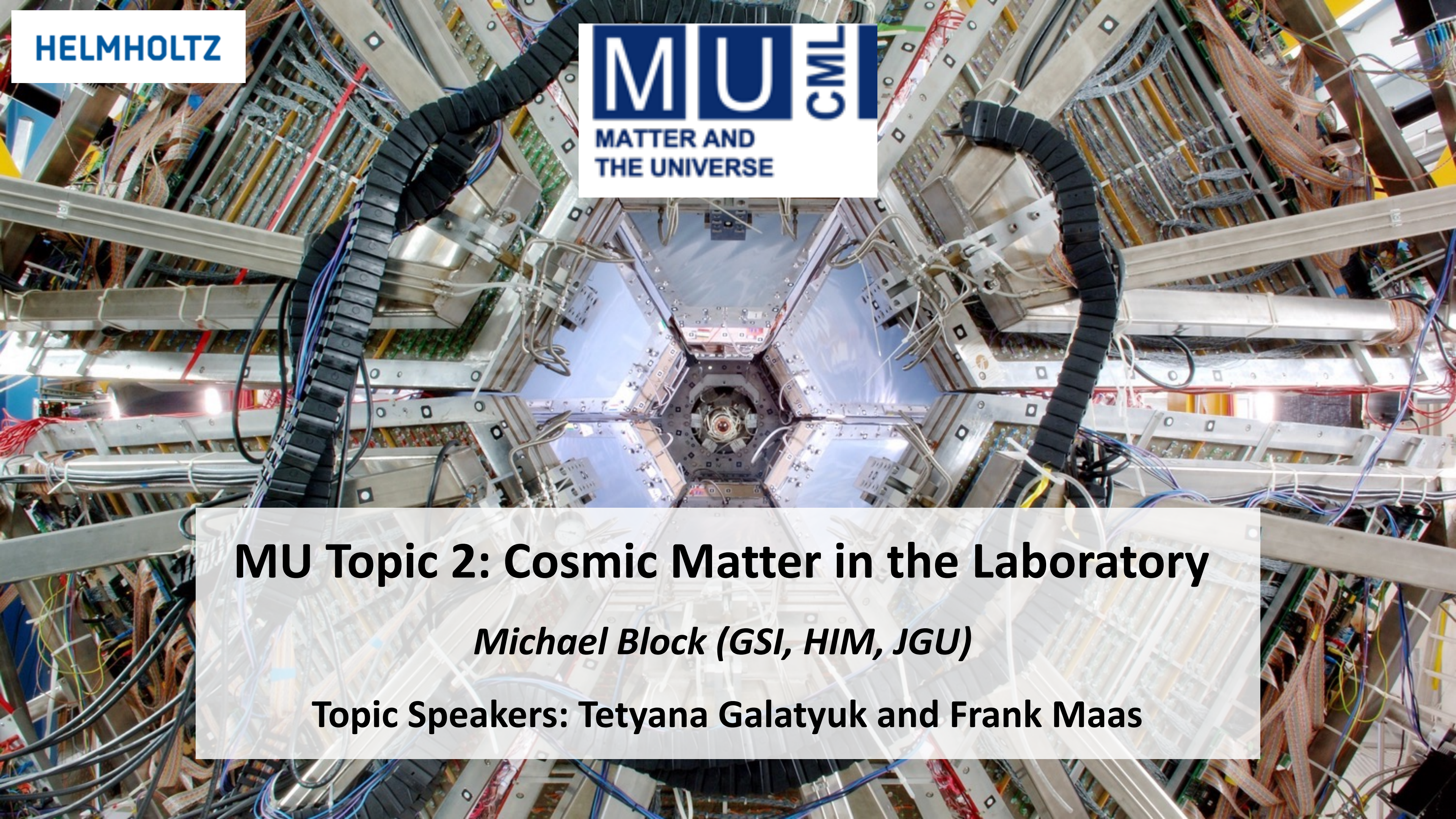


HELMHOLTZ

MU CML
MATTER AND THE UNIVERSE

MU Topic 2: Cosmic Matter in the Laboratory

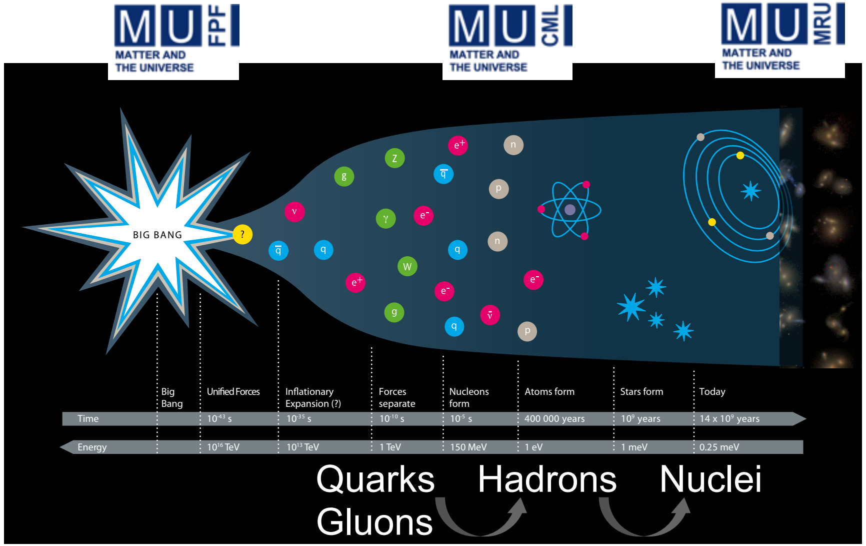
Michael Block (GSI, HIM, JGU)

Topic Speakers: Tetyana Galatyuk and Frank Maas

Cosmic Matter in the Laboratory (CML)

Key contribution to the Helmholtz-Mission:

- Emergence of complex phenomena in strong interaction
- Role of the strong interaction in evolution of our universe



Mission

- Unravel the properties of hadrons; access and understand the QCD spectrum
- Explore strongly interacting systems under extreme conditions of temperature, density, isospin

Strategy

- Study cosmic matter in the laboratory
- Use primary and secondary ion beams from (anti-)protons to uranium
- Apply forefront technologies

Strong link to MT MATTER AND TECHNOLOGIES

Uniqueness

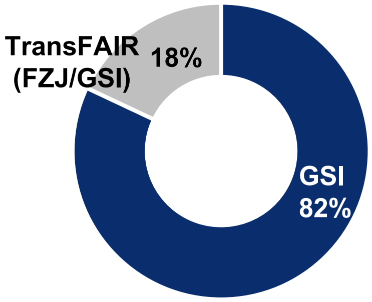
- Relativistic ion beams of highest intensities
- Storage rings for cooled (secondary) beams
- Innovative experiment instrumentation

MATTER AND THE UNIVERSE

Who we are

Budget: 18.9 Mio €/y

People:
82 FTE core-funded scientists
64 FTE doctoral students
22 FTE scientific support



6 ERC Grants
20 joint positions with universities
3 female former HYIG promoted to university professor
6 (co)spokespersons of large international collaborations

Properties of hadrons and their excitation spectrum

Nuclear structure, nuclear reactions, and superheavy elements

Theory

QCD phase structure and properties of QCD matter

Test of fundamental symmetries

User facilities and instruments available for FAIR Phase 0

MU ion facilities and experimental setups

Nuclear structure, nuclear reactions, and super-heavy elements

- UNILAC p to U beams up to 11.4 MeV/u
- heavy ion storage ring ESR
- fragment separator FRS
- heavy-ion synchrotron SIS18

Properties of hadrons and their excitation spectrum

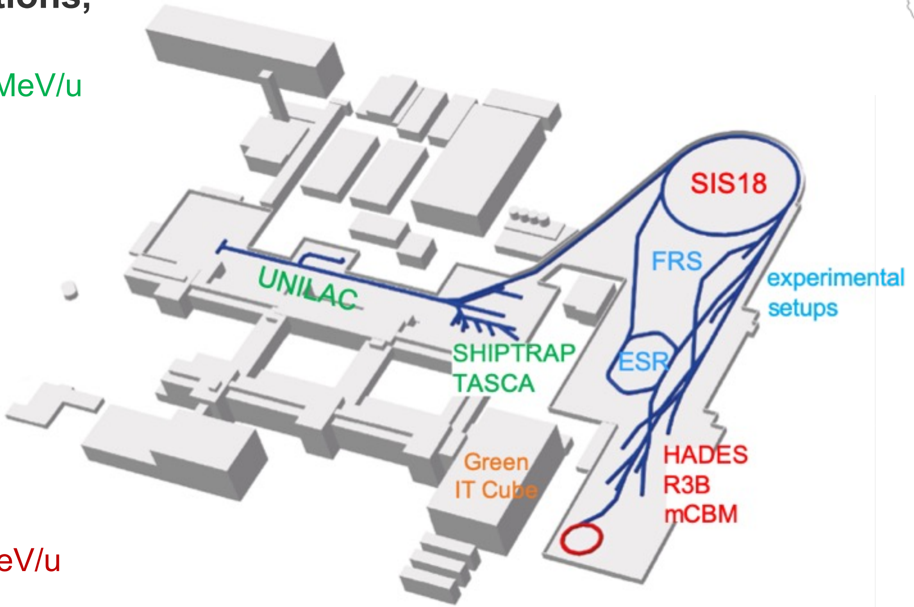
- SIS18 π, p beams up to 4.5 GeV

QCD phase structure and properties of QCD matter

- SIS18 heavy-ion beams up to 1 GeV/u

Scientific high-performance computing

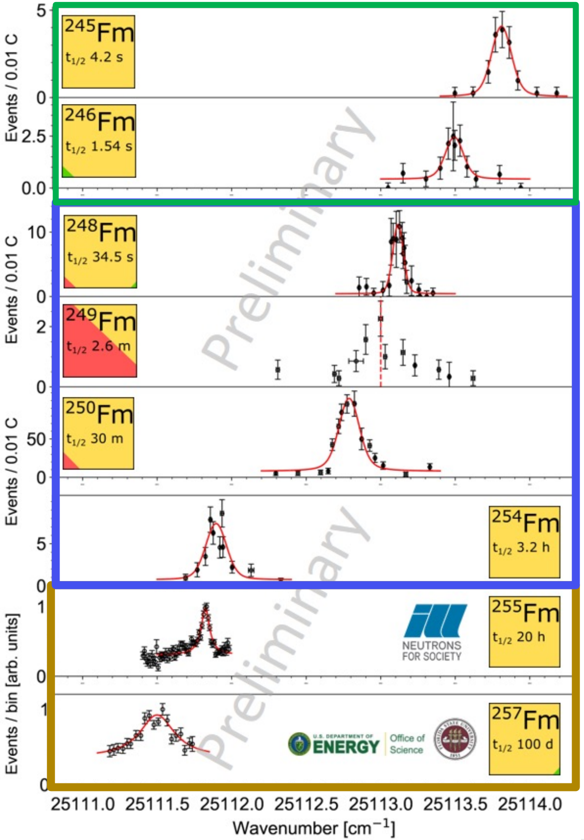
- GSI, HIM, FZ Jülich, KIT



FAIR Phase 0 outside campus:
LHC / CERN
AD / CERN
BEPCII / China
GANIL / France
COSY / Germany
MAMI / Germany
TRIGA / Germany
RIKEN / Japan
CEBAF / USA
RHIC / USA

Cosmic Matter in the Laboratory -
Recent Achievements and Highlights
including the FAIR Phase-0 Beamtime 2022

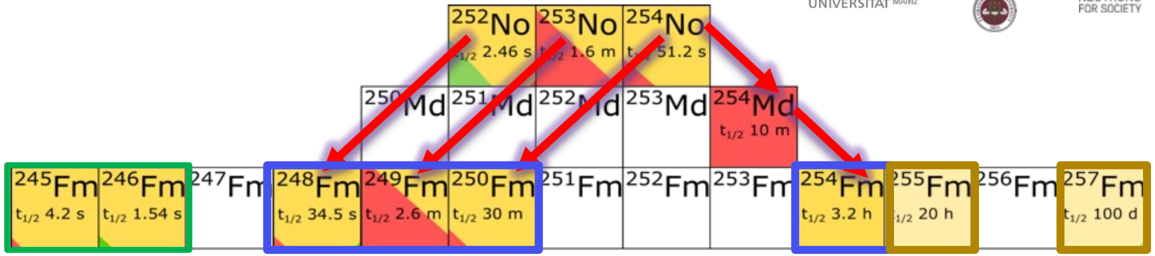
Beam time achievement
Laser spectroscopy of Fm isotopes



Long isotope chain studied in Fm across N=152

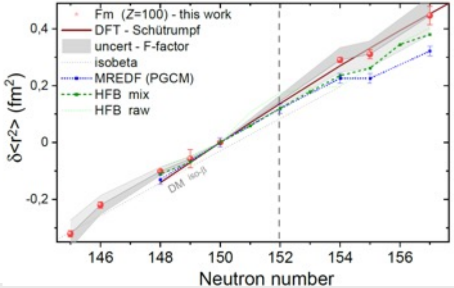
- indirectly produced from nobelium decay
- direct production with Ar beam
- off-line isotopes – *in collaboration with*

(FAIR Phase 0 Research Program; JOHANNES GUTENBERG UNIVERSITÄT MAINZ; OAK RIDGE National Laboratory; NEUTRONS FOR SOCIETY)



Data evaluation for nuclear charge radii ongoing - nuclear theory support by

B. Bally, M. Bender, S. Goriely, S. Hilaire, W. Nazarewicz, S. Peru, P.G. Reinhard



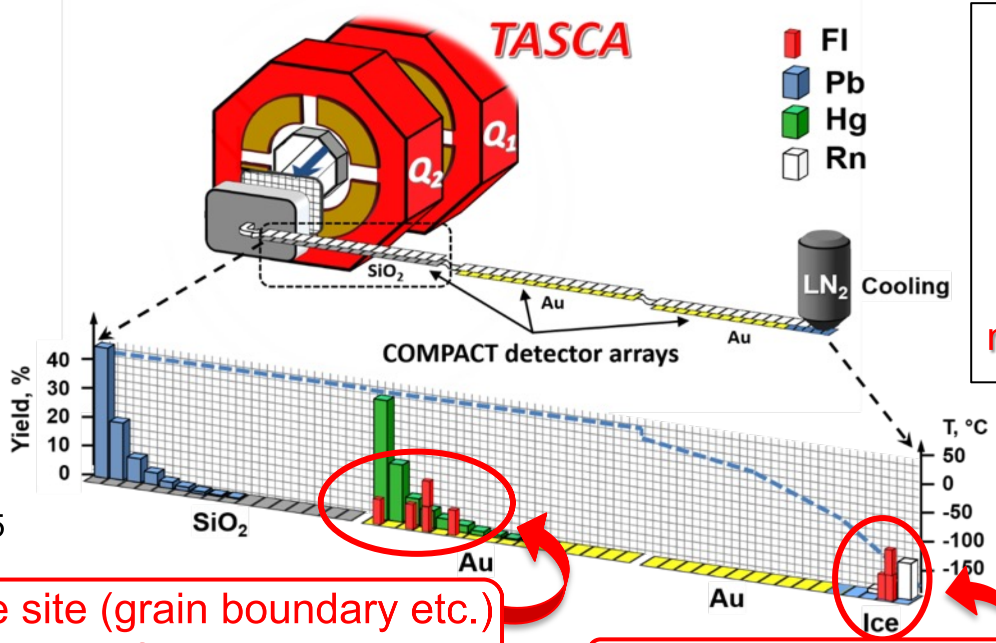
Highlight
Chemical properties of element 114, flerovium elucidated at GSI/FAIR

- Flerovium: heaviest element with experimentally studied chemical properties
- Eight registered atoms in three beamtimes of total 2.5 months duration

Production:
$^{244}Pu(^{48}Ca,3\text{-}4n)$
^{288}Fl: $t_{1/2}$ ~0.7 s
^{289}Fl: $t_{1/2}$ ~2.0 s

Isolation in **TASCA**; Chemical study and detection: COMPACT

A. Yakushev *et al*., Front. Chem. 10 (2022) 976635



Volatility:
Rn > **Fl** > Hg >> Pb

Reactivity:
Rn < **Fl** < Hg << Pb

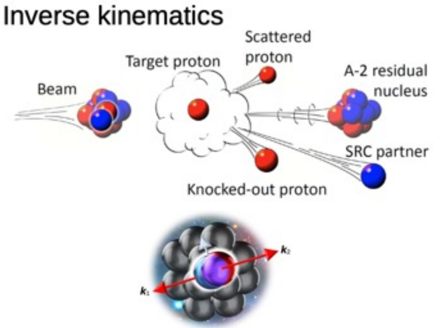
Fl is the most volatile metal in the periodic table

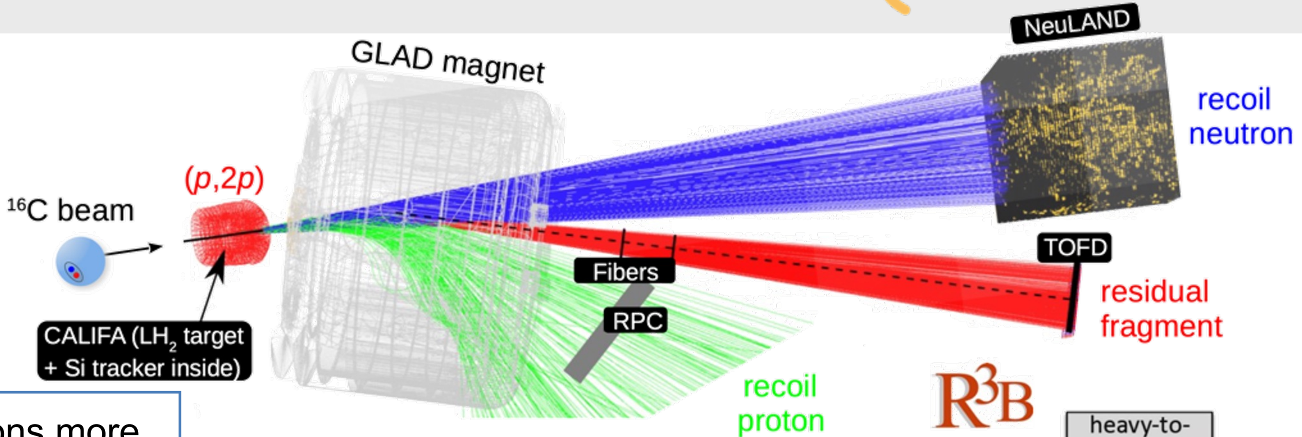
Atoms hitting a reactive site (grain boundary etc.) on the inhomogeneous Au surface bind like Hg

Other atoms reach location of Rn adsorption

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

Beam time highlight
R3B: Short-range correlated nucleons in n-rich nuclei





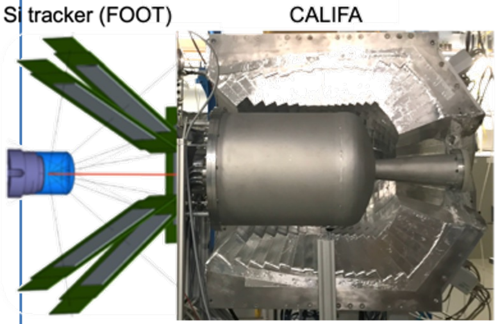
JLAB (e+A) conclusion: Protons more correlated in neutron-rich, stable nuclei

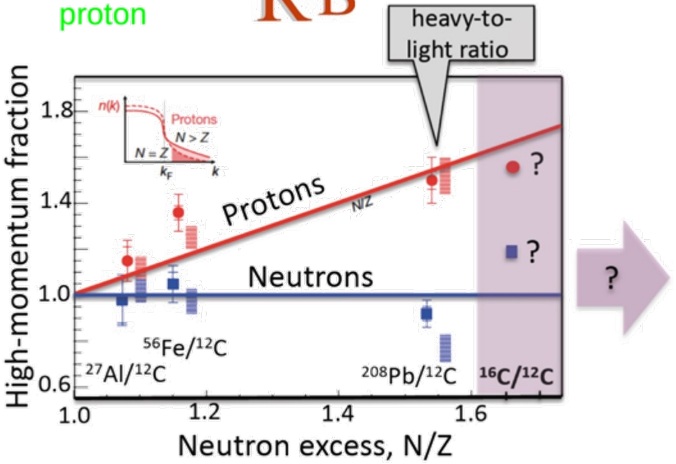
Open questions

- effect of mass ratio or asymmetry?
- development towards large N/Z

FAIR Phase-0 experiment at R3B

- changing N/Z at similar mass
- kinematically complete measurement using ^{12}C, ^{16}C beams
- A. Corsi et al.





Beam time highlight
Nuclear spectroscopy: First full β-strength measurement

Investigation of the beta strength crossing N=126 and the formation of the 3rd r-abundance peak

Improved performance

- Modular detector: **18 NaI** crystals 15 x 15 x 25cm^3
- Standalone DACQ **‘GASIFIC’**
- Full integration into the **FAIR MBS** DAQ system

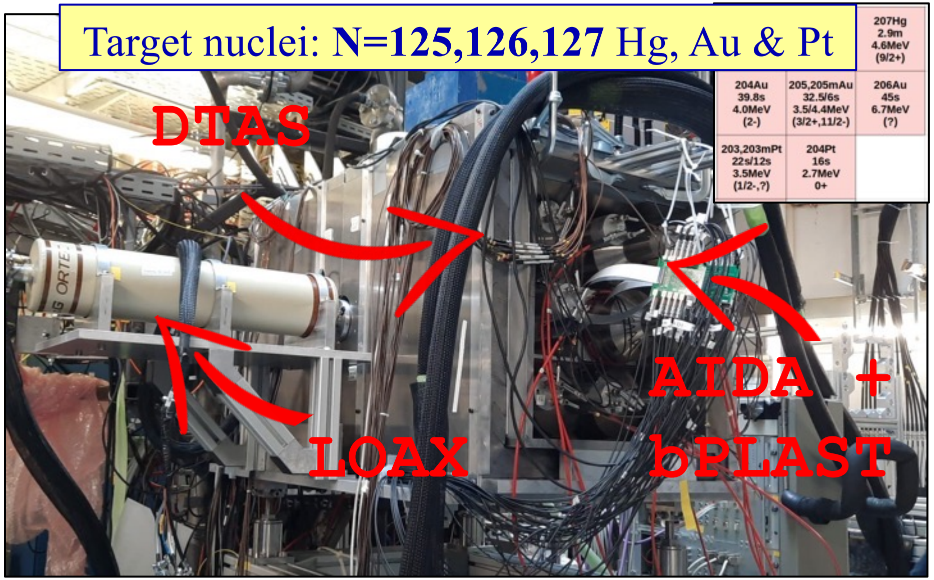
- **Improved analysis** of β intensity distributions
- Conventional spectroscopy of **very exotic species**

Scientific highlights

- **Uniqueness of the FRS+DTAS setup**: First full β-strength measurement of neutron-rich nuclei across N=126 in the world.

Target nuclei: **N=125,126,127** Hg, Au & Pt

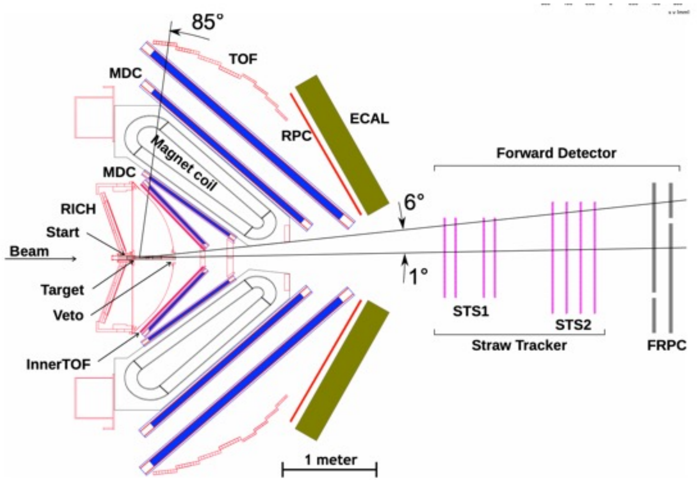
		207Hg 2.9m 4.6MeV (9/2+)
204Au 39.8s 4.0MeV (2-)	205,205mAu 32.5/6s 3.5/4.4MeV (3/2+,11/2-)	206Au 45s 6.7MeV (?)
203,203mPt 22s/12s 3.5MeV (1/2-,?)	204Pt 16s 2.7MeV 0+	



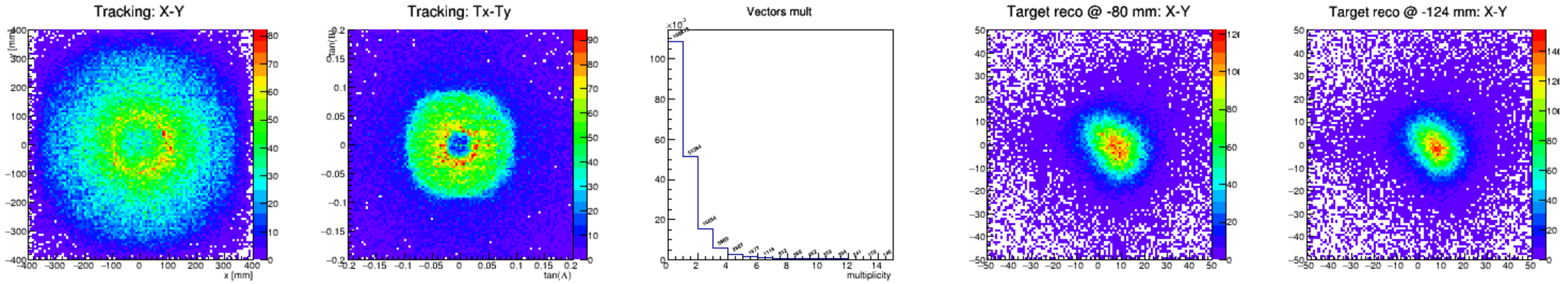
- **β-strengths provide information on β decay matrix element:** better suited to understand discrepancies in β half-lives across N=126 observed in RISING

Spokespersons: **Tain, Morales, Nacher**

Beam time achievement
HADES



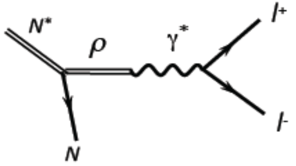
- Tracking of forward going protons with straw trackers (PANDA technology)



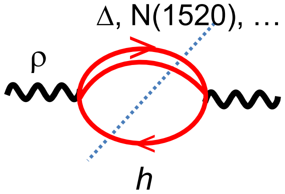
Highlight
HADES Pion Induced Reactions

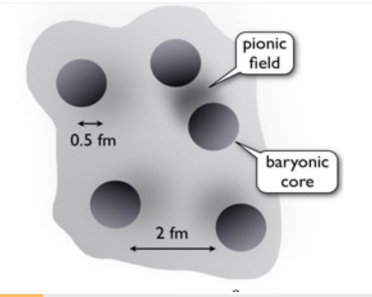
$$\pi^- + p \rightarrow e^+e^- + n$$

- Effective transition form factor (time-like) extracted by subtracting QED expectation from exclusive invariant mass distribution.
  - Resonance-Dalitz decay …

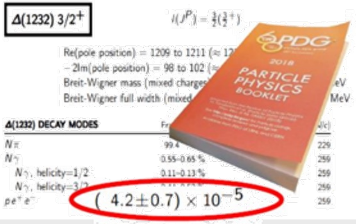


… is analogous to baryonic contribution to in-medium ρ self energy

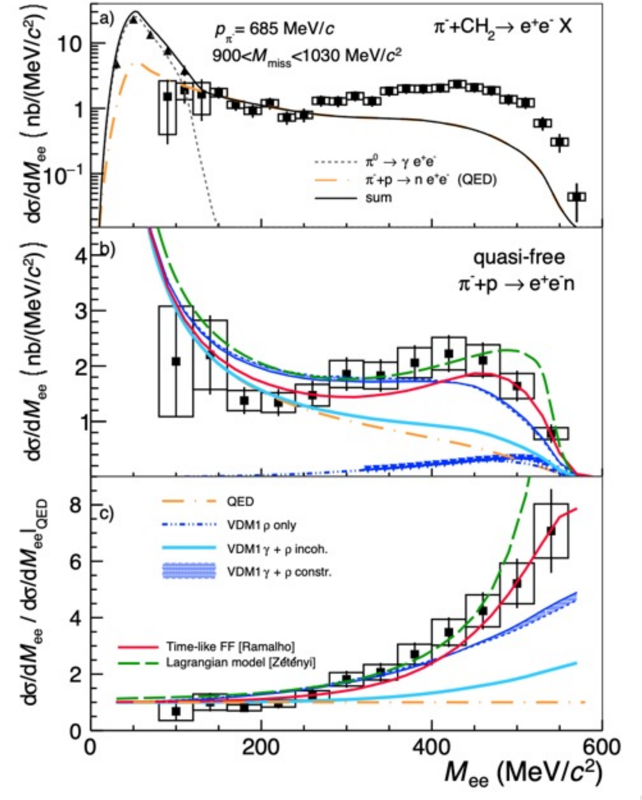




Eight new PDG entries, also from analysis of hadronic final states (PWA)



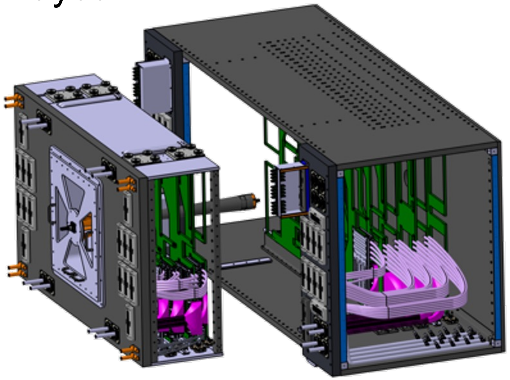
HADES arXiv:2205.15914 [nucl-ex]



Highlights and achievements
CBM Silicon Tracking Stations (STS)

Modified Detector Layout

- Potentially no delivery of CBM dipole magnet from Budker institute
- New magnet (design) allows for optimized detector layout

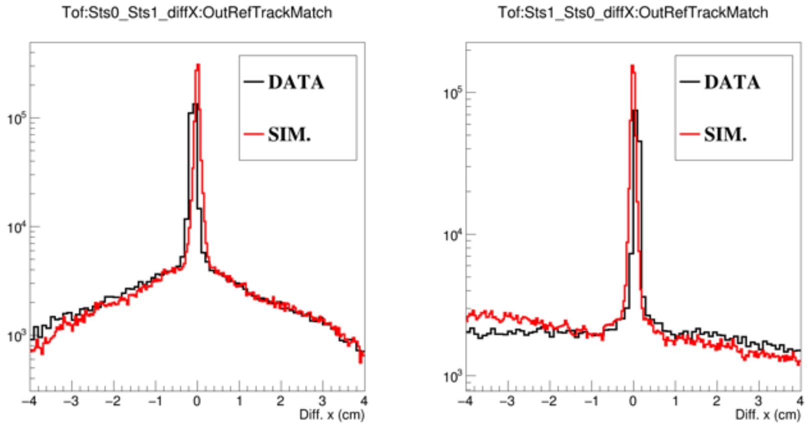


Separation of CBM STS in 3 + 5 stations

- Upgrade of upstream detectors more easily possible

miniCBM results

- Layout of miniSTS includes two tracking layers

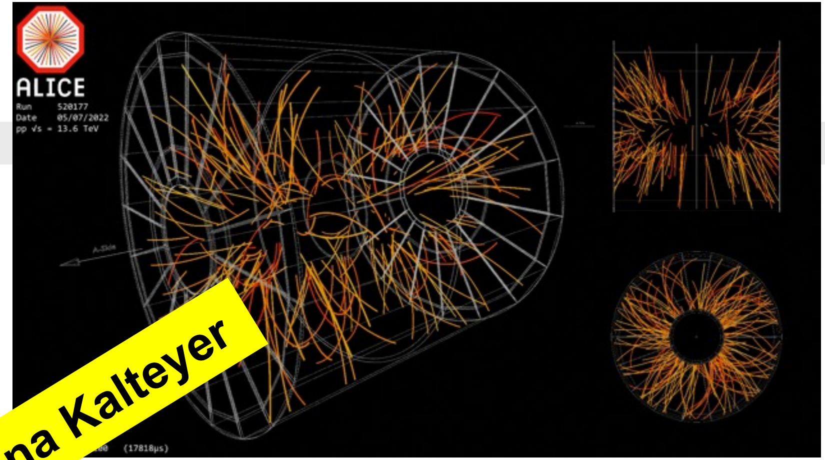


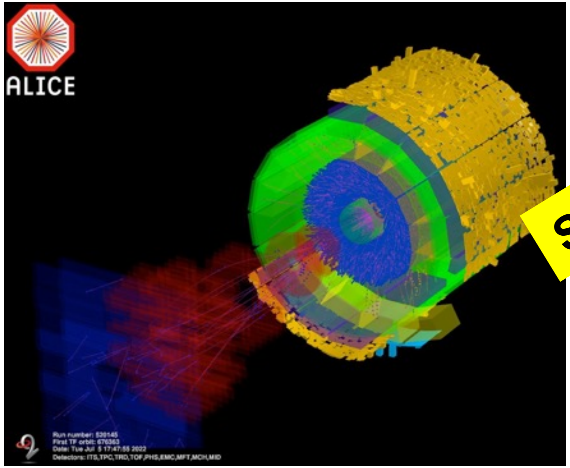
Residuals in X between extrapolated and reconstructed hits in ST1 and ST2

- Performance observed so far shows that targeted STS system can be constructed in line with expectations

Highlight
ALICE LHC Run 3 started

LHC at CERN:
operation restarted on July 5, 2022
Proton-proton collisions at 13.6 TeV

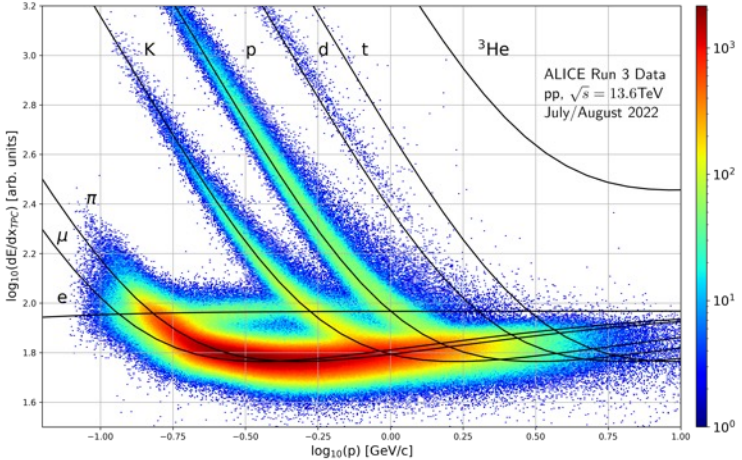




Upgrad… he
Proj… Chamber

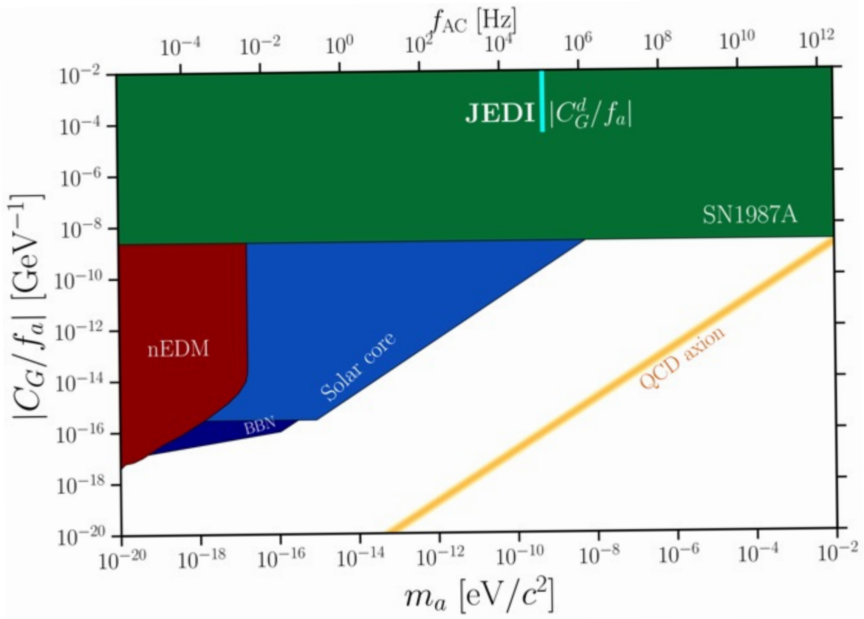
See flash talk by Annalena Kalteyer

- …inuous readout
- Particle identification
- Readout concept similar to the one of CBM and PANDA



Highlight
Search for Dark Matter at COSY

arxiv:2208.07293: *“First Search for Axion-Like Particles in a Storage Ring Using a Polarized Deuteron Beam”* published by JEDI collaboration



Limits on axion nucleon coupling constant

- New method to search f… rk matter particles establish… COSY
- Use of polar… deuteron beam
- Meth… be further exploited at E… ryring at GSI

See flash talk by Karanth Swathi

Recent Results from Borexino

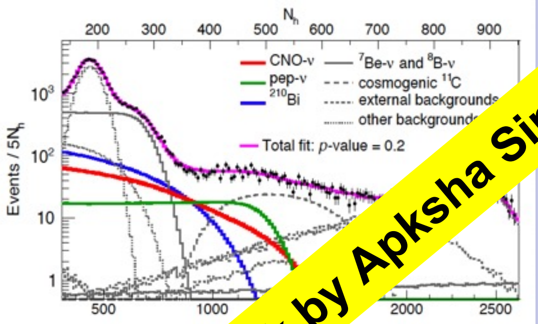
New CNO solar neutrino measurement with the complete Phase III

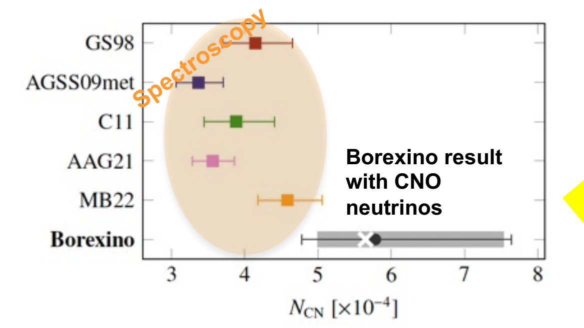
Released at Neutrino 2022 (June 2nd) + accepted for publication in PRL

CNO fusion confirmed with 7σ CL

$R_{CNO} = 6.7^{+2.0}_{-0.8}$ counts/(day*100ton)

CNO flux is sensitive to the C+N abundance in the solar core.



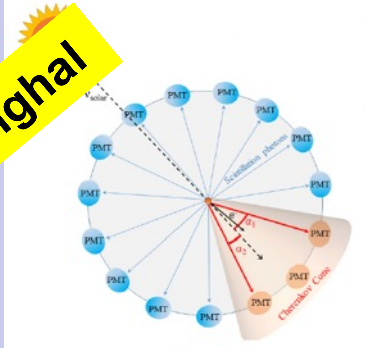


2σ t[...] with low [...]icity [...]ctroscopy [...]easurements, agreement with the high metallicity ones.

See flash talk by Apksha Singhal

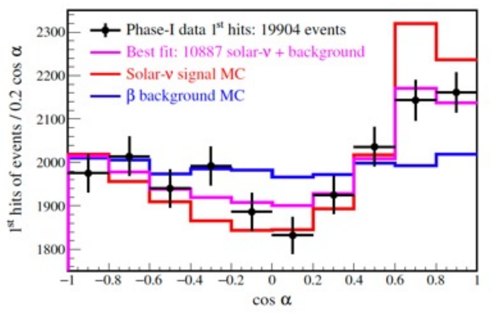
First directional measurement of sub-MeV solar neutrinos

PRL 128 (2022) 091803 + PRD 105(2022) 052002.



Using the subdominant **Cherenkov light**, that is fast and directional, we **recognized (>5σ) the solar neutrino signal** correlated with **the known position of the Sun.**

Cos(α) distribution of the 1st hits of 19904 Phase I events around **the ^{7}Be solar ν edge**



Erwin Schrödinger Prize 2021

HELMHOLTZ

An interdisciplinary research award presented by the Hermann von Helmholtz Association of German Research Centres

- Breakthrough in nuclear magnetic resonance and magnetic resonance imaging for applications in medicine, e.g., cancer diagnostics and evaluation of efficacy of therapies
- demonstrated how to produc… …cant amounts of chemically clean hyperp… …d molecules, ready for biomedical use in … …eveloped MRI contrast agent

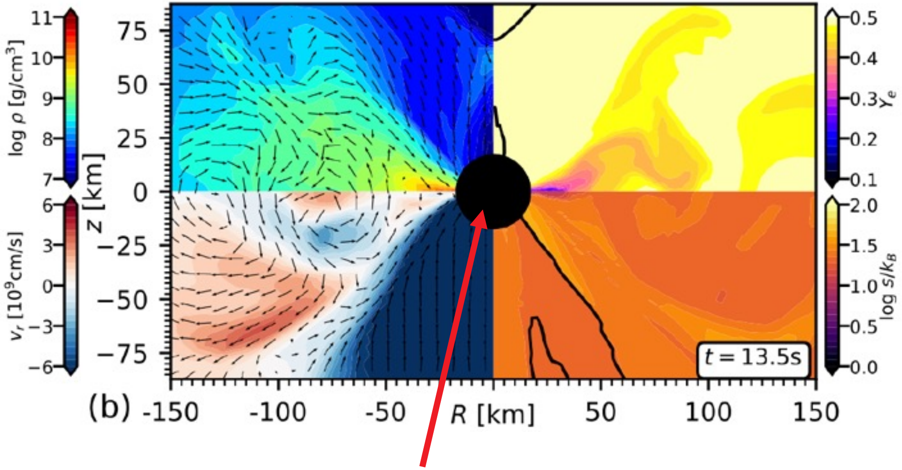
See flash talk by D. Barsky

Awardees:

- **Dmitry Bu…er, James Eills, John Blanchard, Danila Barskiy (HIM)**
- Kerstin Münnemann (Uni Kaiserslautern)
- Francesca Reineri, Eleonora Cavallari, Silvio Aime (Uni Turin)
- Gerd Buntkowsky, Stephan Knecht (TU Darmstadt)
- Malcolm H. Levitt, Laurynas Dagys (University of Southampton)

Collapsars as r-process sides

- Collapsar: collapsing massive star forming a black-hole torus
- Outflows from these tori are potential sites for element production through rapid neutron capture process
- New simulations of theory group:
  - viscous hydrodynamics simulation with detailed neutrino transport
  - start from massive stellar progenitor
  - torus evolution followed with detailed outflow properties
- Inefficient r-process sites in these modes
- Not considered magnetohydrodynamic effects may increase r-process prospects



Black hole

Just et al., Astrophys. J. Letters 934, L30 (2022)

Summary

- Many highlights in all areas
- FAIR phase-0 very successful
- Upgraded TPC in ALICE successfully used in LHC run 3
- many synergies of technical / methodological developments

CML produces great science and makes good progress towards achieving milestones

THANK YOU FOR YOUR ATTENTION!

THANKS TO ALL PEOPLE PROVIDING SLIDES!

Photo: C. Betz