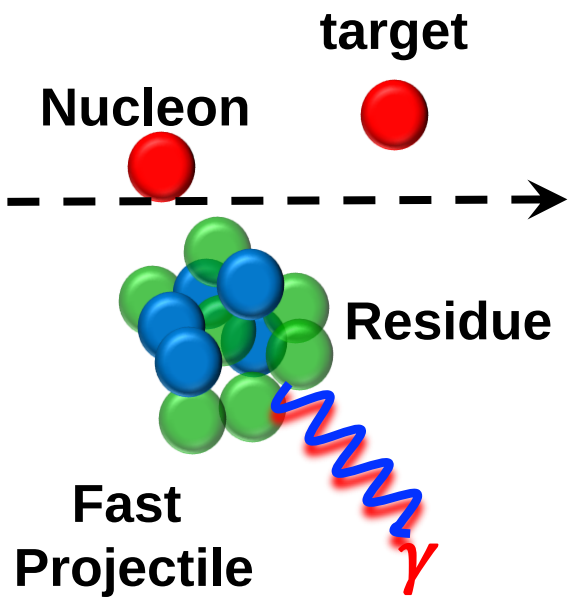
Hypernuclei studies with R^3B

Yelei Sun
CEA Saclay

May 18th 2017

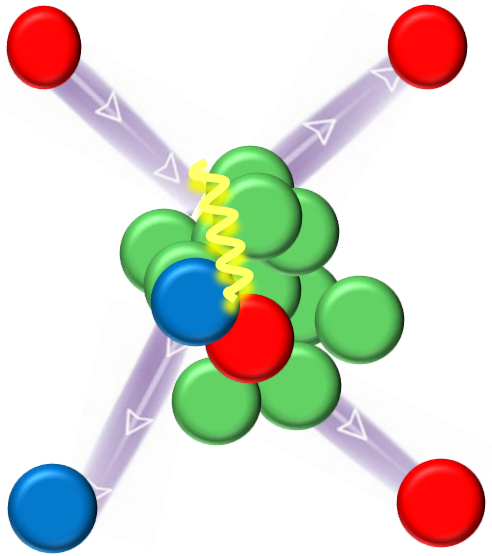
Interests at FAIR

Spectroscopy of exotic nuclei



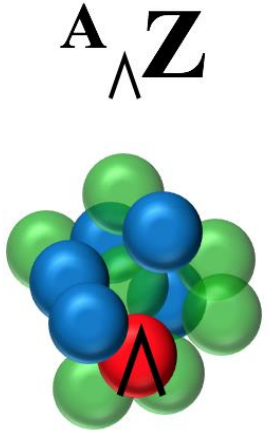
$(p, 2p\gamma)$

Short range correlation in exotic nuclei



$(p, 3p)$ or $(p, 2pn)$

Exotic hypernuclei production

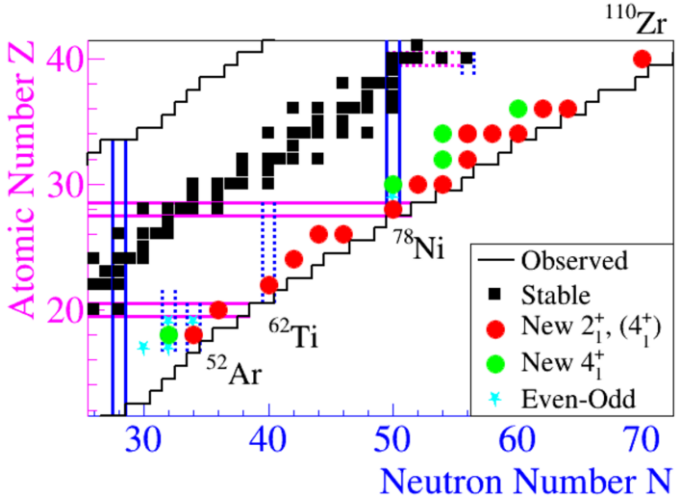


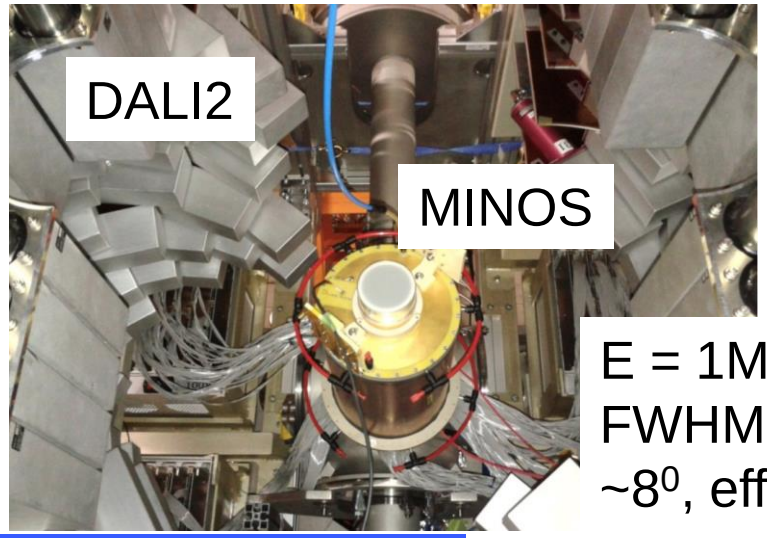
$(p, p'\Lambda)$

Interests at FAIR/HISPEC

SEASTAR1&2&3

MINOS + DALI2 at RIKEN/RIBF

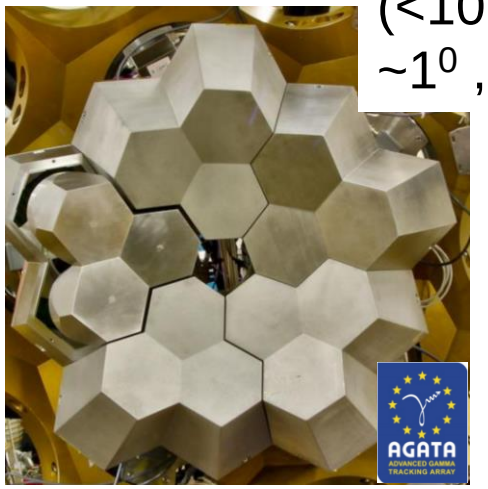




E = 1MeV, β=0.6
FWHM=100keV
~8^0, eff=20%

SEASTAR3 finished at 14th May, 2017

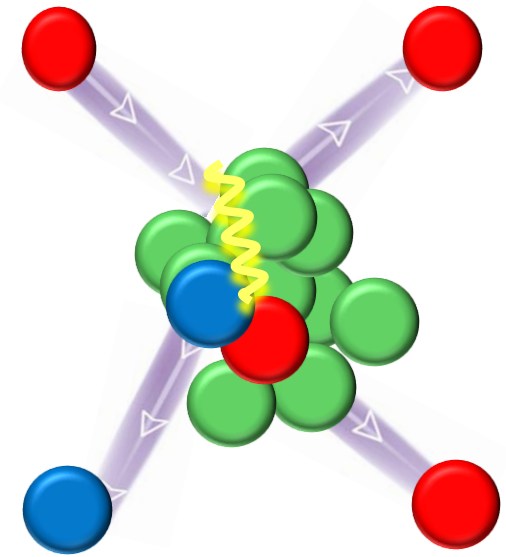
Spectroscopy of rare isotopes
1) heavier nuclei 2) odd-A nuclei
3) γ-γ angular correlation 4) lifetime…
Use MINOS-like device to fully exploit AGATA capabilities
at low beam intensity.



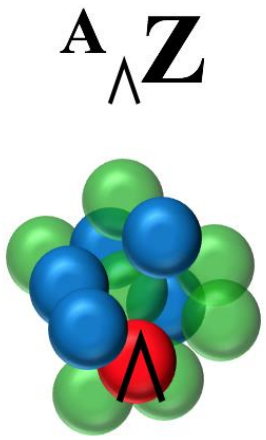
High resolution
(<10keV,
~1^0 , 43%(4π))

Interests at FAIR/R³B

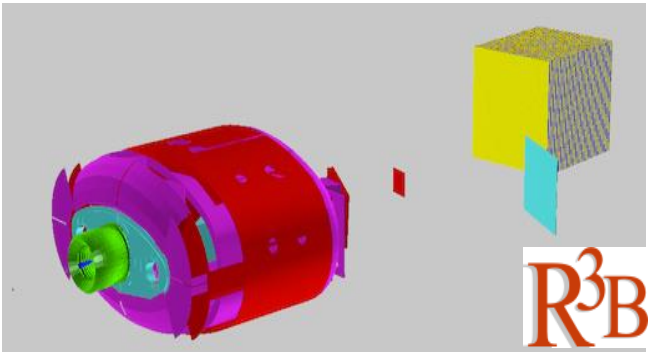
Short range correlation in exotic nuclei



Exotic hypernuclei production



Both with hydrogen target



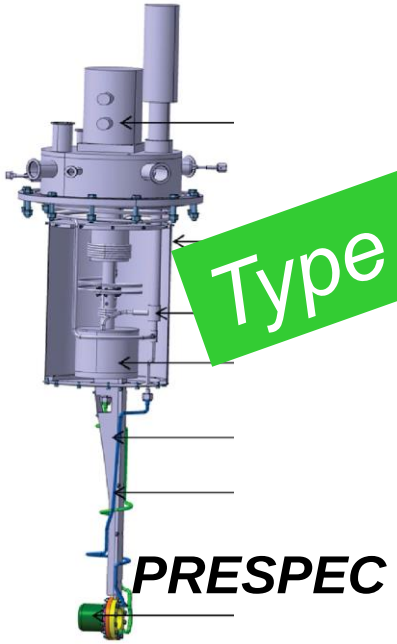
Super-FRS:
Maximum Bρ 20Tm
(^{12}C, 2.2AGeV)

GLAD:
Bρ 5Tm
Acceptance ±2.5%
ΔBρ/Bρ~10^{-3} (σ)

State of the art – Hydrogen targets at CEA/IRFU

1990-1997 at Saturne Laboratory, Saclay
1995-1997 at Jlab/POLDER, CLAS (150 mm)
1996-2000 at GSI/FRS1 (10 mm) 1999-2004 at GSI/FRS2
2006-2007 at GSI/Spallation (6 micron window)
2011- at GSI/SOFIA (10 mm, 35 micron window)

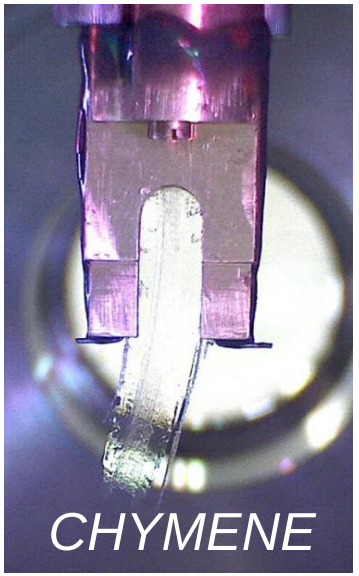
Type fit for R^3B



2011 at GSI
(50 mm, 150 μm windows)

2014-now at RIKEN
(100-150 mm, 150 μm window)

A. Obertelli et al., Eur. Phys. Jour. A 50, 8 (2014)



Windowless solid hydrogen target
(50-200μm)

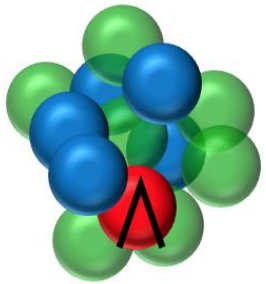
A. Gillibert et al., Eur. Phys. J. A (2013) 49: 155

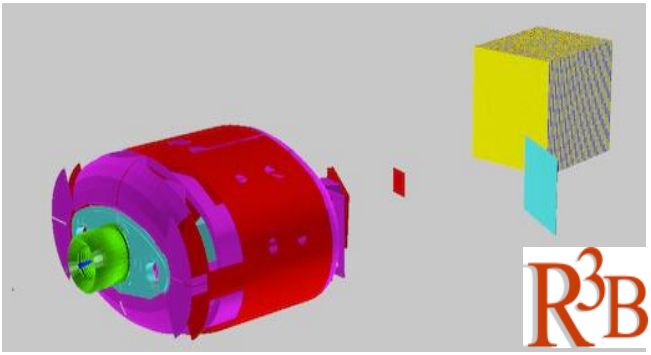
C. Louchart et al., NIM A 736, 81 (2014)

Interests at FAIR/R³B

Short range correlation in exotic nuclei

Exotic hypernuclei production





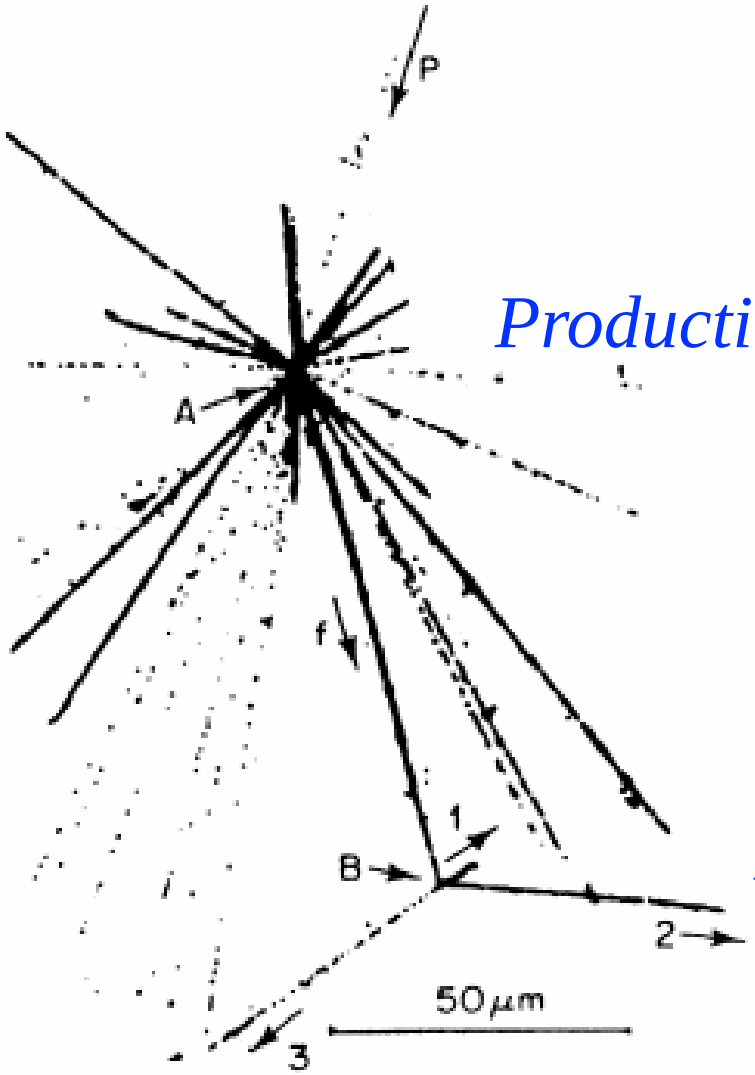
Super-FRS:
Maximum Bρ 20Tm
(^{12}C, 2.2AGeV)

GLAD:
Bρ 5Tm
Acceptance ±2.5%
ΔBρ/Bρ~10^{-3} (σ)

Both with hydrogen target

Discovery of Hypernuclei

Marian Danysz (right) and
Jerzy Pniewski (left)



Production

Decay

Danysz, M., Pniewski, J., Phil. Mag. 44, 348 (1953)

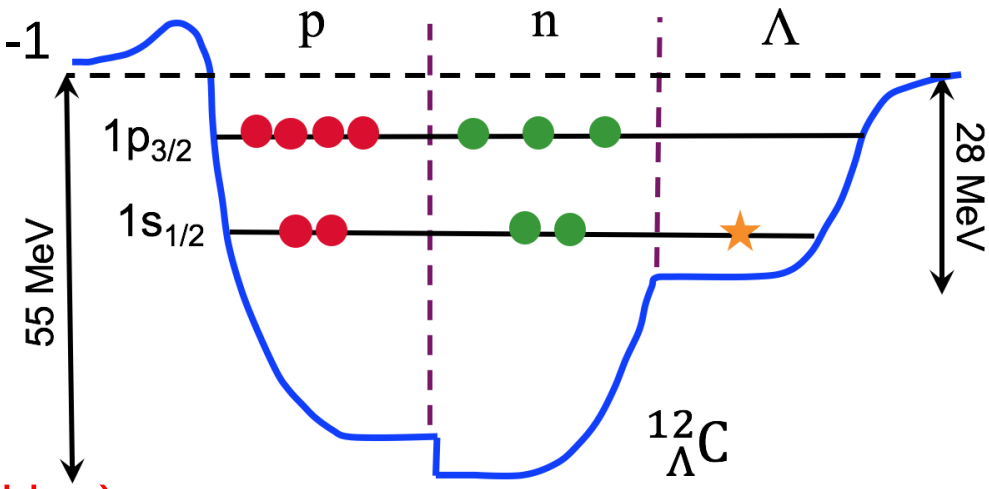
Λ: M = 1116MeV

Physics of Hypernuclei

free Λ: M = 1116MeV, τ = 263ps, S = -1

ΛN, ΛNN Interaction…

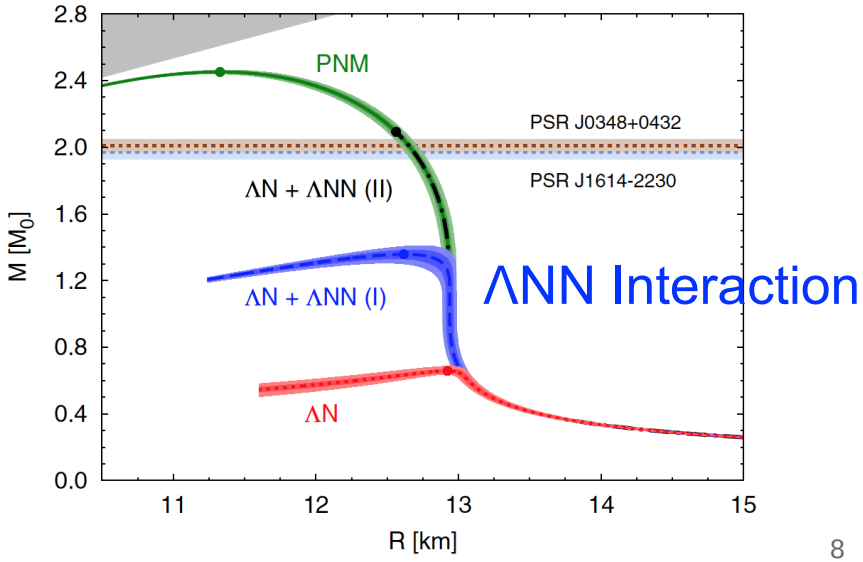
- **Very difficult for scattering experiment**



Λ-Hypernuclei

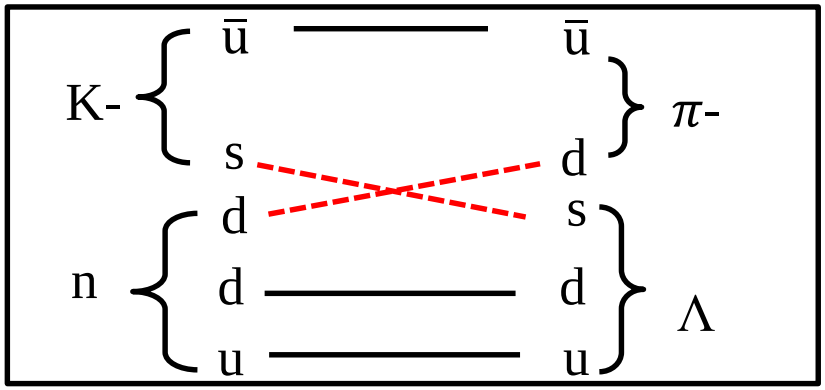
- New effects(glue-like, no Pauli blacking)
  - → Changes of drip line, 3D nuclear chart
  - → Deformation
  - → New Collective mode

- Existence in Neutron star ?
  - →2~3ρ_0

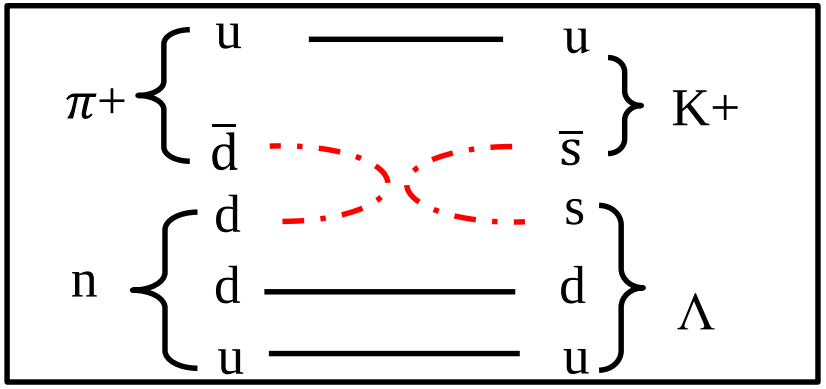


K. Tanida *et al*, PRL. 86 1982-1985 (2001).
K. Hagino *et al*., NPA 914 151-159 (2013).
N. K. Glendenning *et al*., PRL. 67, 2414 (1991)
F. Weber, PPNP 54,193 (2005)
Diego Lonardoni *et al*., PRL 114, 092301 (2015)

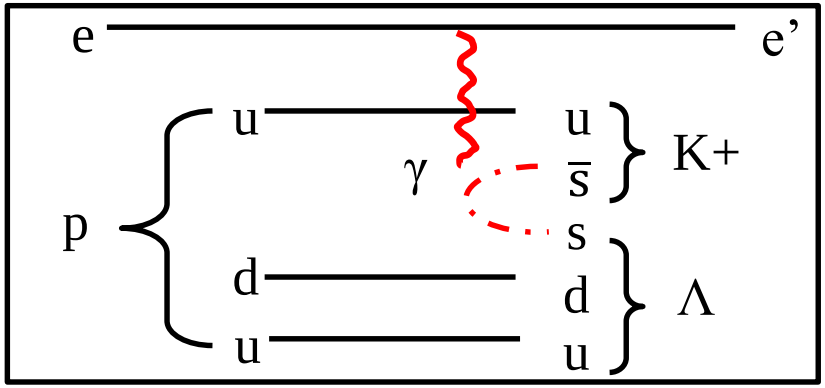
Production of Hypernuclei



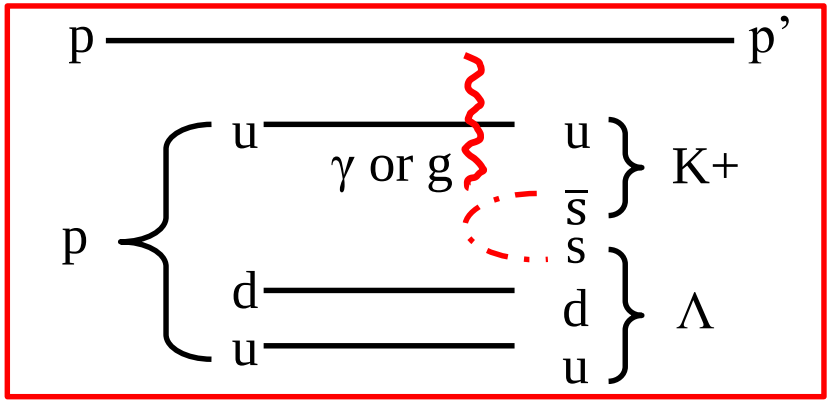
BNL, KEK, INFN(FINUDA) (K-, π-)



BNL, KEK (π+, K+)



Jlab (e, e'K+)

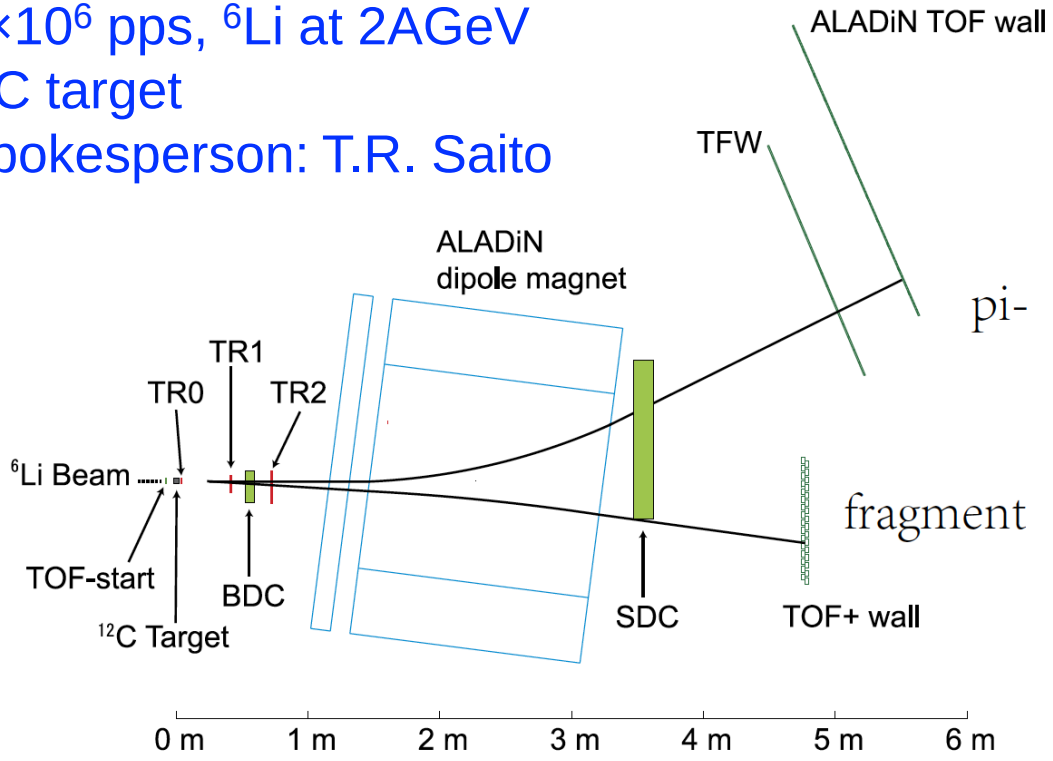


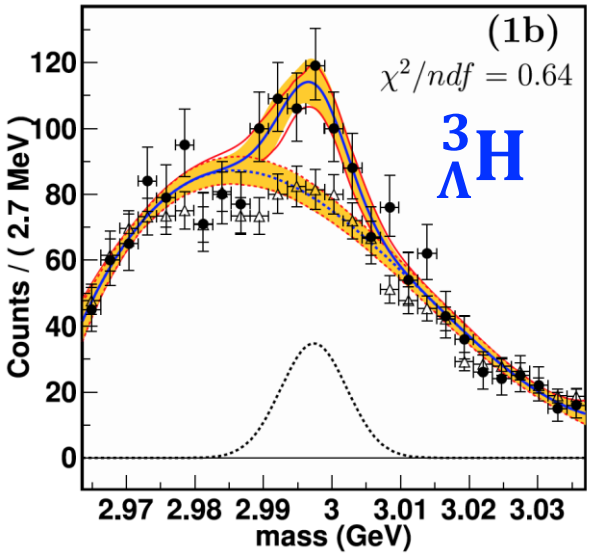
BNL(STAR), GSI(HypHI)
Heavy-ion beam induced reactions

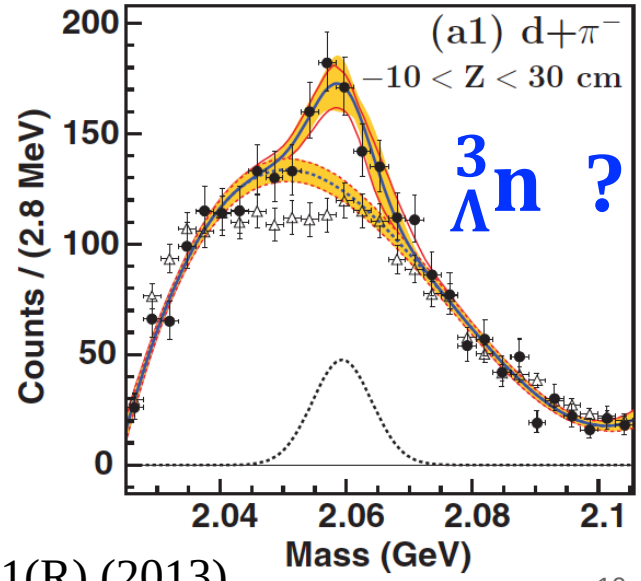
Limited to stability line…

GSI HypHI phase0 experiment

3×10^6 pps, ^{6}Li at 2AGeV
^{12}C target
Spokesperson: T.R. Saito







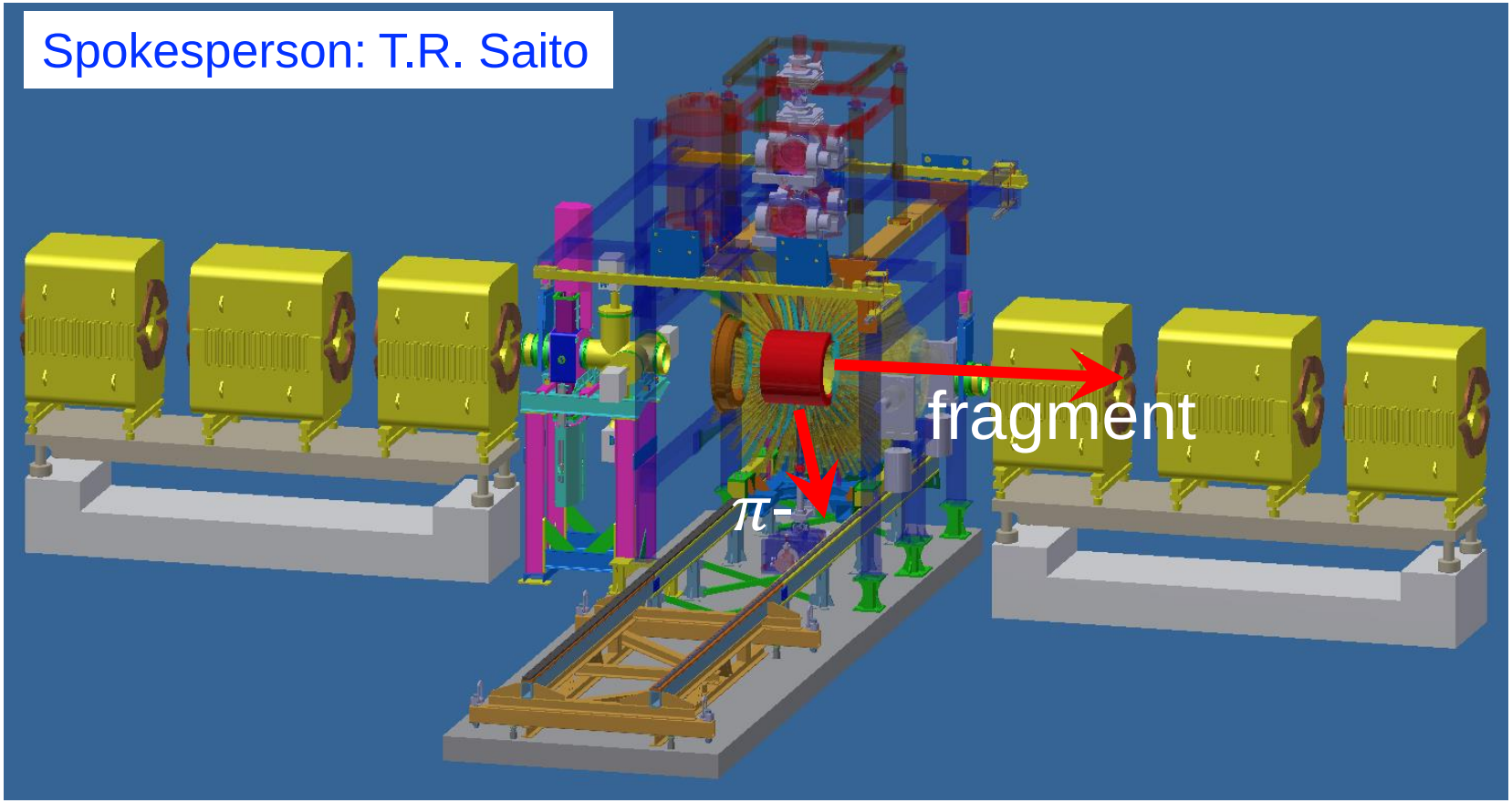
→**Demonstrate the feasibility of heavy-ion induced hypernuclear production.**

$^3_\Lambda$H & $^4_\Lambda$H , Mass and Lifetime

→**Existence of $^3_\Lambda$n ?**

C. Rappold *et al.*, PRC 88, 041001(R) (2013).

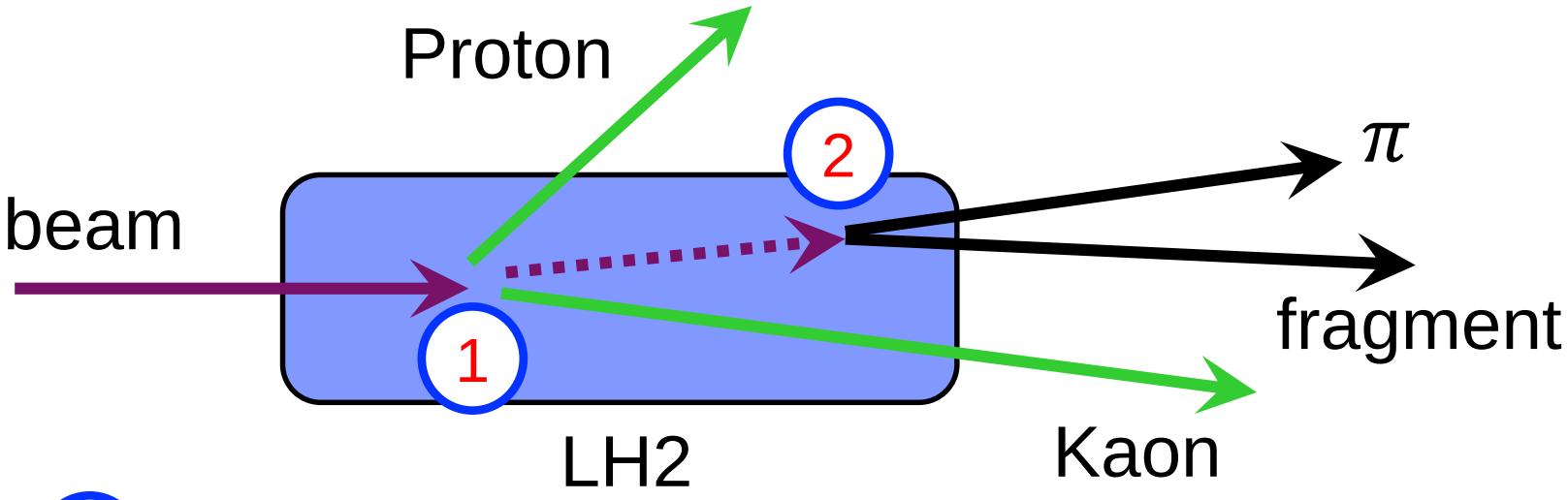
HypHI-FRS-WASA



Proposal (for 2019) with FRS and WASA at FAIR Phase 0:

- To confirm the existence of ${}^{3}_{\Lambda}\mathrm{n}$ bound state.
- To improve the accuracy of the lifetime of ${}^{3}_{\Lambda}\mathrm{H}$ (5σ significance).
- To improve the accuracy of the lifetime of ${}^{4}_{\Lambda}\mathrm{H}$.

Possibility with proton target ?



1 Hypernuclei production. Tagged by Kaon emission.

Hypernucleus progagation

2 Hypernucleus decay.

Tagged by π emission in case of mesonic decay

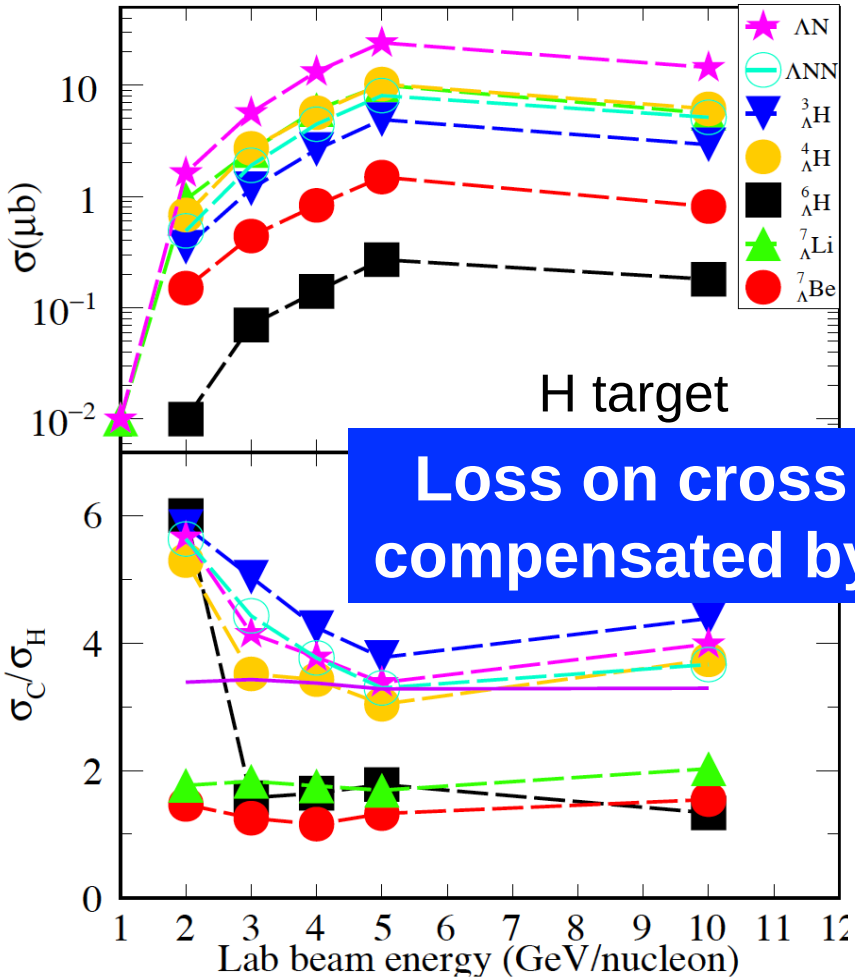
Compared with Heavy-ion target:

1) Higher luminosity; 2) Lower background;
3) Limited energy loss and angle stranggling

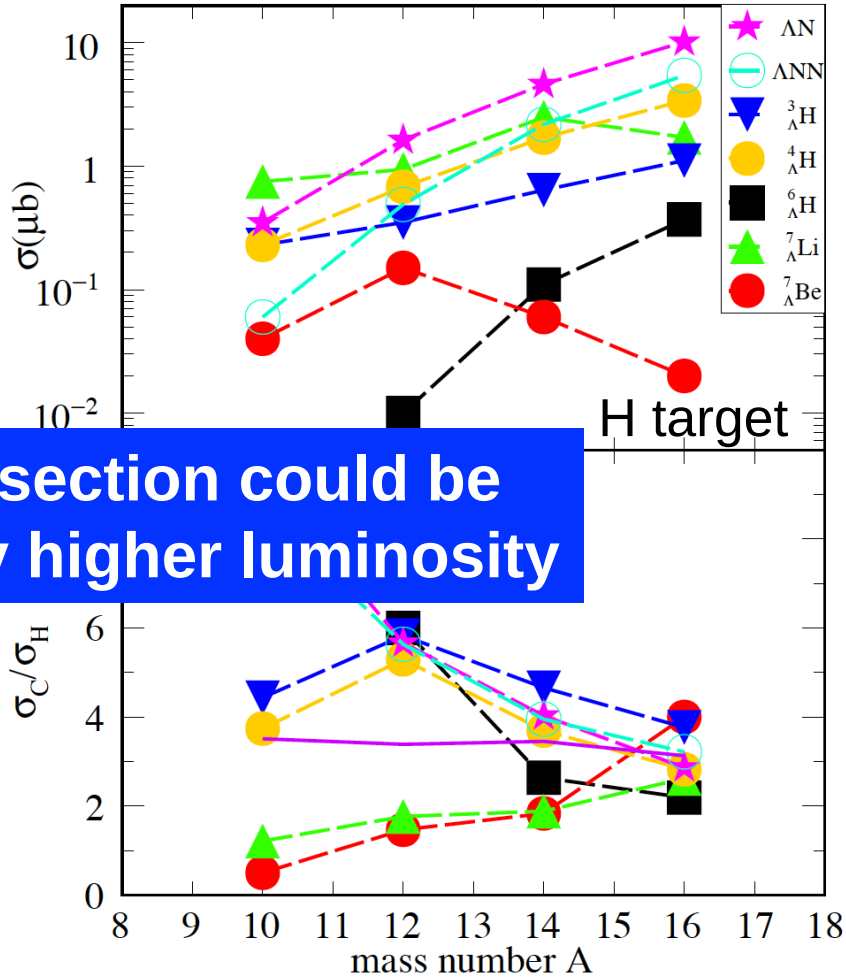
Possibility with proton target ?

Dubna Cascade Cascade (DCM) + Fermi breakup

Collaboration with A. Botvina (FIAS), paper in preparation



^{12}C + proton/^{12}C target
at different beam energies



^{A}C + proton/^{12}C target
at 2AGeV

Loss on cross section could be compensated by higher luminosity

Possibility with proton target ?

Green: background

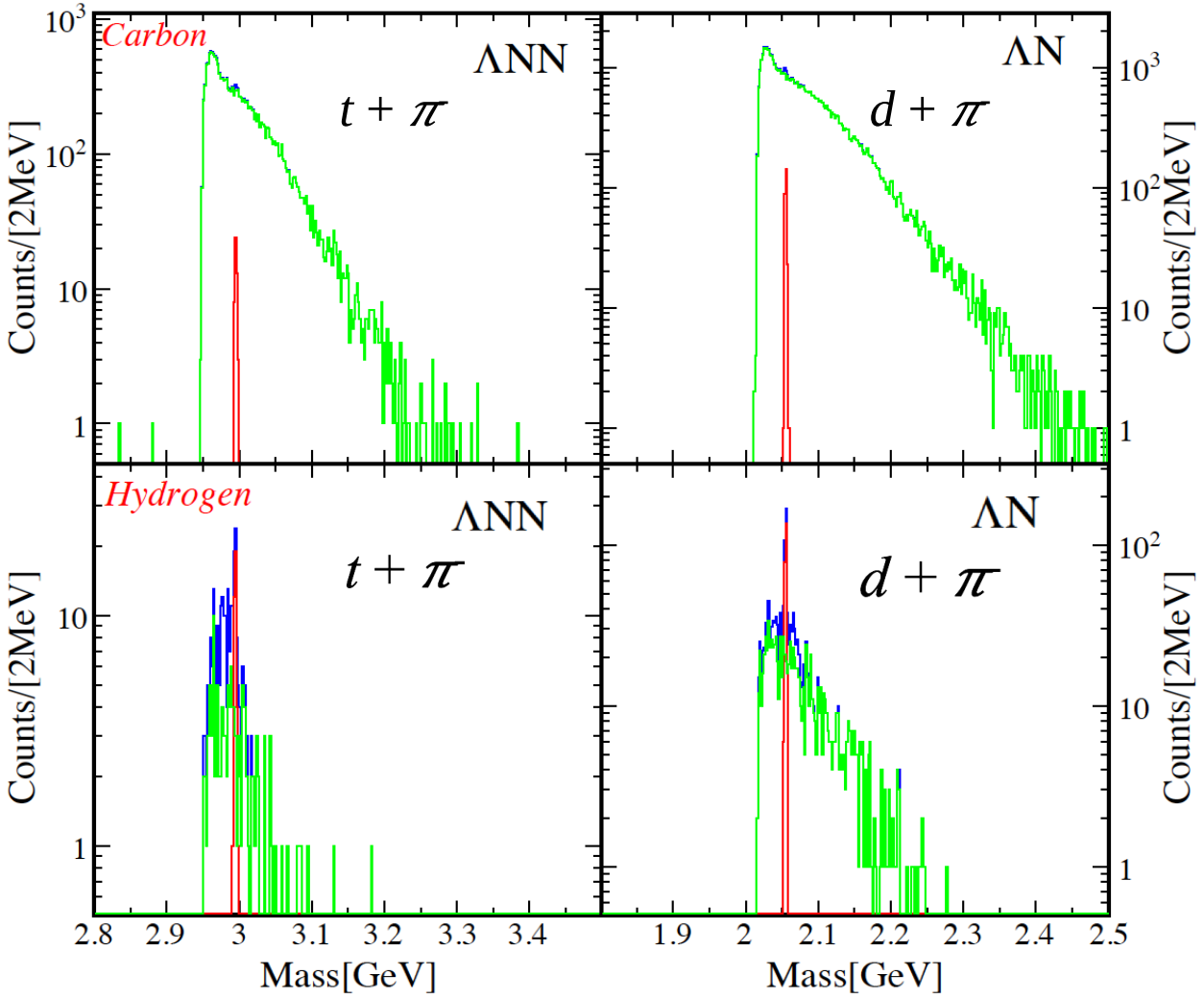
Red: true hypernucle

Blue: all events

DCM + Fermi breakup as event generator

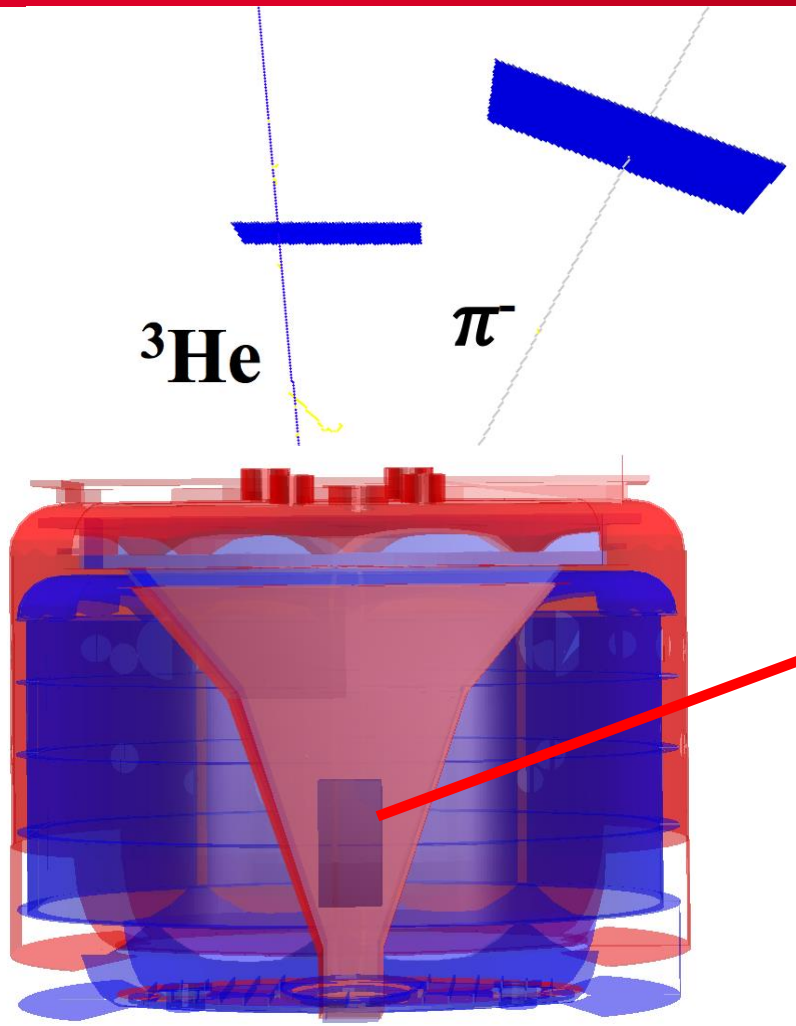
$^{12}C + {}^{12}C$ at 2 AGeV

^{12}C + proton at 2 AGeV

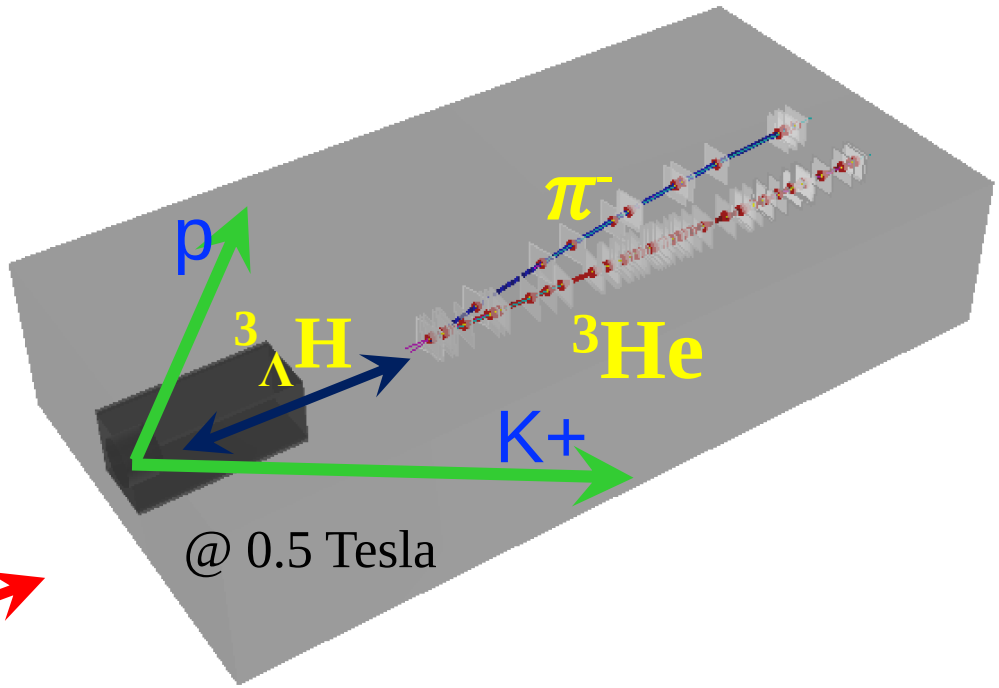


Much better signal-over-background ratio

TPC inside of GLAD ?



Glad



Dimensions to be determined

- TPC for PID & Vertex

Simulation in progress…

→tracking & verticing

- TPC + R^{3}B standard detector to measure momentum for better invariant mass resolution

Agenda

Two working groups established in May, 2017.
LH2 target & TPC

- **LH2**: discussions ongoing for a target in 2019
- **TPC in GLAD around 2024**
  - ❑ Simulations and physics cases in 2017
  - ❑ Detailed solutions with engineers, build collaboration in 2018
  - ❑ Search for funding…
  - ❑ Prototype developement and validation
  - ❑ Physical proposal for R^3B at GSI

The CEA Team

Development and physics

IRFU/SPhN: A. Corsi, A. Gillibert, W. Korten, V. Lapoux, A. Obertelli, E.C. Pollacco, N. Paul, Y. Sun

Target

IRFU/SACM: J. M. Gheller, C. Hilaire

Mechanics and control system

IRFU/SIS: P. Graffin, J.Y. Roussé

Detector & Electronics

IRFU/SéDI: D. Calvet , A. Delbart, A. Giganon

Thank you for your attention !