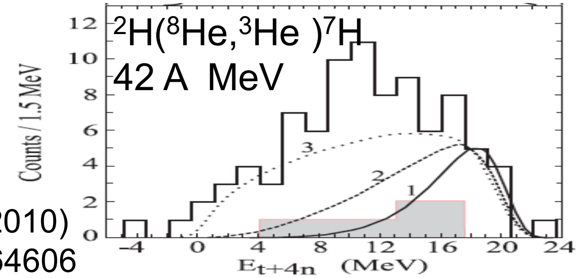




EPJA 32 (2007) 261



PRC81 (2010) 064606

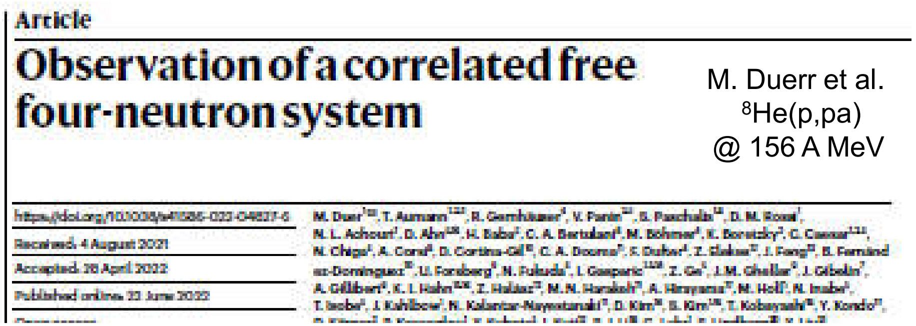


t + 4n up to now restricted to missing mass analysis

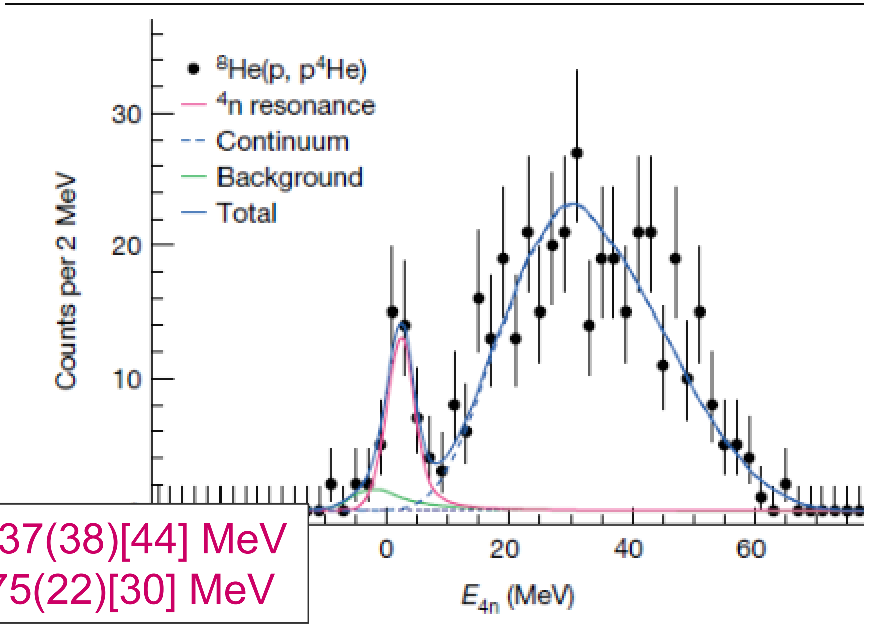
t + 2n full coincidence measurement ➔ invariant mass

and 3 body correlations ➔ access to angular momenta

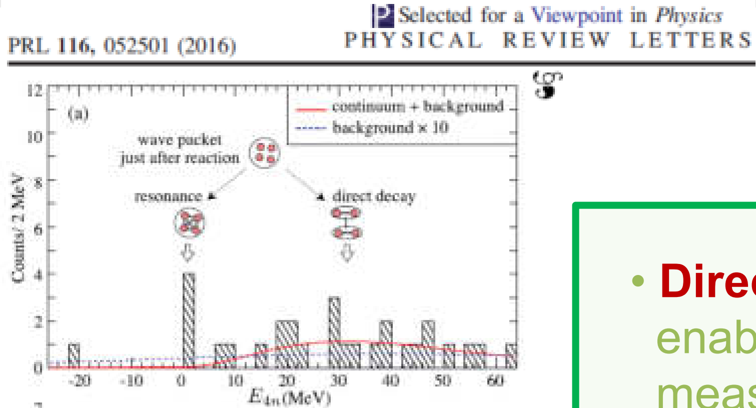
Very exotic systems 4n



M. Duerr et al.
^{8}He(p,pα)
@ 156 A MeV

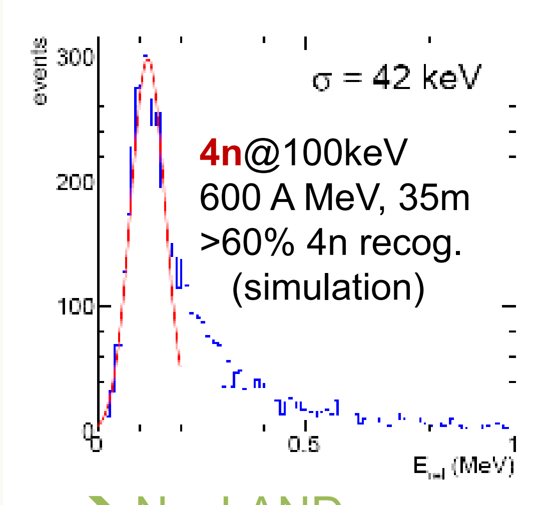


E_r = 2.37(38)[44] MeV
Γ = 1.75(22)[30] MeV



K. Kisamori et al.
^{4}He(^{8}He; ^{8}B)
@ 186 A MeV

- **Direct study** is enabled by exclusive measurements

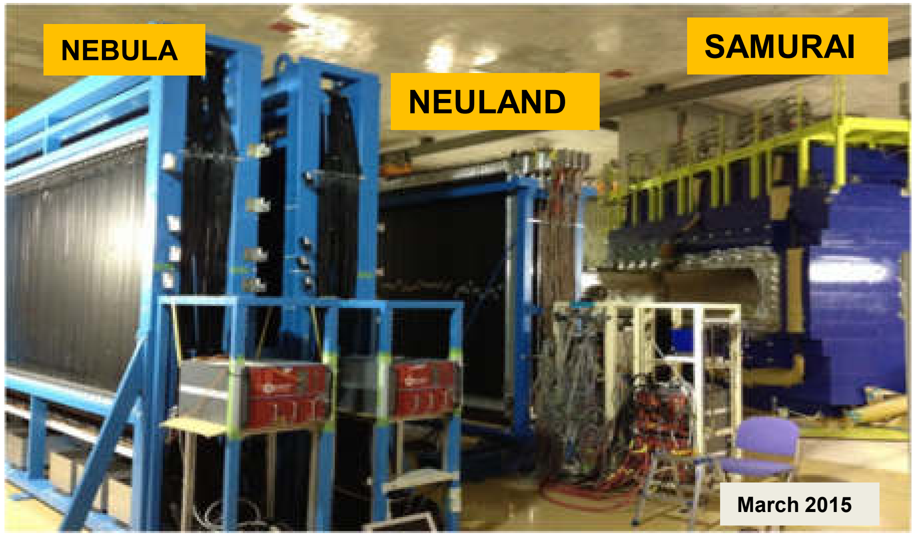


➔ NeuLAND.

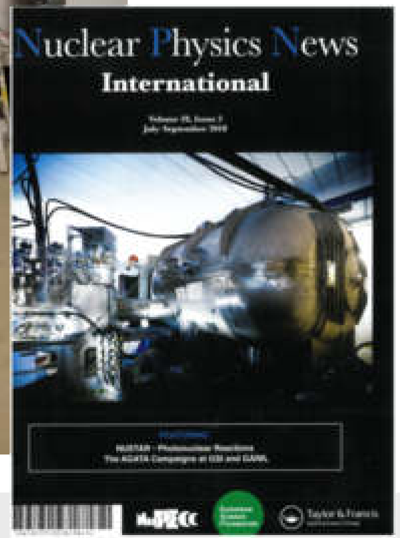
Neuland demonstrator @ RIKEN

- NeuLAND demonstrator (40 cm depth with 4/30 double planes and 800 readout channels) at RIKEN 2014-2017, participation in various beam times

- Several experiments performed and published (e.g. M. Duerr et al., Nature 606 (2022) 678)

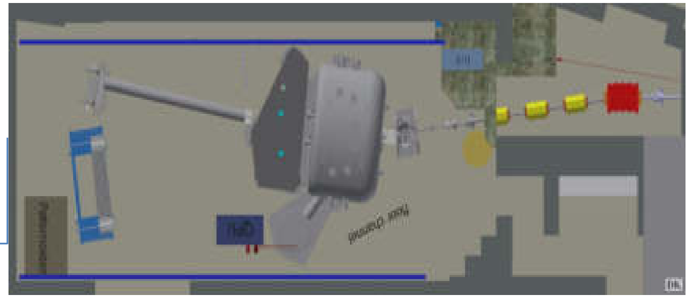


From R³B prototype to R³B precursor



R³B experiments in 2018/19

Modular and versatile experimental setup with unprecedented **efficiency, acceptance, and resolution** for kinematical complete measurements of reactions with high-energy radioactive beams ➔ **first experiments**



2015
Cave C empty

2016 GLAD @ GSI
Cave refurbishment

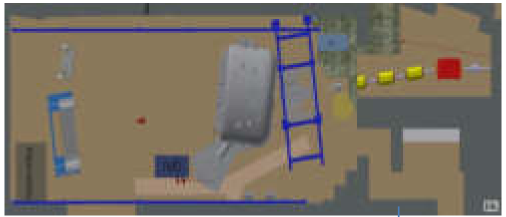
2017
GLAD Installation
HTD detector commiss.

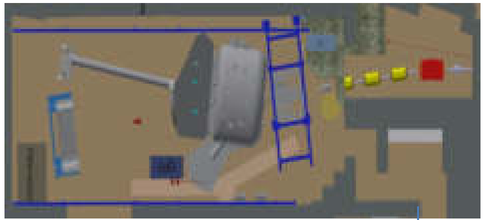
2018/19
GLAD + Big chamber
CALIFA and NeuLAND
Demonstrator

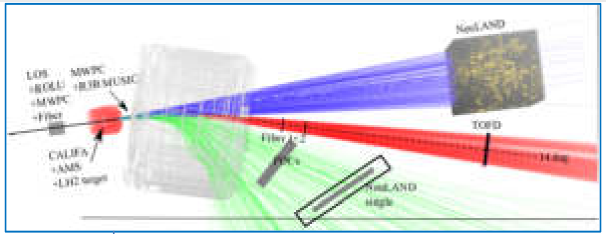
Stable beams

S444 Main detection system commissioning
S454 Studying the astrophysical reaction rate of C(alpha,gamma)
S473 Constraining energy-density functionals and the density-dependence of the symmetry energy (i)

R³B experiments in 2020/21





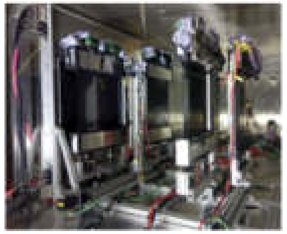


2020
CALIFA Barrel
NeuLAND 8 DP
SOFIA tracking detectors
R3BMusic

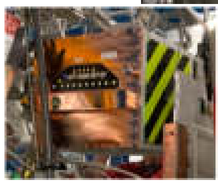
2021
+ LH2 +
CALIFA iPHOS
NeuLAND 12 DP

New Fiber Detectors

2022
+ Proton arm behind GLAD
& LH_2 target preparation



S444 Detection system commissioning
S467 Single-particle structure of neutron-rich Ca isotopes

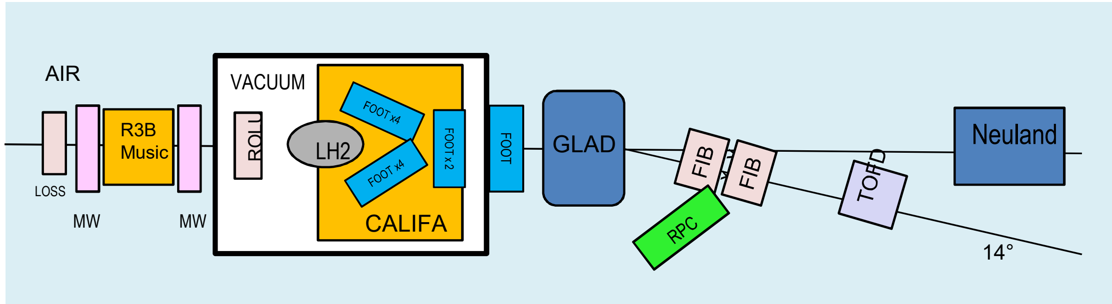


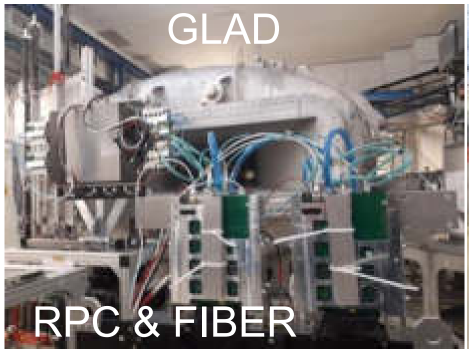
S455 Fission studies @R3B
S515 Constraining energy-density functionals and the density-dependence of the symmetry energy (ii)
S494 Coulomb dissociation of ^{16}O into ^{12}C and ^{4}He.

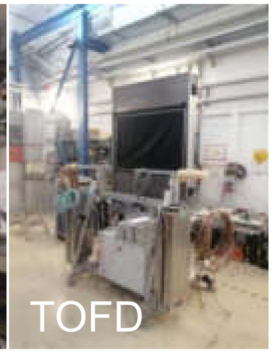
R³B experiments in 2022

S522 First characterization of Short-Range Correlations in exotic nuclei at R³B (^{16}C)
S509 Study of multi-neutron configurations in atomic nuclei
& Dedicated GLAD field mapping for precision tracking

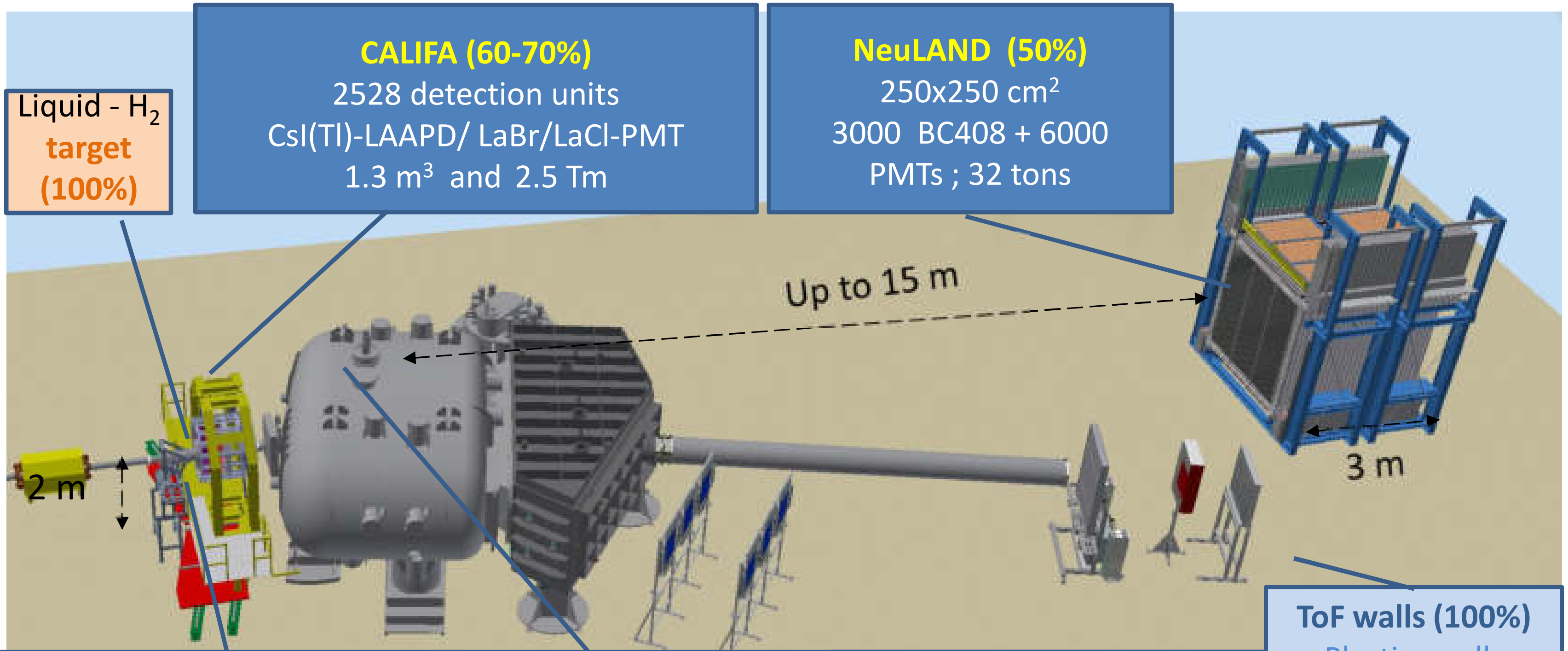
LH2 + FOOT + CALIFA + NeuLAND (13 DP) + Fiber tracking + Proton arm behind GLAD







R^{3}B setup ready
to move to FAIR in 2025



Liquid - H_2 target (100%)

CALIFA (60-70%)
2528 detection units
CsI(Tl)-LAAPD/ LaBr/LaCl-PMT
1.3 m^3 and 2.5 Tm

NeuLAND (50%)
250x250 cm^2
3000 BC408 + 6000
PMTs ; 32 tons

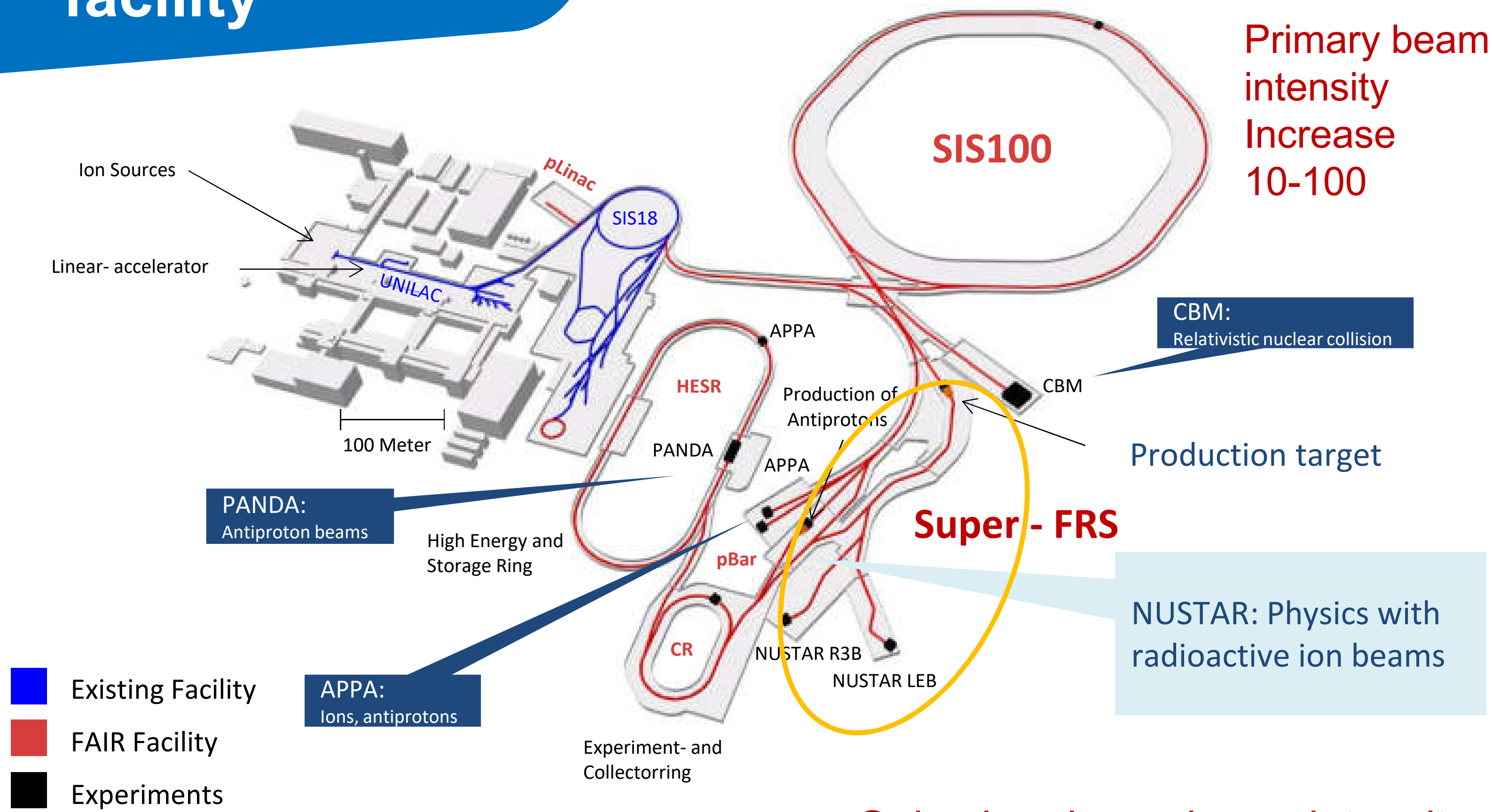
L3T (DSSSD)
18 det.ladders (6+12)
Strip pich 50mm
912 ASICS 116736 channels
AMS-FOOT (SD) prototype

GLAD (100%)
Large aper. 80x100 cm
5 Tm ; 3,5 x7x4 m
50 Tons

Tracking detectors (100%)
Silicon/ Plastics
Fibers 80x80 cm^2, 500 mm
MUSIC´s
MW´s 90x60 cm^2 , 200 mm

ToF walls (100%)
Plastics walls
120x80 cm^2
Plastics walls
84x60 cm^2 (15 ps)
RPC system
(protons)

FAIR – schematic view of the facility



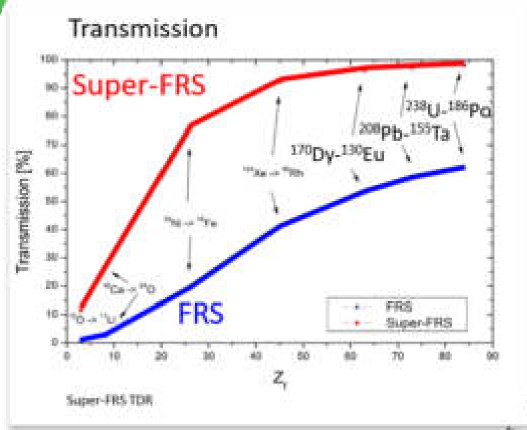
Primary beam intensity Increase 10-100

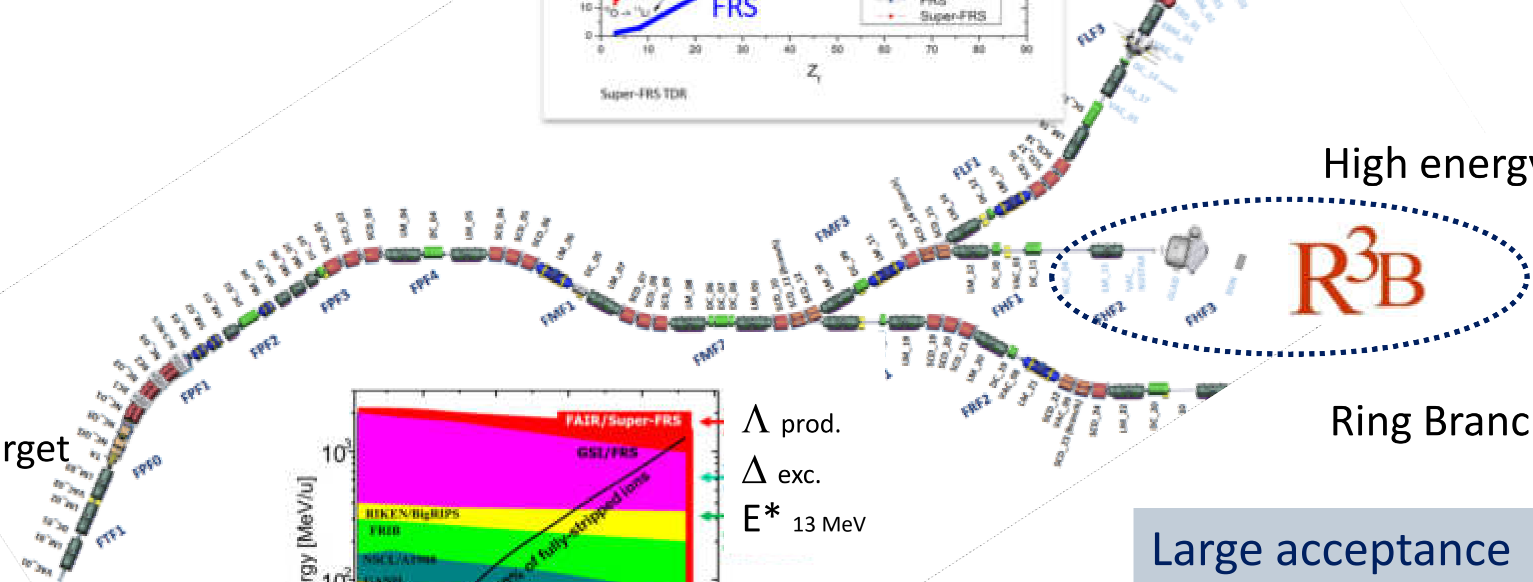
Gains in primary beam intensity & separator perfomance matched

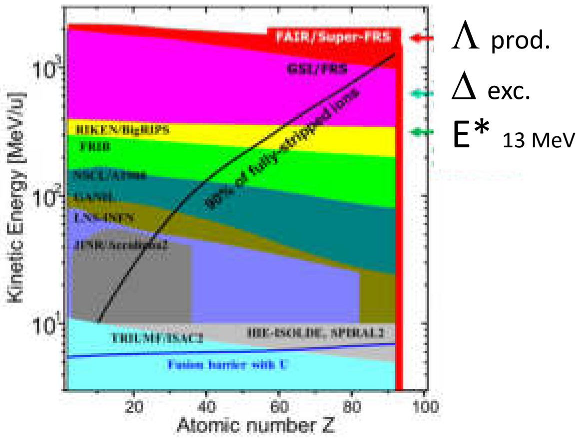
Super-FRS (@SIS18/SIS100) workhorse for

NUSTAR

One of worlds most powerful separators for exotic nuclei







Large acceptance
High rigidity, minimized losses
→ Thick production targets
→ Most effective use of primary beam for experiments

Technical Design Report:
H. Geissel, M. Winkler, H. Weick, et al. (2009)

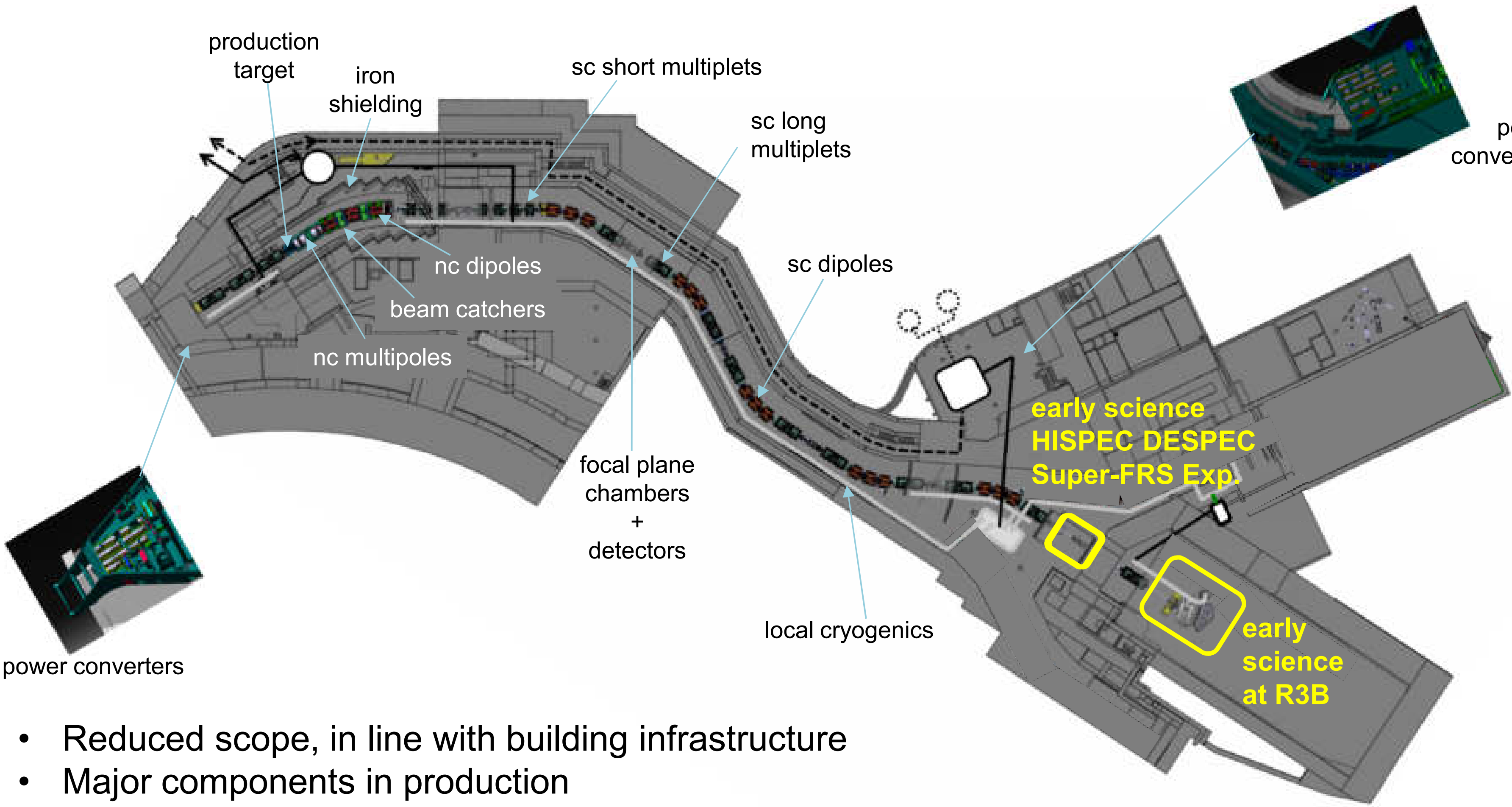
NUSTAR - The Experiments (sub-collaborations)

Branch	Super-FRS	RIB production, separation, and identification
LEB	**HISPEC/ DESPEC**	In-beam γ-spectroscopy at low and intermediate energy, n-decay, high-resolution γ-, β-, α-, p-, spectroscopy
LEB	**MATS**	In-trap mass measurements and decay studies
LEB	**LaSpec**	Laser spectroscopy
HEB	**R^3B**	Kinematical complete reactions with relativistic radioactive beams
RB	**ILIMA**	Large-scale scans of mass and lifetimes of nuclei in ground and isomeric states
integ.	**Super-FRS EC**	High-resolution spectrometer experiments
GSI	**SHE (#)**	Synthesis and study of super-heavy elements
RB	**ELISe(*)**	Elastic, inelastic, and quasi-free e^--A scattering
RB	**EXL(*)**	Light-ion scattering reactions in inverse kinematics

(#) NUSTAR experiments@UNILAC/GSI
(*) Experiments requiring NESR – alternative solutions within FAIR MSV under consideration

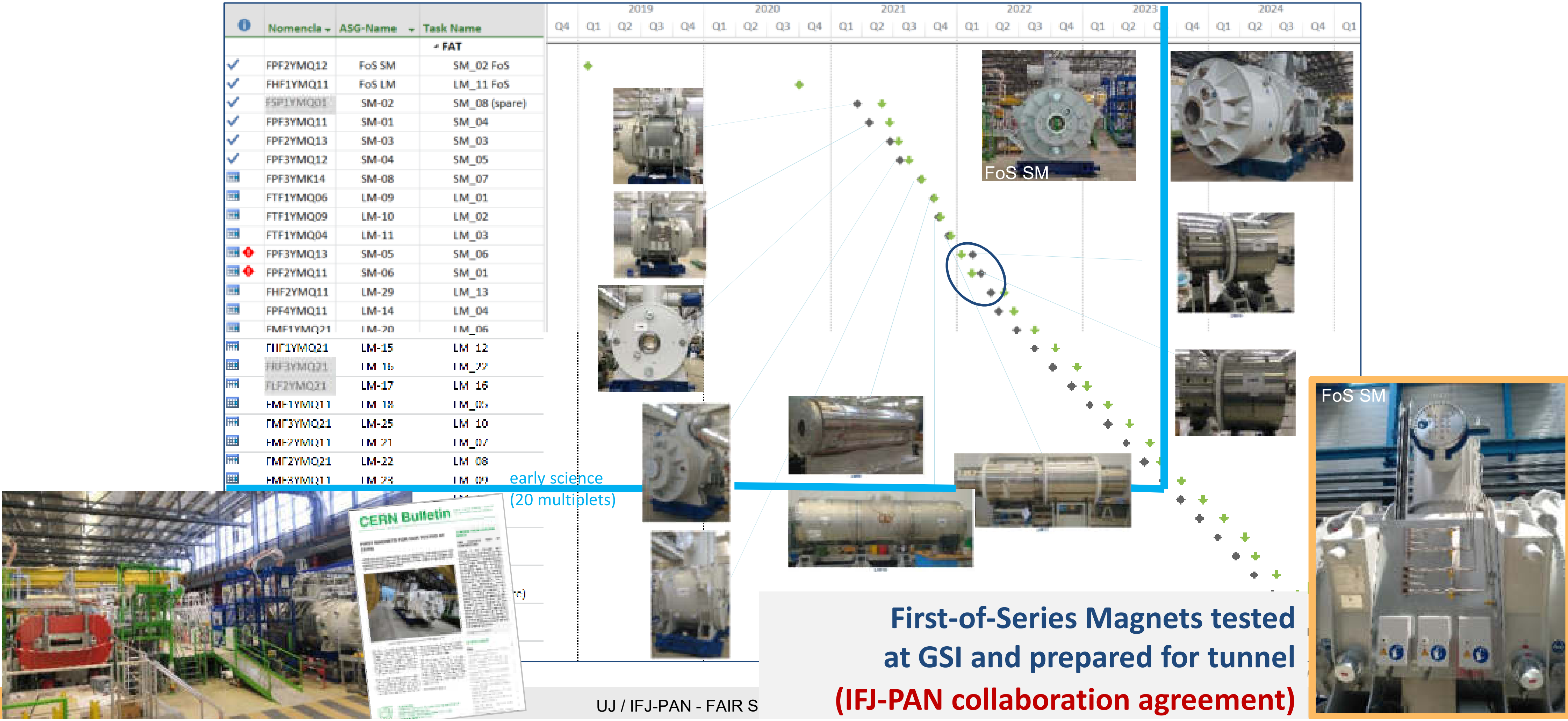
Courtesy: W. Korten

Main components for early science aiming for Q4/2026



- Reduced scope, in line with building infrastructure
- Major components in production

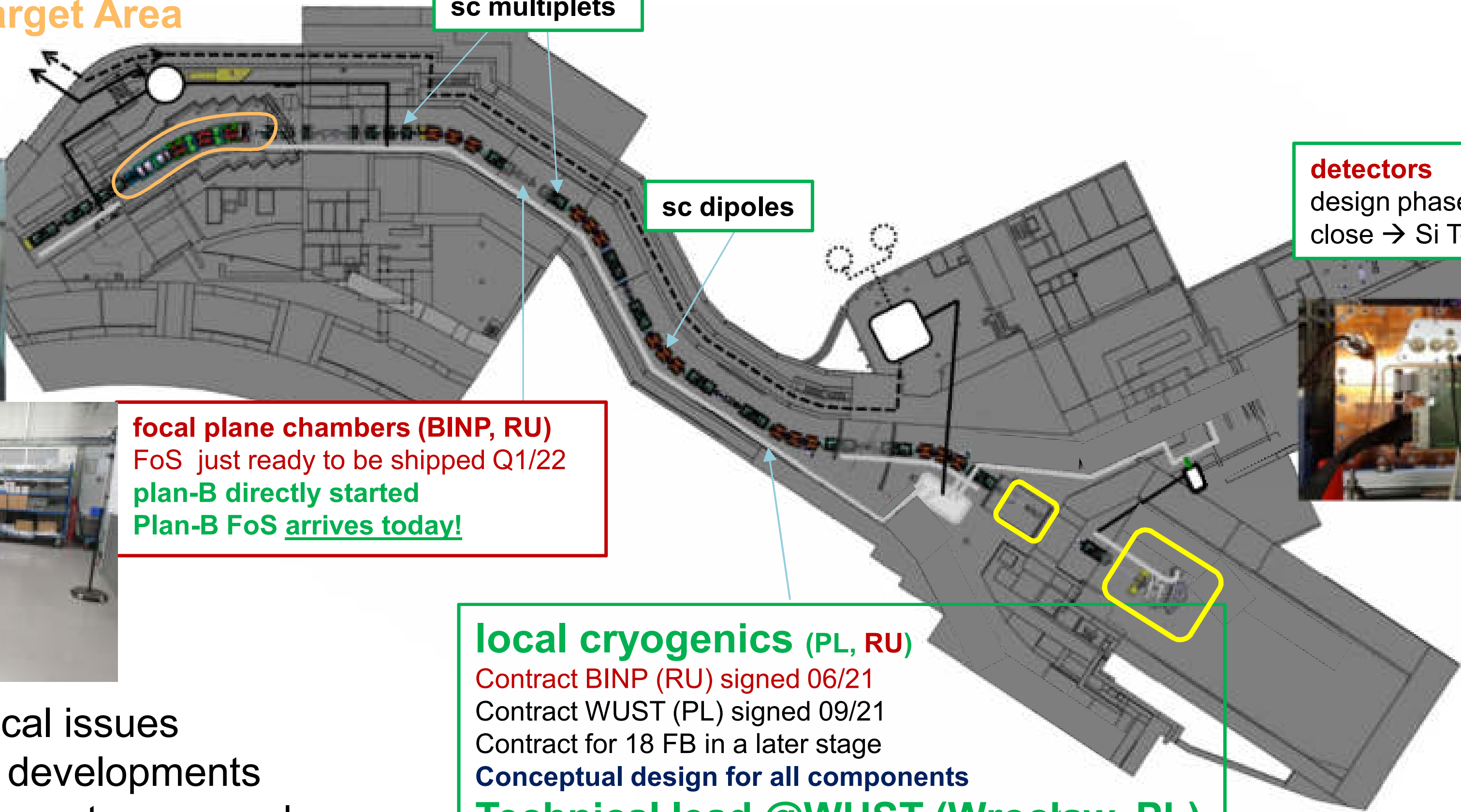
Example for major component: sc multiplets in series production

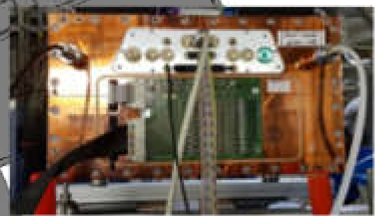


Nomencla	ASG-Name	Task Name
		FAT
FPF2YMQ12	FoS SM	SM_02 FoS
FHF1YMQ11	FoS LM	LM_11 FoS
FSP1YMQ01	SM-02	SM_08 (spare)
FPF3YMQ11	SM-01	SM_04
FPF2YMQ13	SM-03	SM_03
FPF3YMQ12	SM-04	SM_05
FPF3YMK14	SM-08	SM_07
FTF1YMQ06	LM-09	LM_01
FTF1YMQ09	LM-10	LM_02
FTF1YMQ04	LM-11	LM_03
FPF3YMQ13	SM-05	SM_06
FPF2YMQ11	SM-06	SM_01
FHF2YMQ11	LM-29	LM_13
FPF4YMQ11	LM-14	LM_04
FMF1YMQ21	LM-20	LM_06
FHF1YMQ21	LM-15	LM_12
FRF3YMQ21	LM-16	LM_22
FLF2YMQ21	LM-17	LM_16
FMF1YMQ11	LM-18	[illegible]
FMF3YMQ21	LM-25	LM_10
FMF2YMQ11	LM-21	LM_07
FMF2YMQ21	LM-22	LM_08
FMF3YMQ11	LM-23	LM_09

First-of-Series Magnets tested at GSI and prepared for tunnel (IFJ-PAN collaboration agreement)

Russian in-kind:
replacement strategy necessary





detectors
design phase about to close → Si ToF alternative

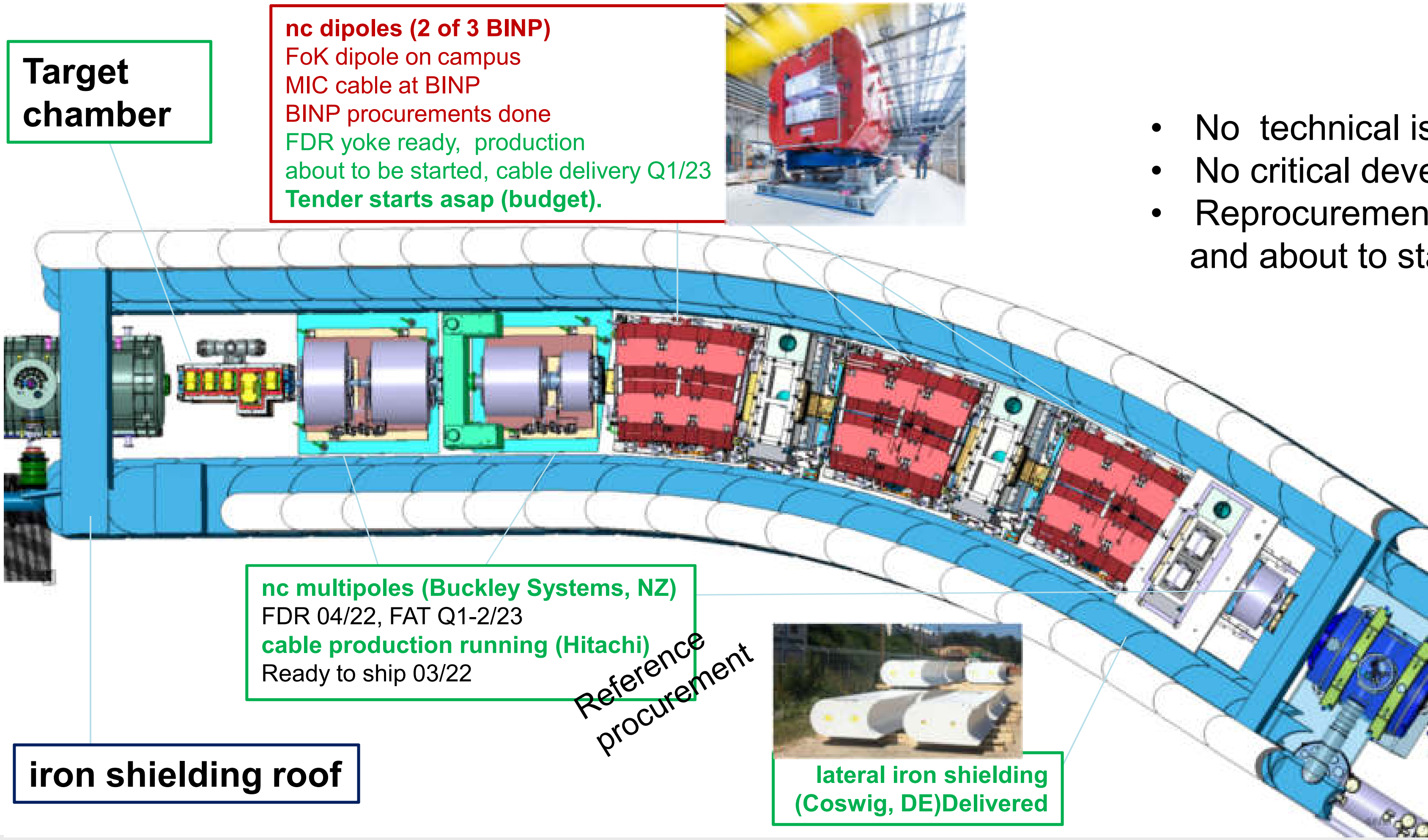
focal plane chambers (BINP, RU)
FoS just ready to be shipped Q1/22
plan-B directly started
Plan-B FoS arrives today!

local cryogenics (PL, RU)
Contract BINP (RU) signed 06/21
Contract WUST (PL) signed 09/21
Contract for 18 FB in a later stage
Conceptual design for all components
Technical lead @WUST (Wrocław, PL)
Reprocurement of Branch Box running

- No technical issues
- No critical developments
- Reprocurements prepared

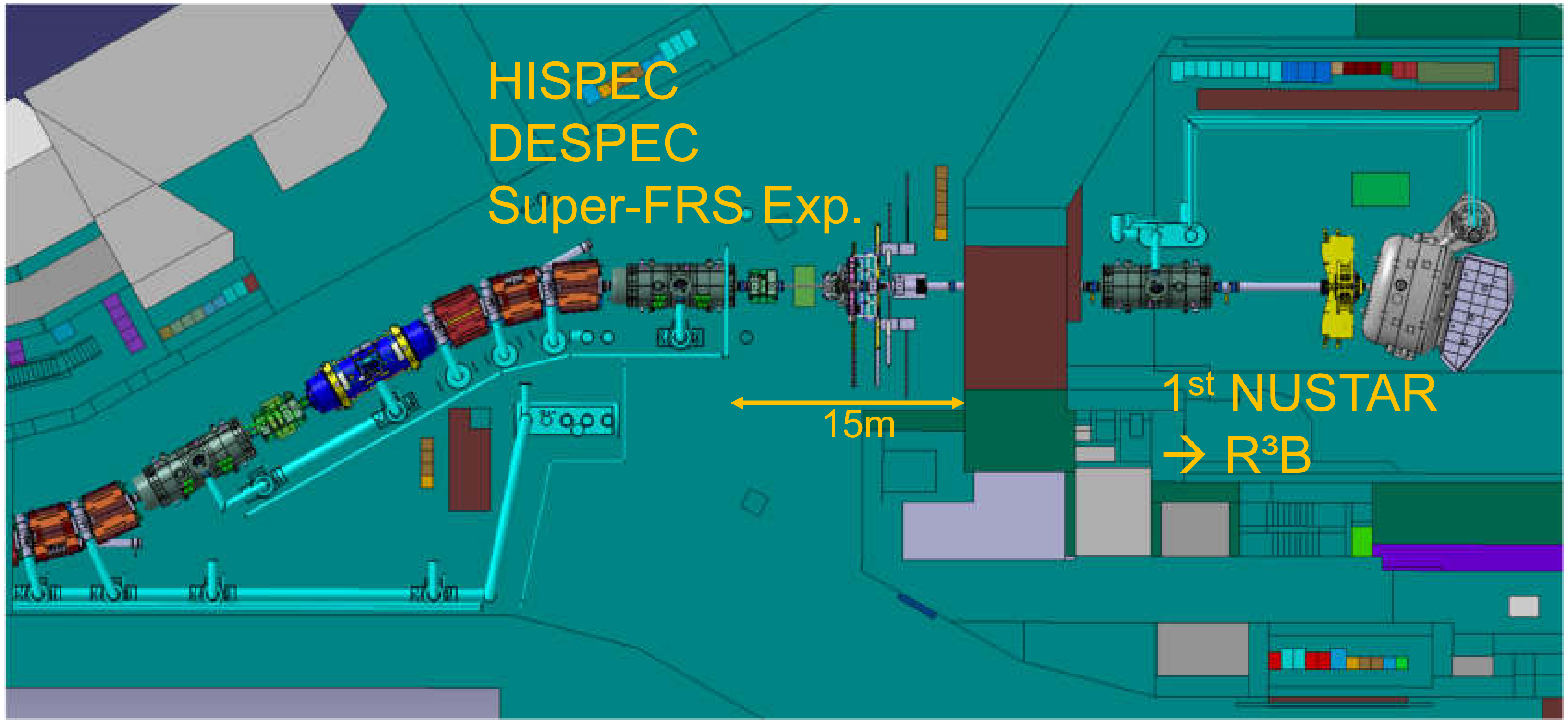
Russian in-kind:
replacement strategy necessary

Target Area



- No technical issues
- No critical developments
- Reprocurements prepared and about to start.

First stage: "Early Science"
High energy branch R3B/GLAD
(and setup @ FHF1)



All Experiments possible
(some in start versions @ FHF1)

Exception: ring experiments & MATS LASPEC @ Super-FRS

Status project

- Super-FRS project work progresses overall well, despite all difficulties arising from Russian warfare in Ukraine

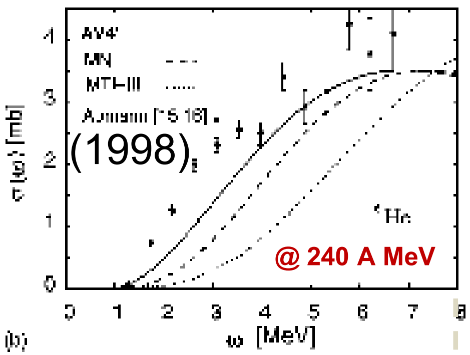
- **Phase-0** physics program running in FAIR setup preparation phase. Full swing physics programme (also in other facilities e.g. RIKEN) benefiting from FAIR components. ➔ Commissioned systems will move to new facility.

- **Day-1** experiments in early physics phase cover comprehensive part of full NUSTAR physics program.

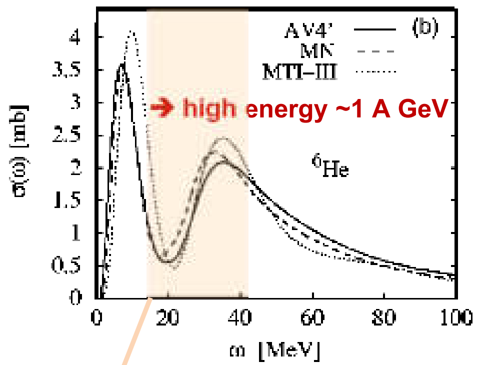
FAIR beams (with suitable intensities)

- Up to 20Tm beam rigdity ➔ high energy coulomb excitation

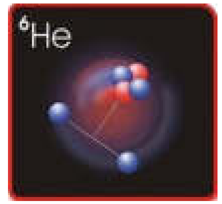
GSI



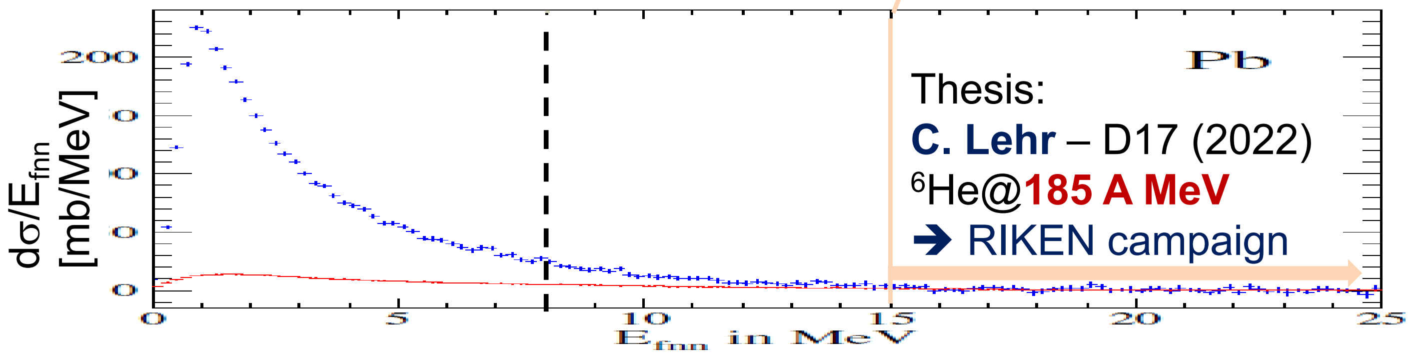
FAIR



S. Bacca et al.
PRL **89** (2002) 052502
PRC **69** (2004) 057001

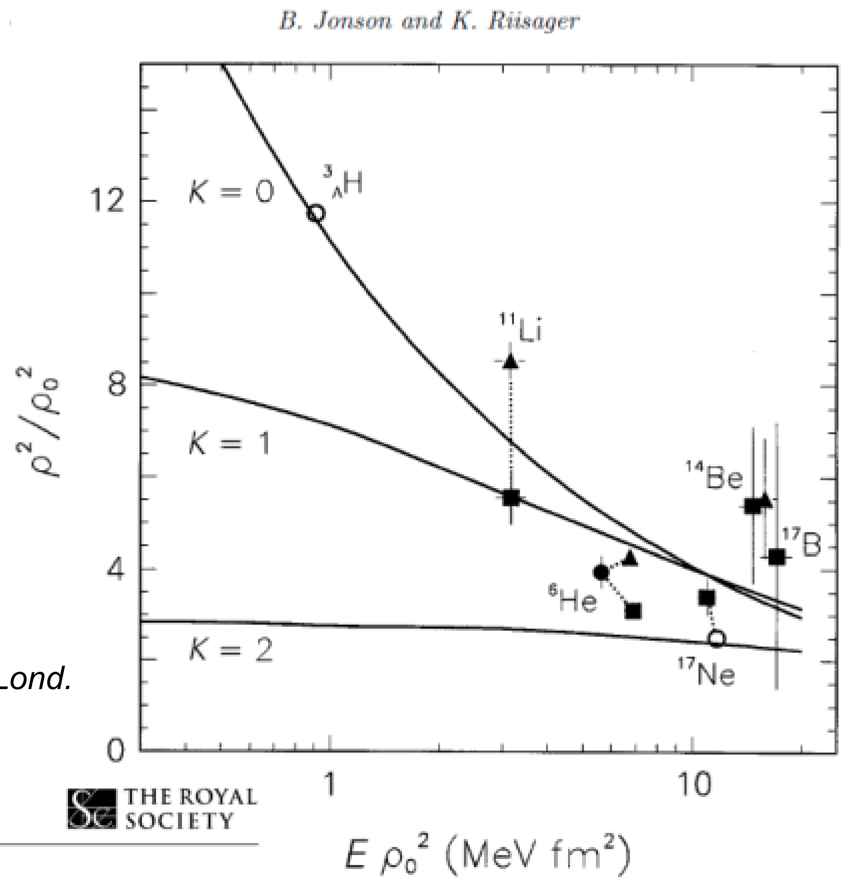


© ANL



Heavier systems !
- clean separation
- no charge states

FAIR beams (with suitable intensities)

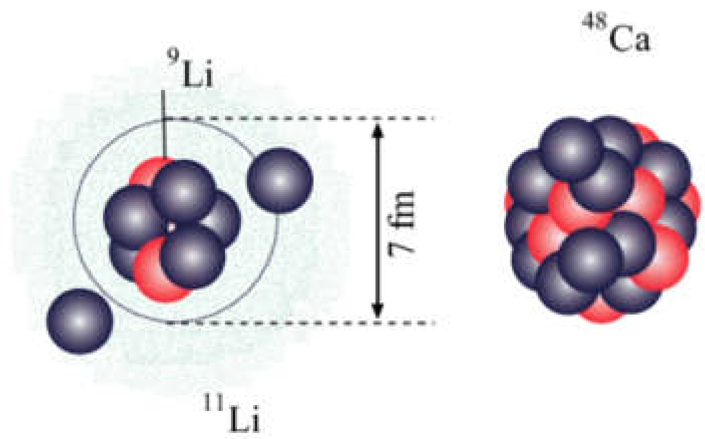


Phil. Trans. R. Soc. Lond.
A**356** **(1998)** 2063

THE ROYAL SOCIETY

Halos and halo excitations

By B. Jonson[1] and K. Riisager[2]



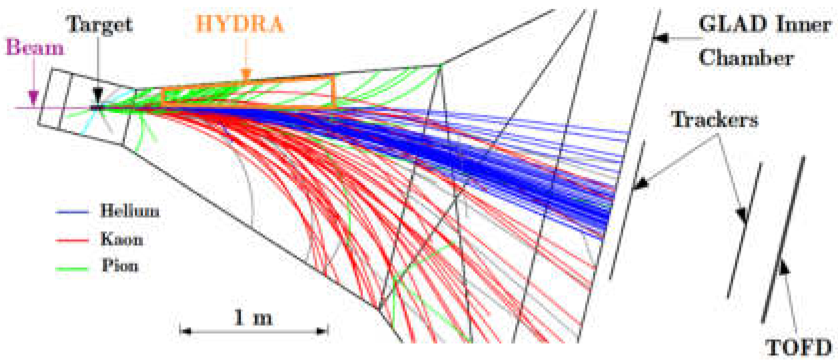
Not only ^{11}Li but also
$^3_\Lambda$H forms presumably a halo system !

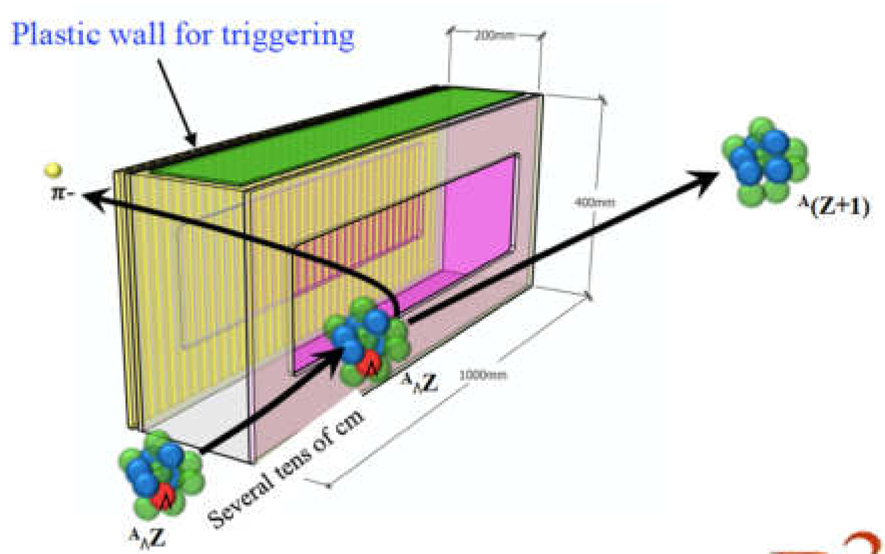
➔ **1.57 A GeV threshold**

Λ hypernuclei @ R3B

Study of Hyperhalos, determination of binding energies and lifetimes

Program at R3B based on a new high-resolution pion tracker (TPC) , HYDRA, inside GLAD



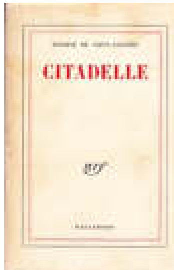


➔ Halo properties can be probed

Summary

- Instrumentation suitable for halo and dripline physics constructed and commissioned within Phase-0 experiments of the R³B experiments, examples presented
- FAIR facility enables exclusively dedicated program especially suited for energetic intense secondary beams in particular also for heavy nuclei (N=126)
- Installation/(commissioning) scenario for NUSTAR experiments@FAIR presented
  → coverage of broad program during ramp up

- "If you want to build a ship, don't drum up people to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea."
  - Antoine de Saint Exupéry



Thanks

- Super-FRS project group and

www.gsi.de/superfrs

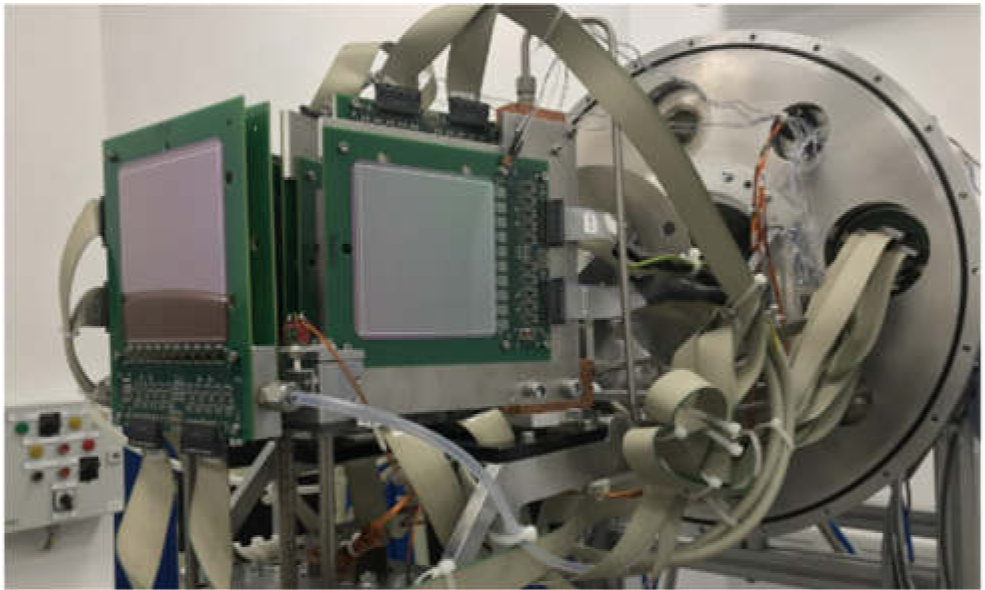
R3B collaboration

www.gsi.de/r3b
www.r3b-nustar.de

FAIR in construction

First Runs expected 2026/27

A new vertex tracker for R^3B assembled for FAIR Phase-0 2022



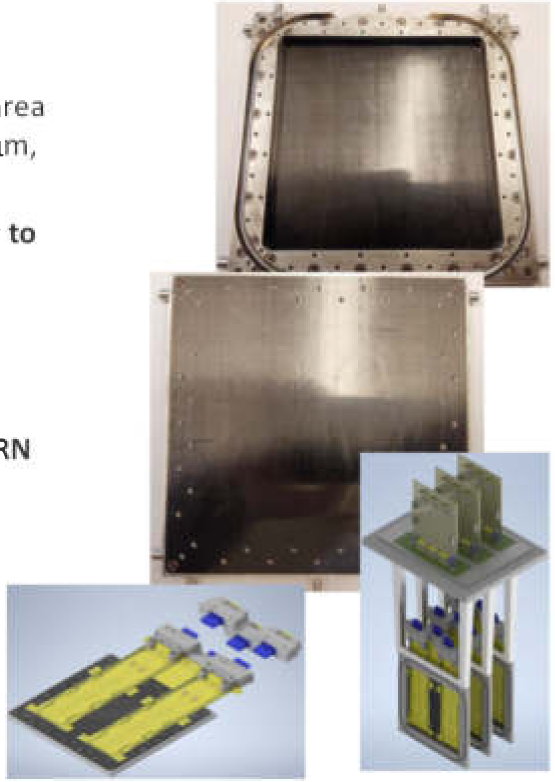
Si microstrip vertex tracker assembled for 2022 FAIR Phase-0 beam time

Si vertex detector developments

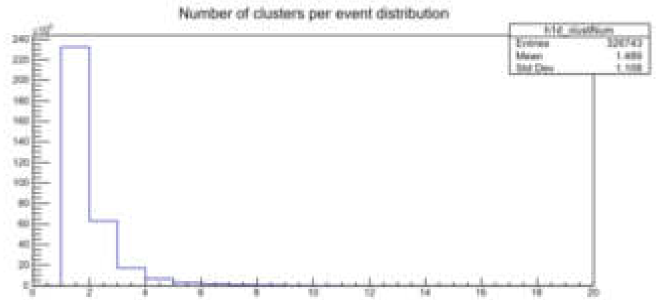
- **ALPIDE pixel detector** station (area 100 cm², position resolution 5 µm, rate up to 100 kHz)
- **Developed for MIPs, possibility to measure heavy ions is proved**
- Holding/mounting frame is developed, production started
- **Cooling carbon-fiber plate is developed and produced at CERN**

Beam tests:
CERN, relativistic muons
FZ Jülich, deuterons @300 MeV, 800 MeV and 1 GeV

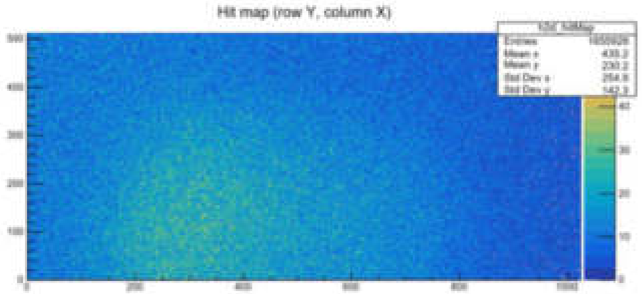
Investigation of efficiency,
maximum trigger / data rate,
PID (via cluster size),
synchronous readout
of many detectors



MOSAIC FPGA readout boards

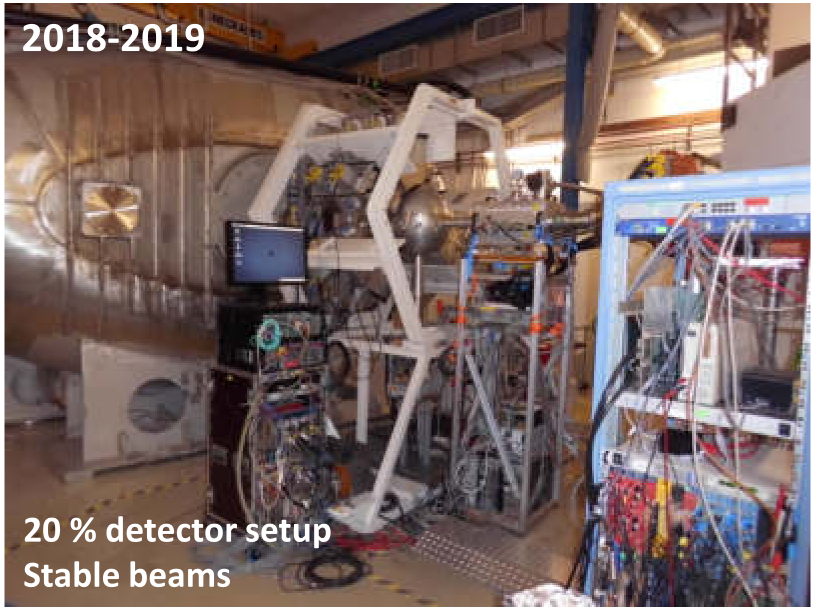


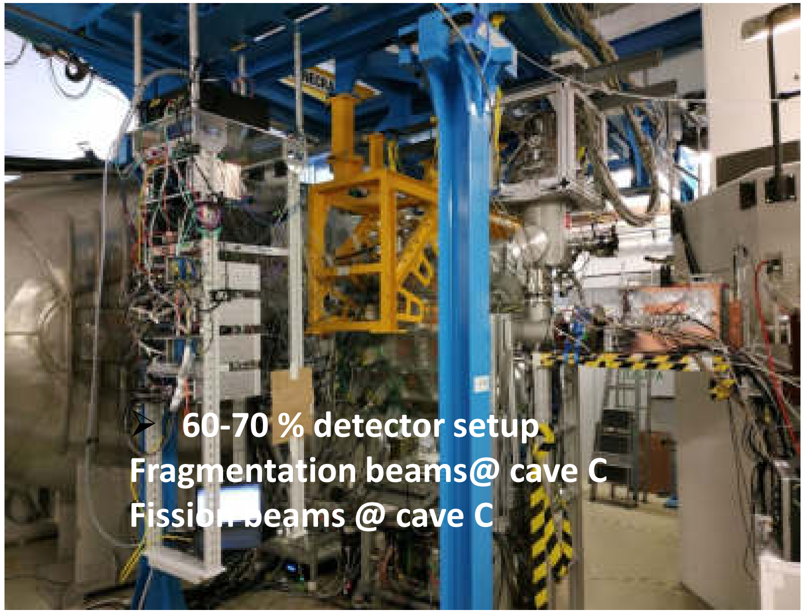
Cluster size and hit occupancy measurements at Jülich



Courtesy: W. Korten

From precursor to (almost) final





History of RIBF commissioning

Dec. 28th , 2006

First Beam $^{27}Al^{10+}$ 345 MeV/u at RIBF-SRC

Break at the facility !

March, 2007

12th $^{86}Kr^{31+}$ beam at 345 MeV/u several pnA.

13th First production of RI beams with ^{86}Kr beam

23rd First successful acceleration of $^{238}U^{86+}$ beam at 345 MeV/u and 0.002 pnA

27th First production of RI beams with ^{238}U beam

May-June, 2007 (without ZDS)

with ^{238}U beam at 345 MeV/u and 0.02 pnA max (~1x10^{8} pps)

May 16th-23th BigRIPS commissioning experiment

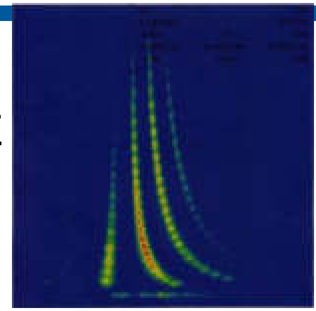
May 24th – June 3rd Search for new isotopes

End of June(a few days) detector testing

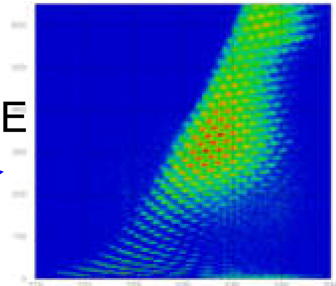
Nov. 2007 acceleration test with ^{86}Kr beams, 30 pnA

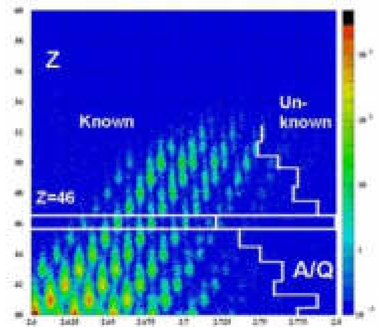
TOF

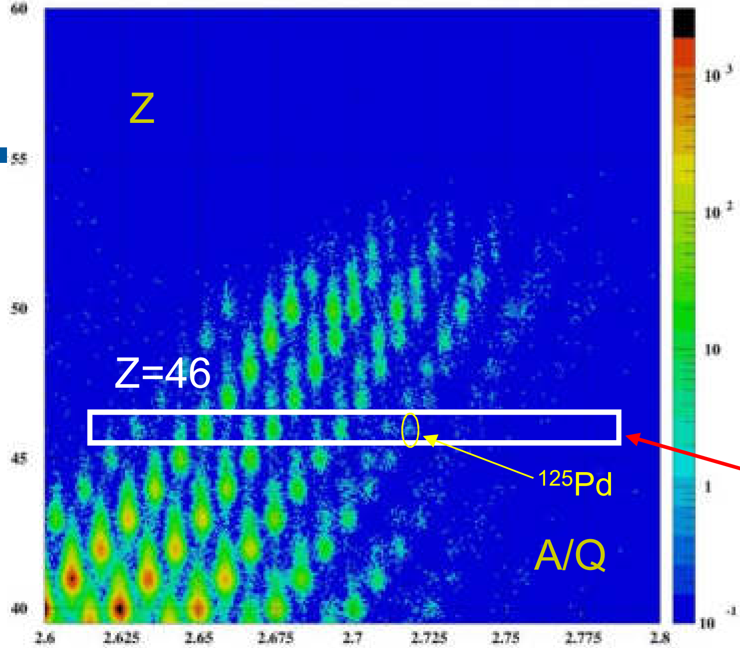
ΔE



ΔE







Bρ: 7.438 Tm

Total dose: 3.6×10^{12}
Total time: 25.4 hour