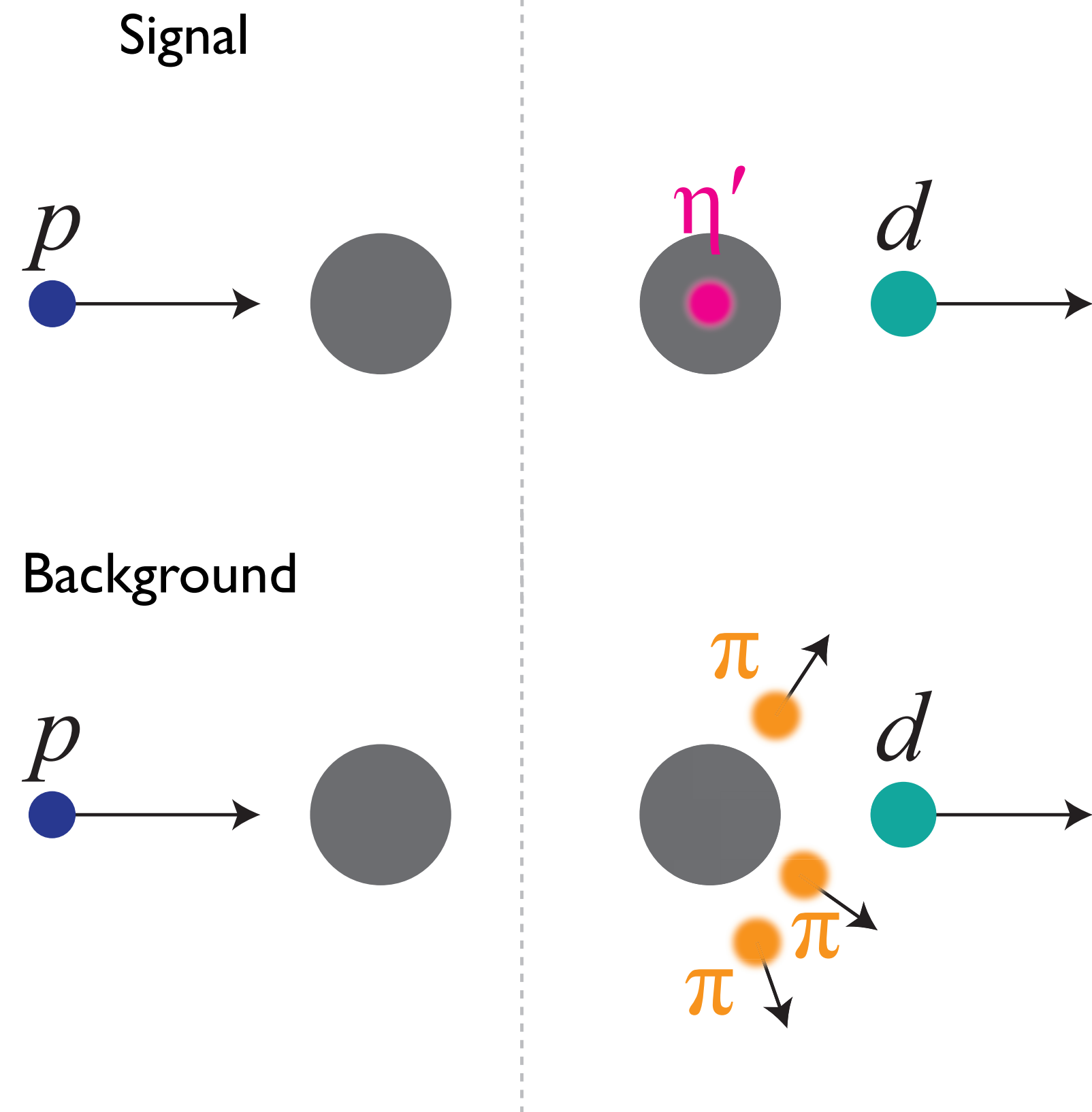


WASA2 (LEPS solenoid) magnet at SPring-8 to be transferred to (Super-)FRS/GSI-FAIR

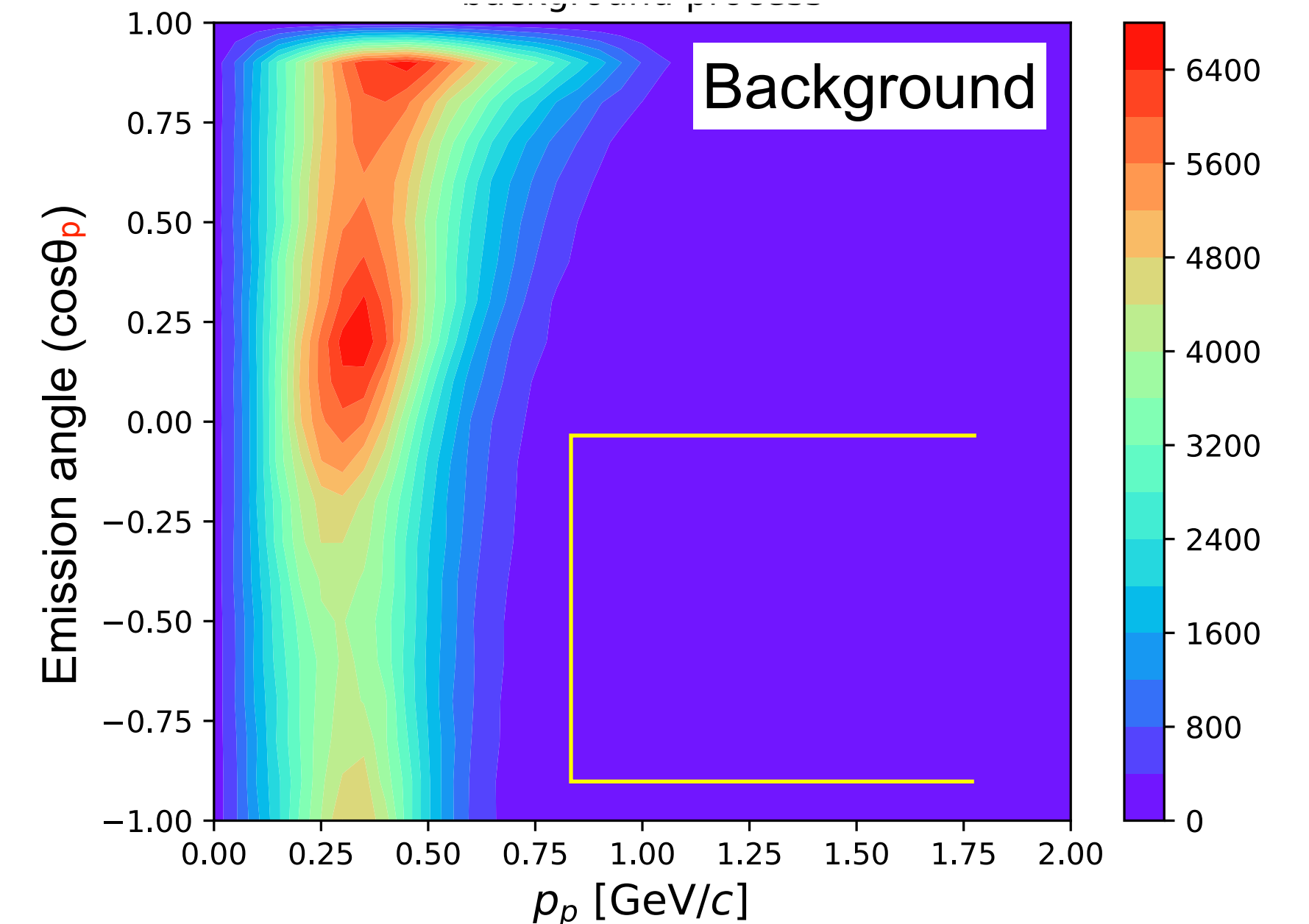
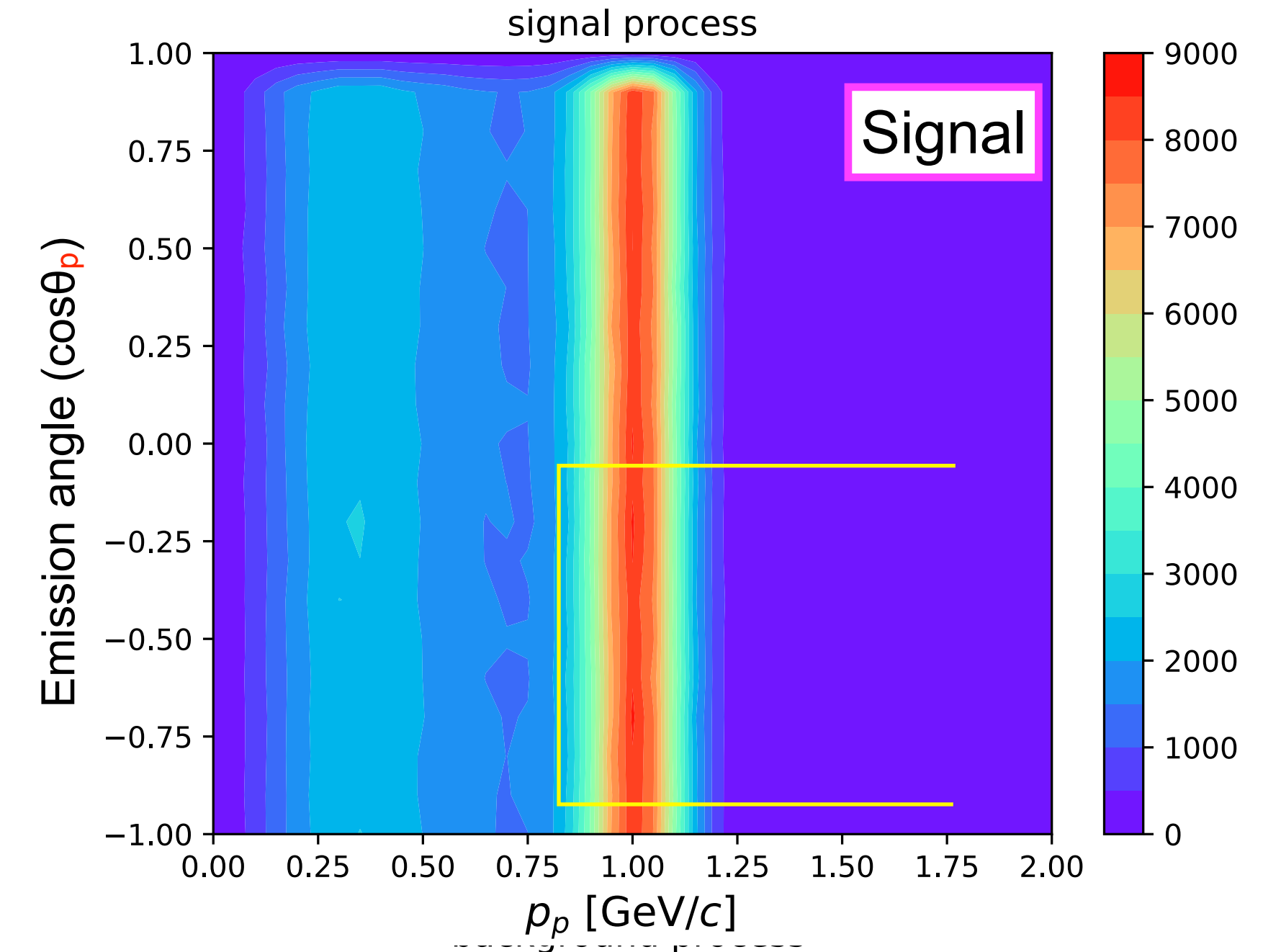
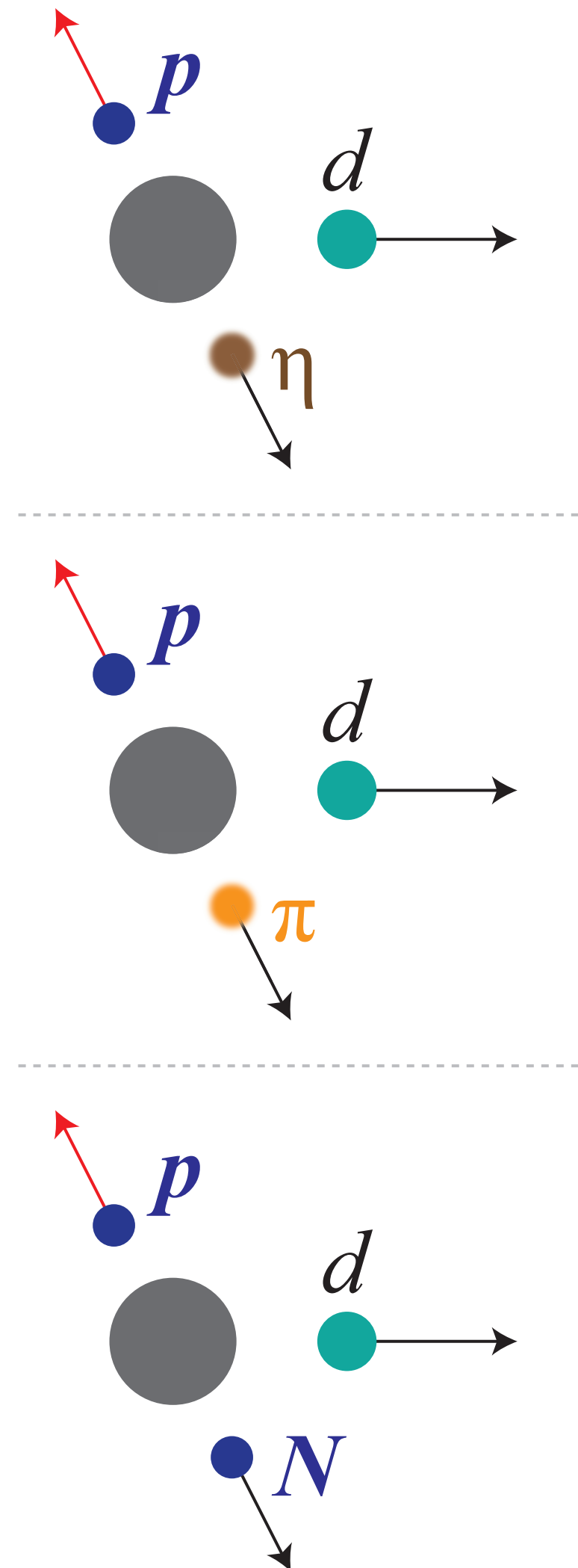
Kenta Itahashi
The University of Osaka

η PriME: search for η' -mesic nuclei

Missing mass measurement of
(p,d) with 2.5 GeV proton beam
 η' transfer + neutron pickup reaction

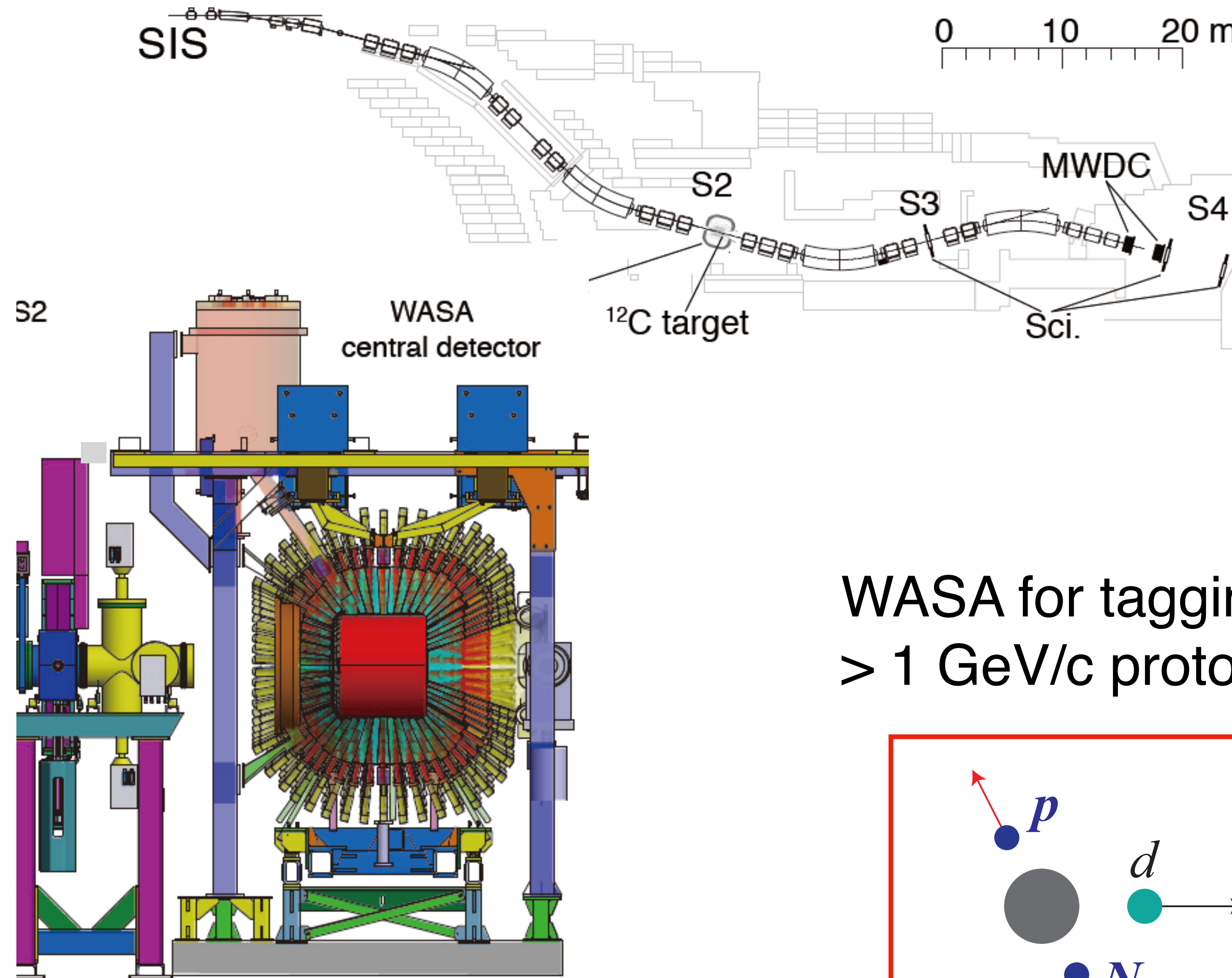


3 major decay modes of
 η' -mesic nuclei

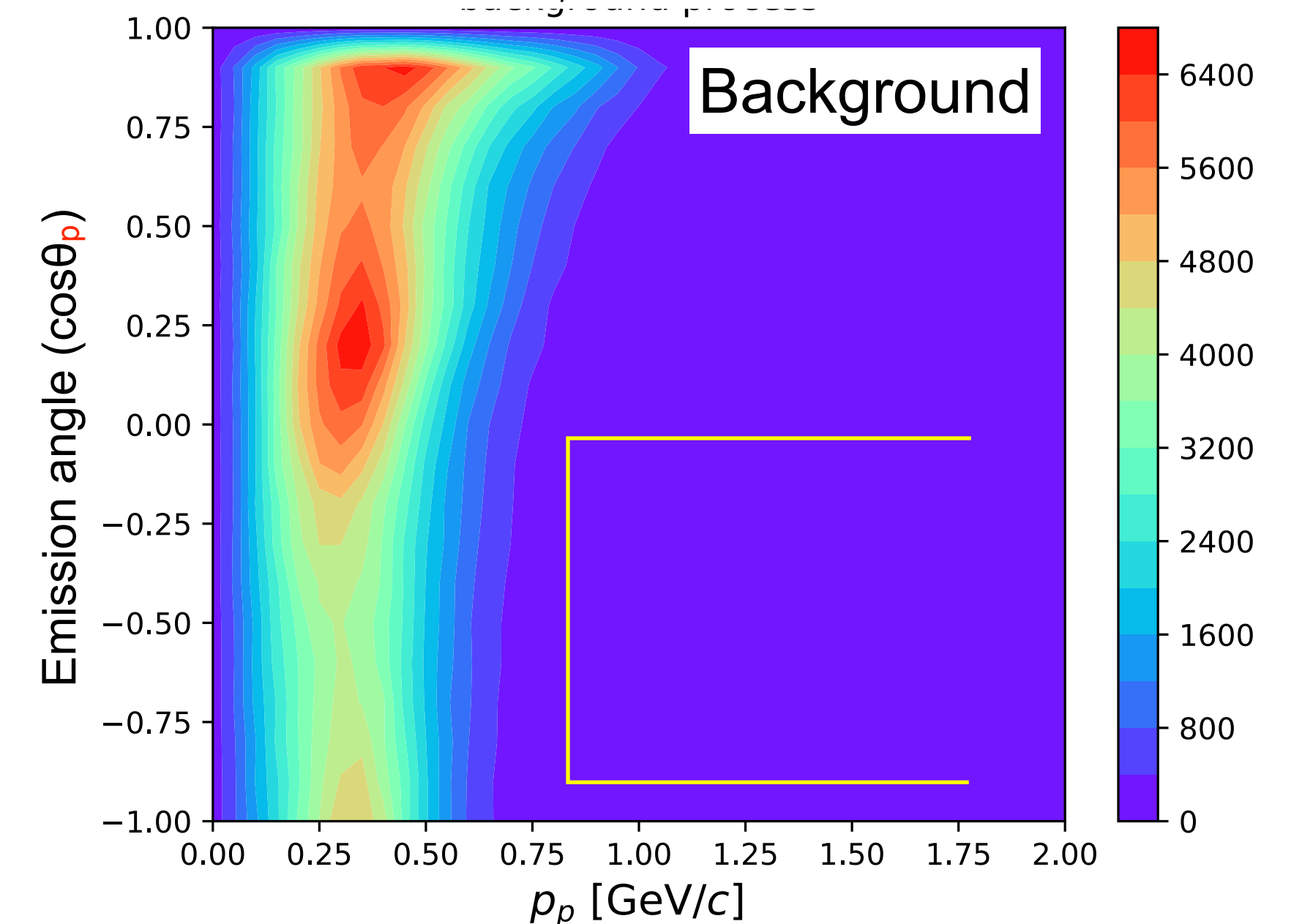
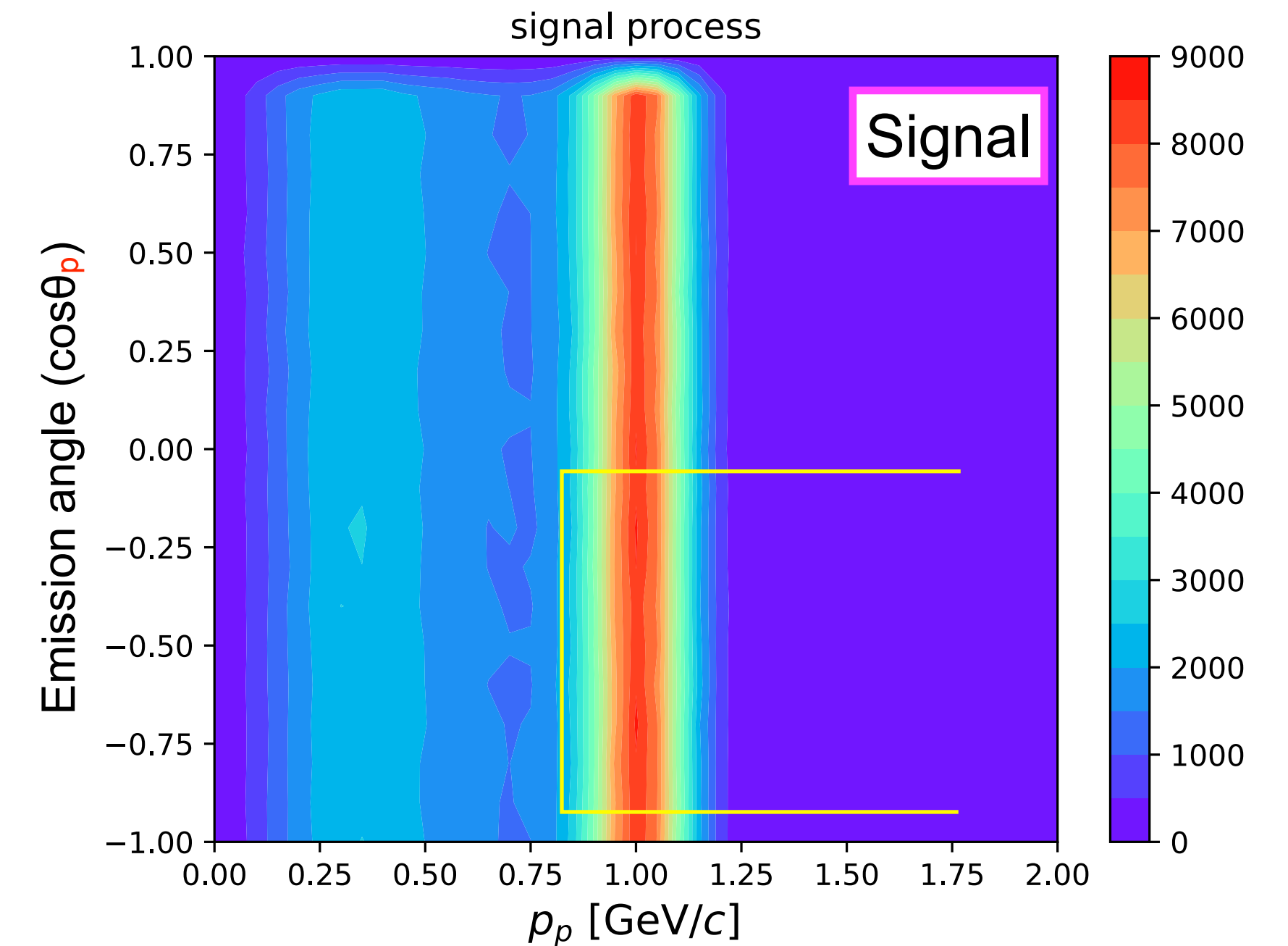
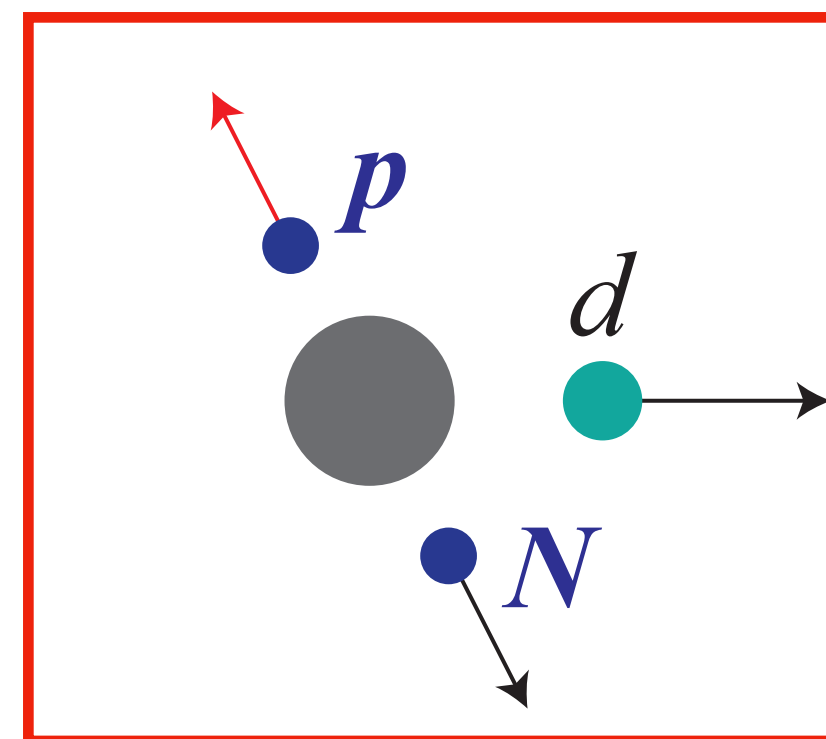


WASA at FRS for η PRiME: search for η' -mesic nuclei

Feb-Mar 2022

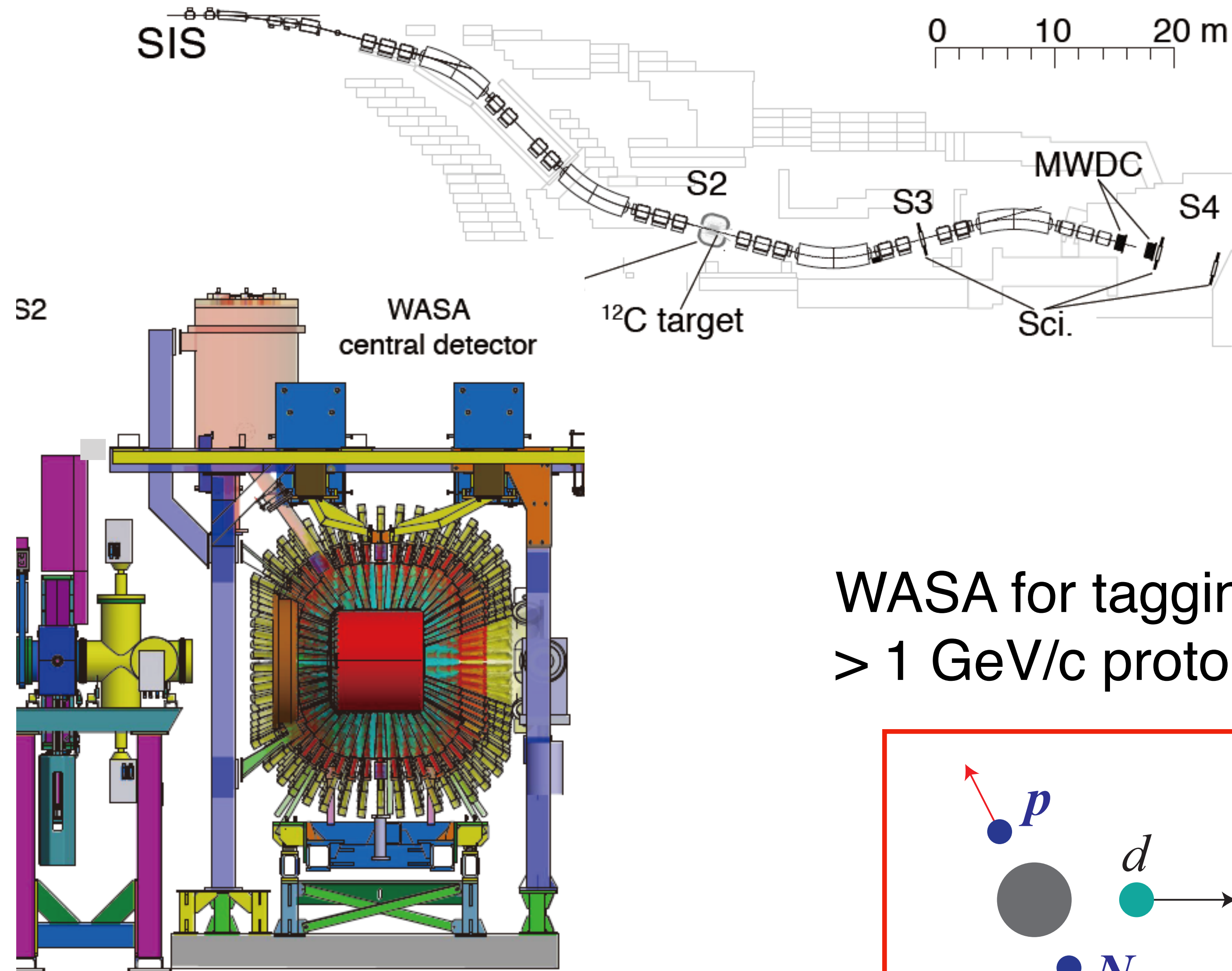


WASA for tagging
 $> 1 \text{ GeV}/c$ protons

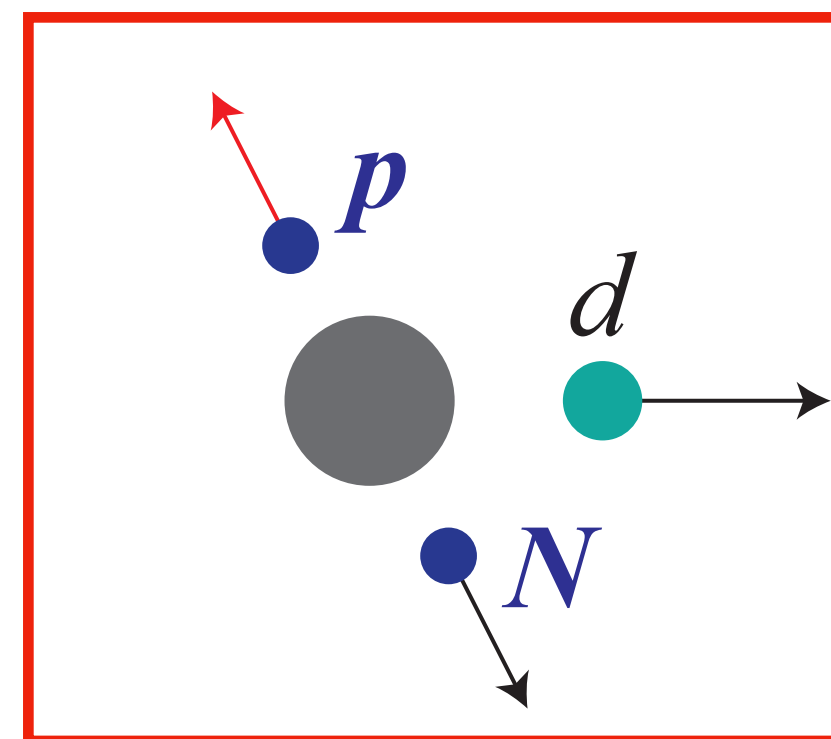


WASA at FRS for η PRiME: search for η' -mesic nuclei

Feb-Mar 2022



WASA for tagging
 $> 1 \text{ GeV}/c$ protons



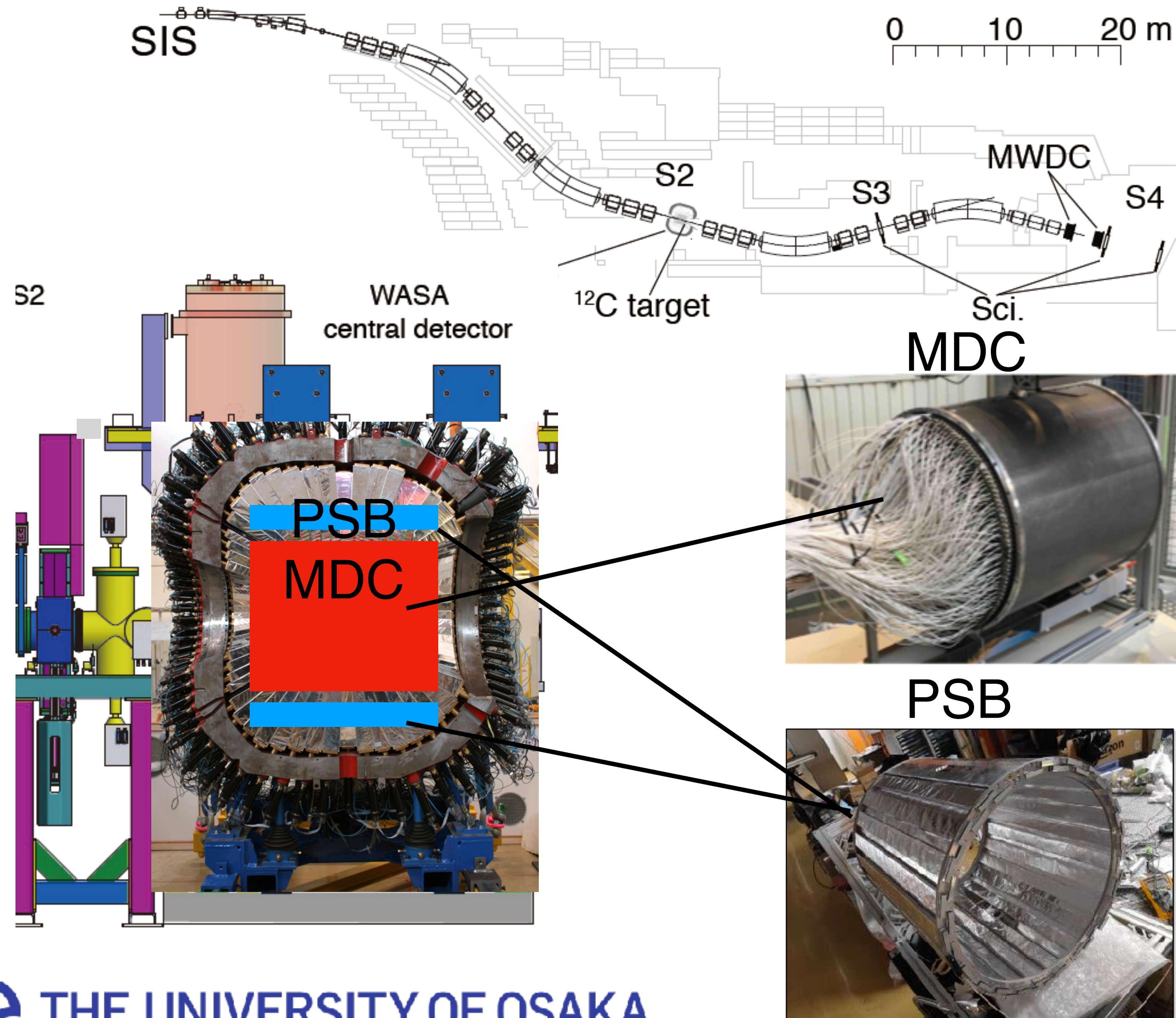
Ryohei Sekiya: PhD candidate
Yoshiki Tanaka: co-spokesperson



Together with HypHI group

WASA at FRS for η PRiME: search for η' -mesic nuclei

Feb-Mar 2022



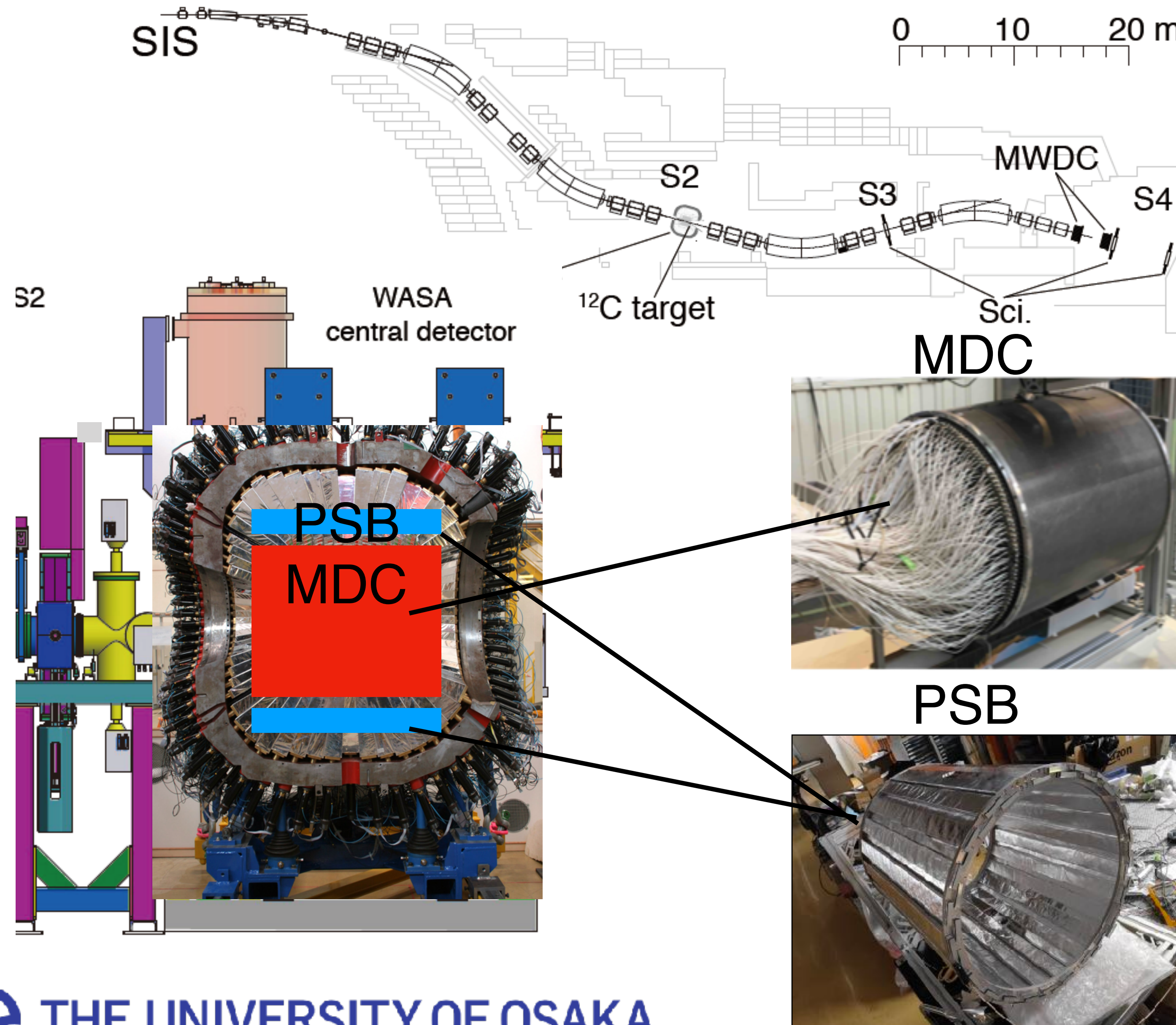
Ryohei Sekiya: PhD candidate
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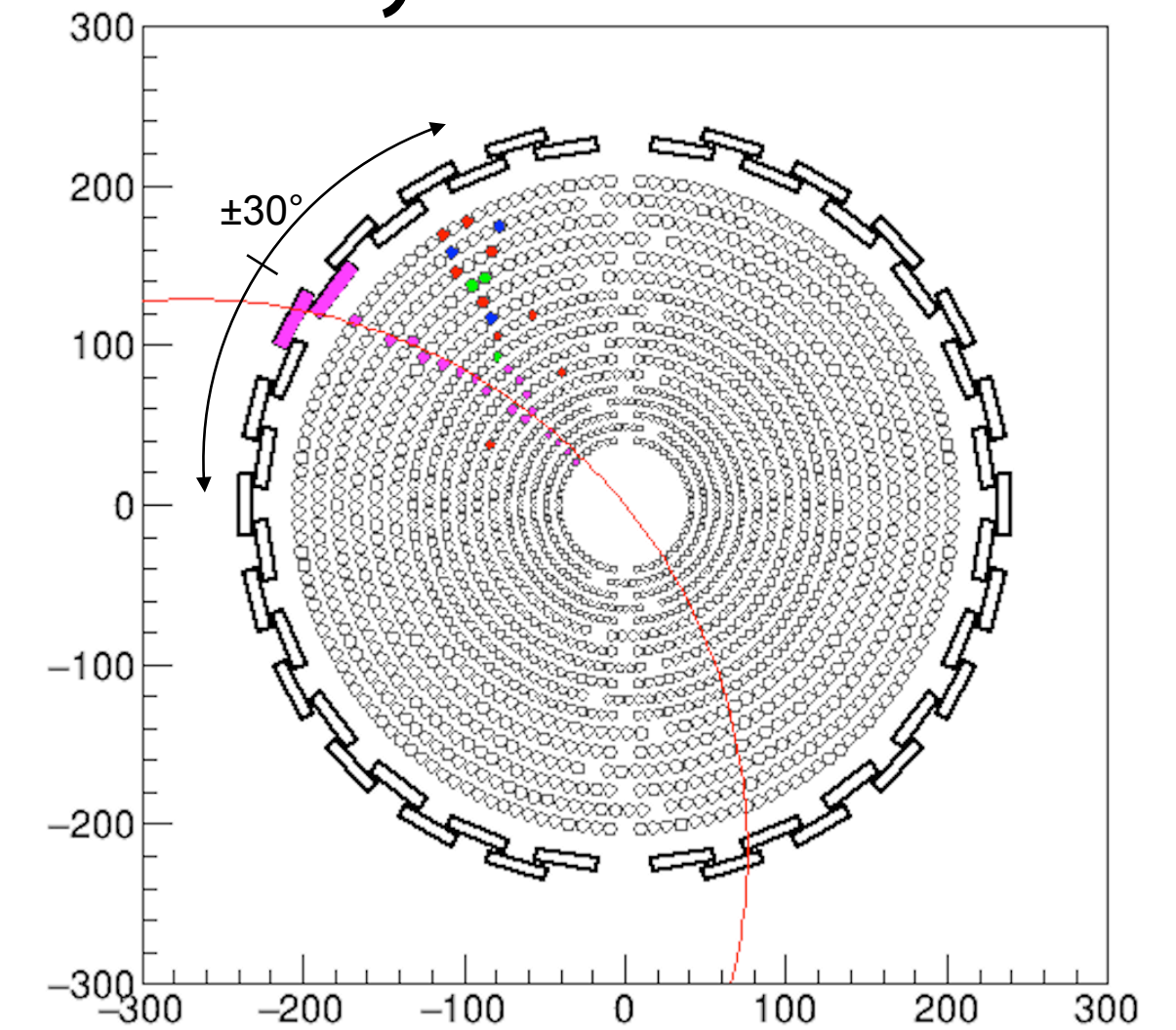
Together with HypHI group

WASA at FRS for η PRiME: search for η' -mesic nuclei

Feb-Mar 2022



Charged analysis
by MDC-PSB



WASA in η PRiME Experiment

Fairly good PID capabilities
(such as p/pi separation)

Resolution (for 1 GeV/c, p, 90 deg)

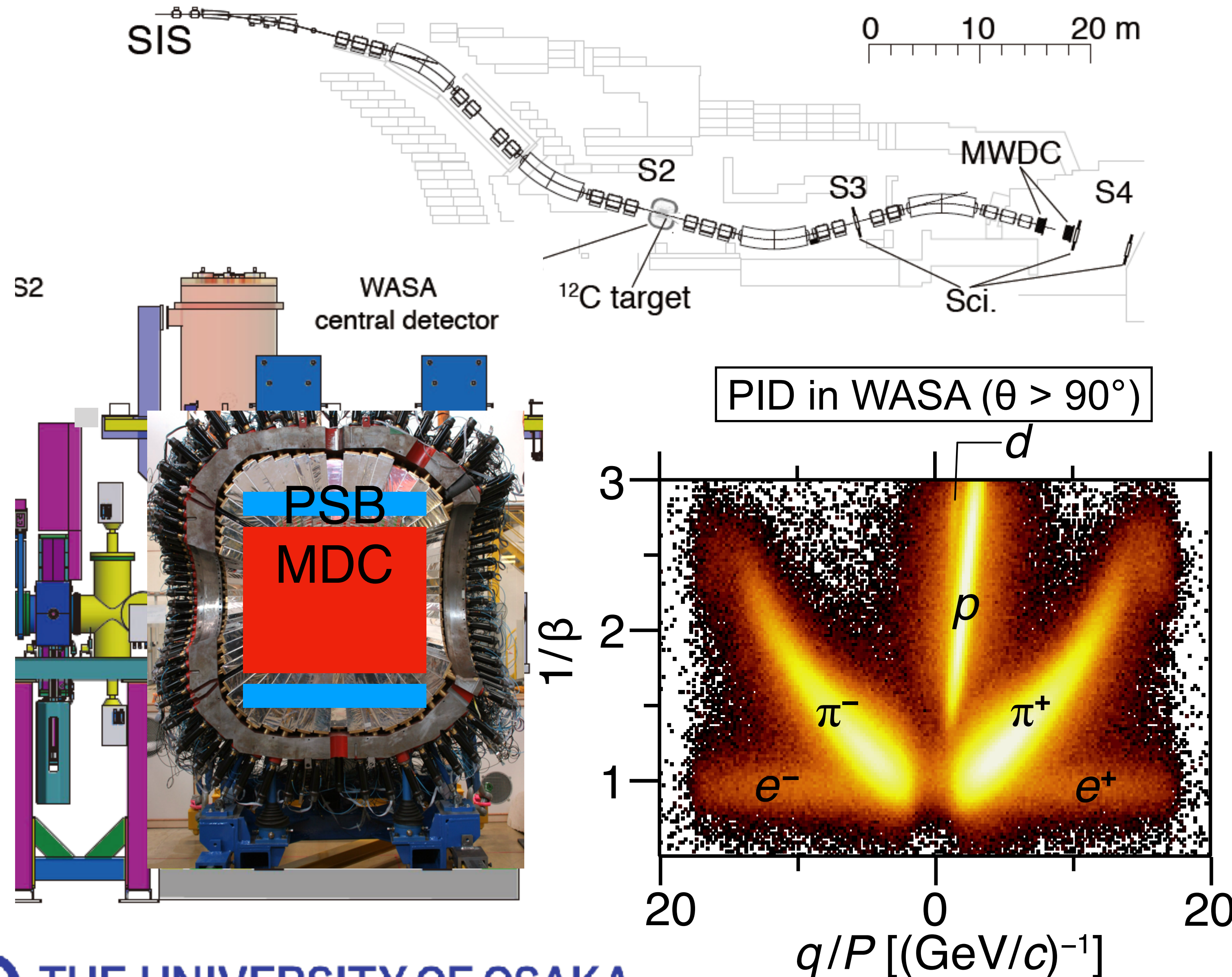
q/P 27%

$1/\beta(\text{combined})$ 11%

dE 8.2%

WASA at FRS for η PRiME: search for η' -mesic nuclei

Feb-Mar 2022



High-resolution spectroscopy of rare systems

Spectroscopy by FRS in coincidence
with WASA to measure
associated particle emission

WASA in η PRiME Experiment

Fairly good PID capabilities
(such as p/pi separation)

Resolution (for 1 GeV/c, p, 90 deg)
 q/P 27%

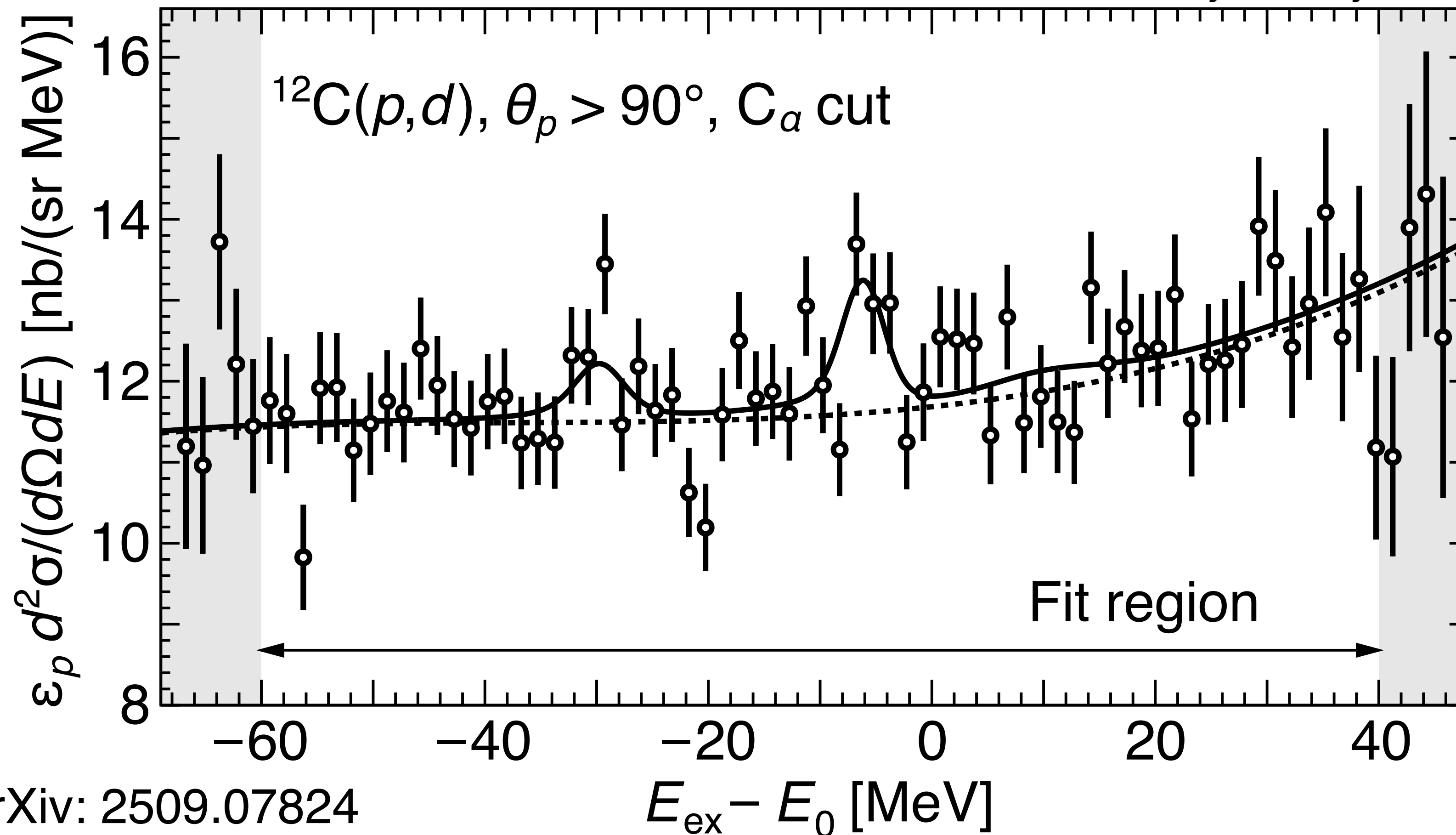
$1/\beta$ (combined) 11%

dE 8.2%

First indication of η' -mesic nuclei

GSI-S490 Semi-exclusive spectrum $^{12}\text{C}(p,d)$ w. p tagging

Thank you for your cooperation



arXiv: 2509.07824

submitted to PRL

See GSI-S490 (Thursday 18 Sep.)

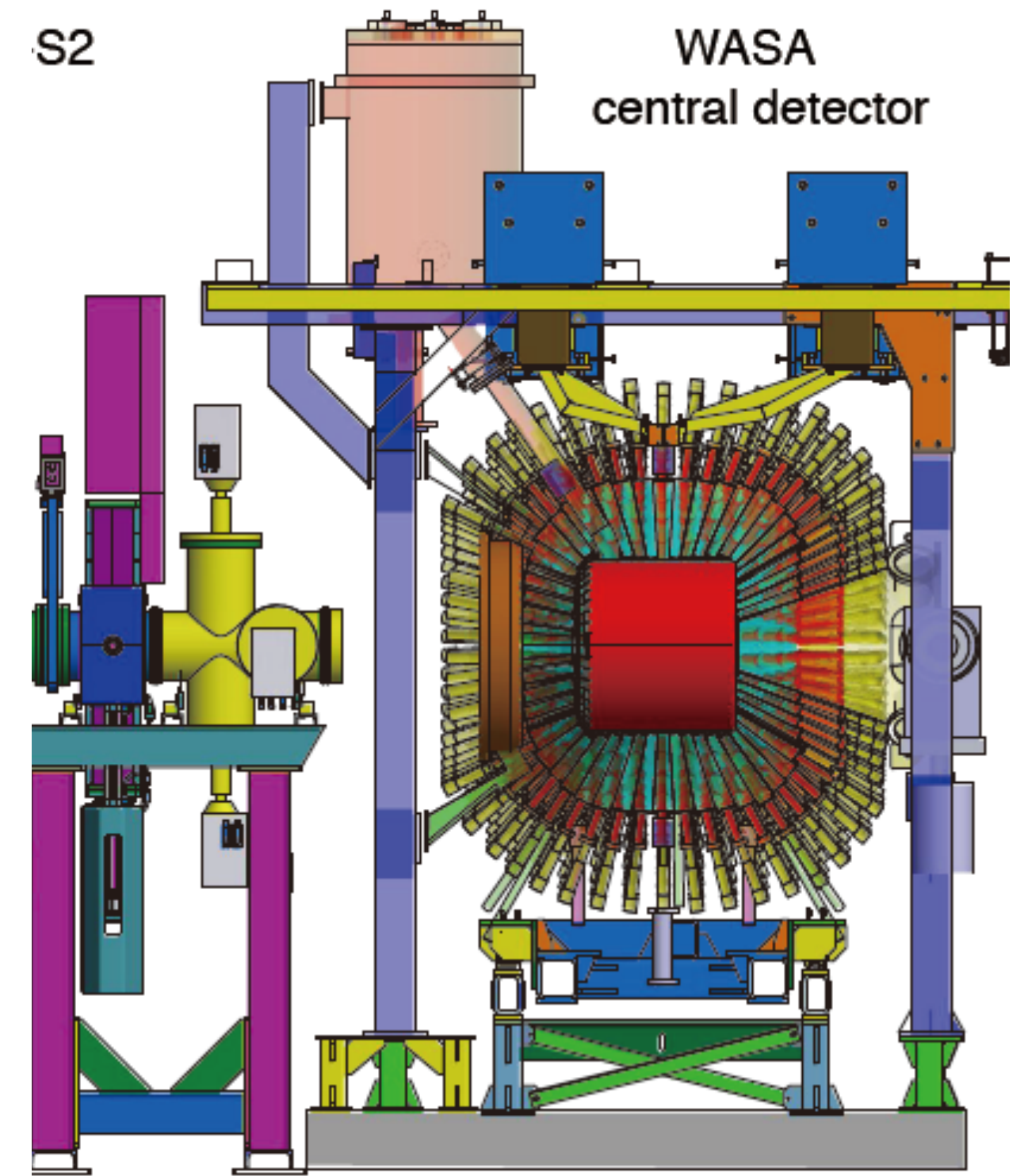
Statistical significance 2.1σ (global)

Fit indicates $V_0 = -62$, $W_0 = -2$ MeV

To continue our research
WASA is too big...

for FAIR tunnel
for LHe consumption

We do **not** need neutral detectors for the first
moment. We need charged particle identification
and momentum analysis only



WASA2 at SPring-8 in Hyogo, Japan



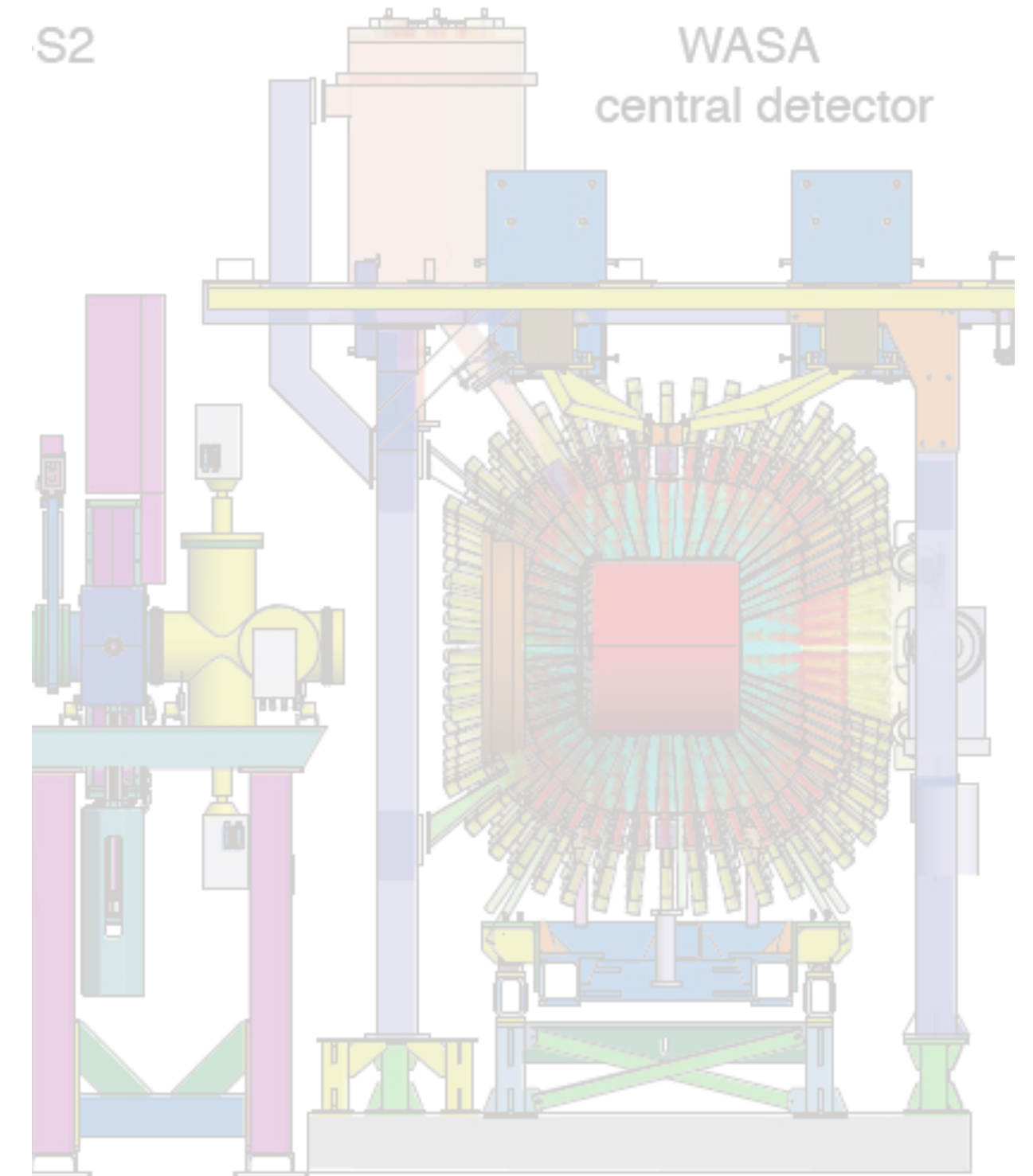
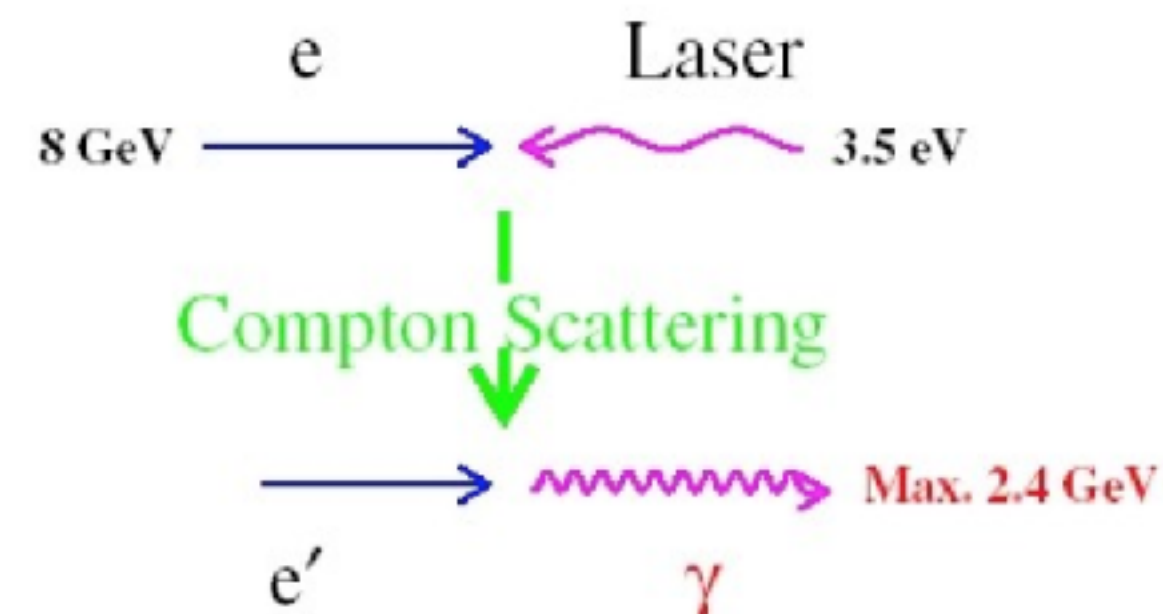
2024.11

WASA is too big...

for FAIR tunnel
for LHe consumption

We do **not** need neutral detectors for the first moment. We need charged particle identification and momentum analysis only

SPring-8 SOR 8 GeV



BL33LEP at SPring-8
Backward compton scattering for
< 2.4 GeV γ beam
Various hadron physics such as
 η ω ϕ ... meson production
 η' -mesic nuclei
Kaonic nuclei

WASA2 at SPring-8 in Hyogo, Japan



Toshiba
Superconducting solenoid magnet
(Helmholtz magnet)
Cryogenic system directly attached

Max Field

2.6 T

Bore diameter

605 mm

Length

1500 mm

Outer dimension

L1500 x W2800 x H2400 mm

Weight

~ 5.4 t

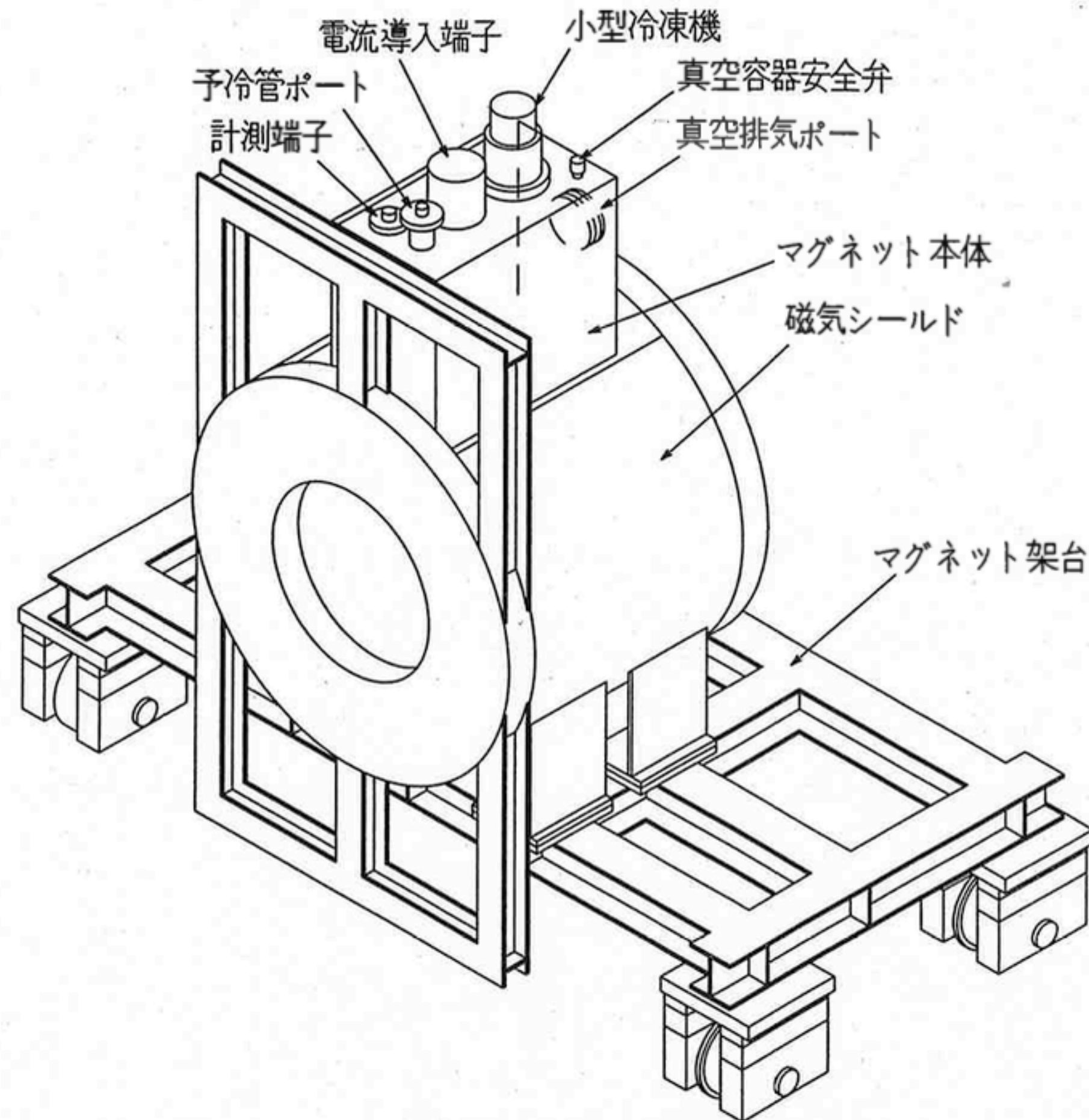
2024.11

Property of RCNP, The University of Osaka

WASA2 at SPring-8 in Hyogo, Japan

TOSHIBA

E-KN501093-α
18/156



Pedestal/support structure can be modified

Toshiba
Superconducting solenoid magnet
(Helmholtz magnet)
Cryogenic system directly attached

Max Field 2.6 T

Bore diameter 605 mm

Length 1500 mm

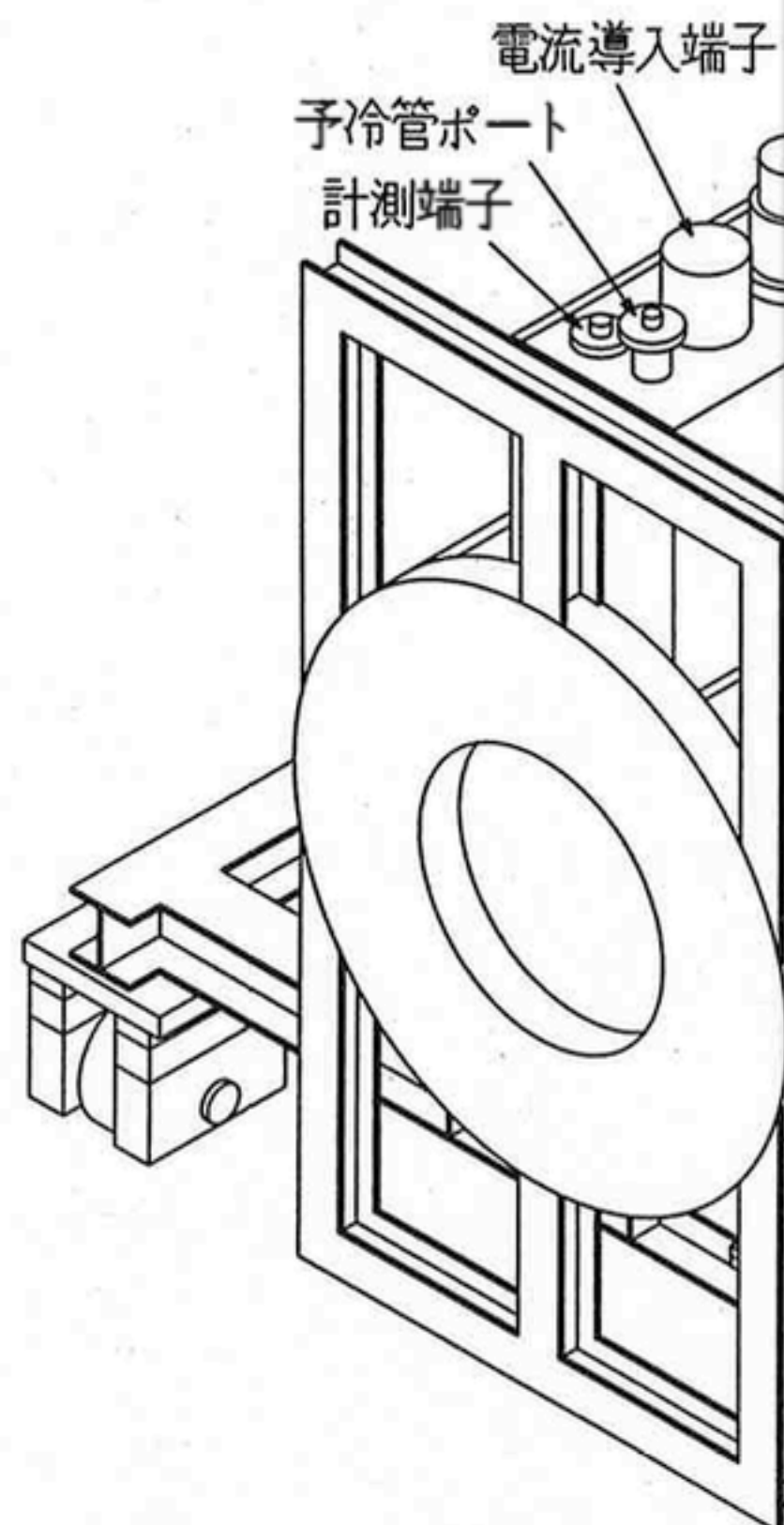
Outer dimension L1500 x W2800 x H2400 mm

Weight ~ 5.4 t

Property of RCNP, The University of Osaka

Application for the RCNP Joint Usage/Research Program
(Category 2. Use of RCNP properties at other institution)

TOSHIBA



Title of the research: Hadron physics experimental campaign at GSI/FAIR

Spokesperson: Kenta Itahashi, Dr.

Address: 2-1 Hirosawa, Wako, Saitama 351-0198, Japan

Email: itahashi@a.riken.jp

Tel: 048-467-9354

Fax: -

List of collaborators:

Hiroyuki Fujioka, Dr.

Takehiko R. Saito, Dr.

Yoshiki K. Tanaka, Dr.

Period of research:

2025 Apr. - 2029 Mar.

(subject to extension)

Requirements for the apparatuses:

LEPS superconducting solenoid magnet and the power supply are required for momentum reconstruction and charged particle identification.

Location for use of the apparatuses:

GSI/FAIR, Germany

APPROVED

Pedestal/support structure

magnet

attached

.6 T

5 mm

00 mm

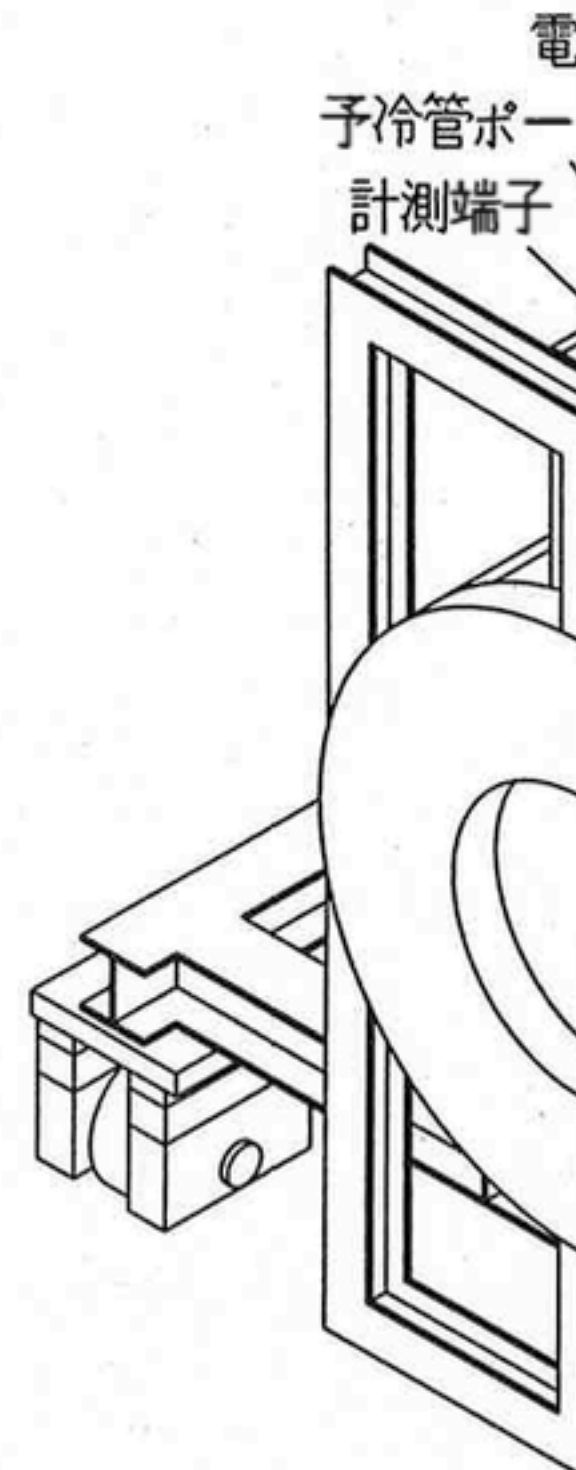
00 x H2400 mm

5.4 t

University of Osaka

WASA2 at SPring-8 in Hyogo, Japan

TOSHIBA



magnet
attached

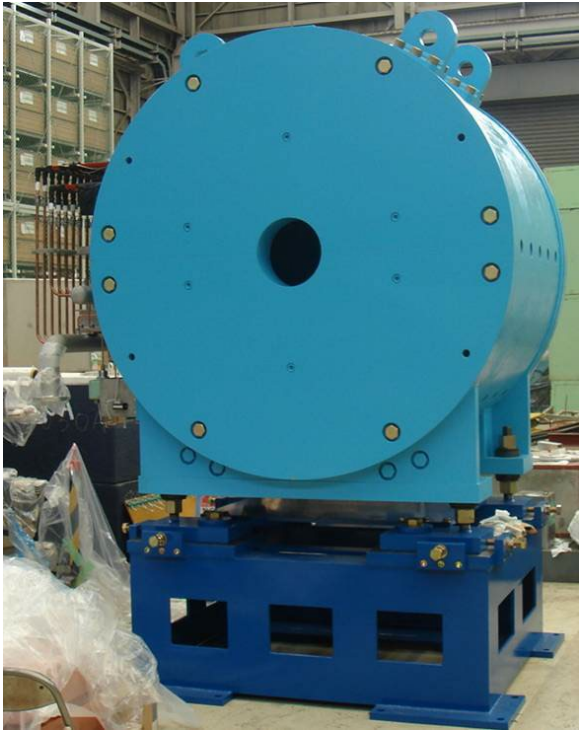
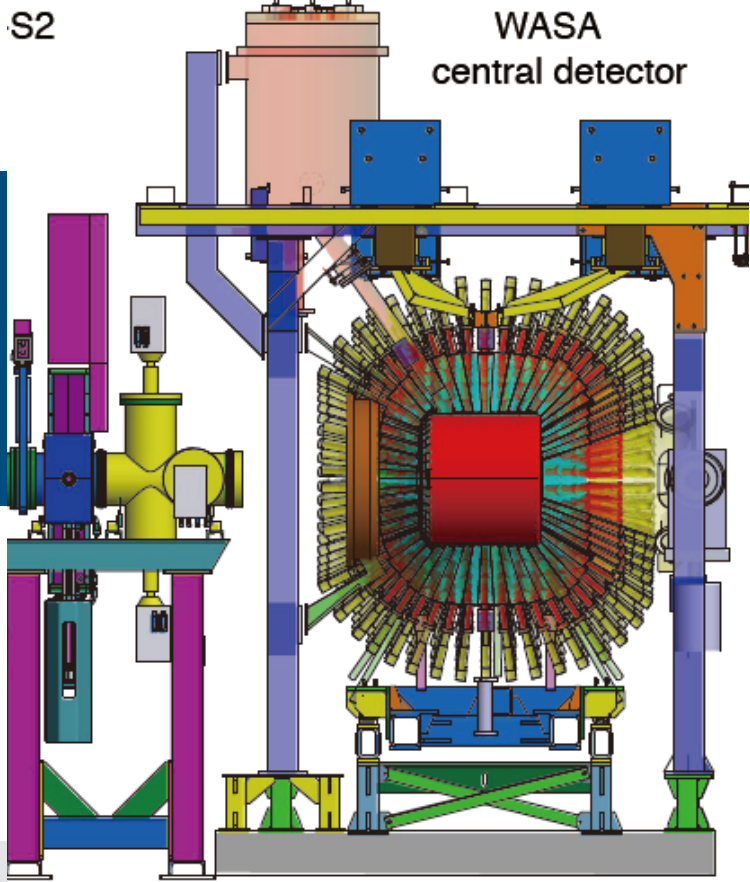
n
H2400 mm

weight ~ 3.4 ton

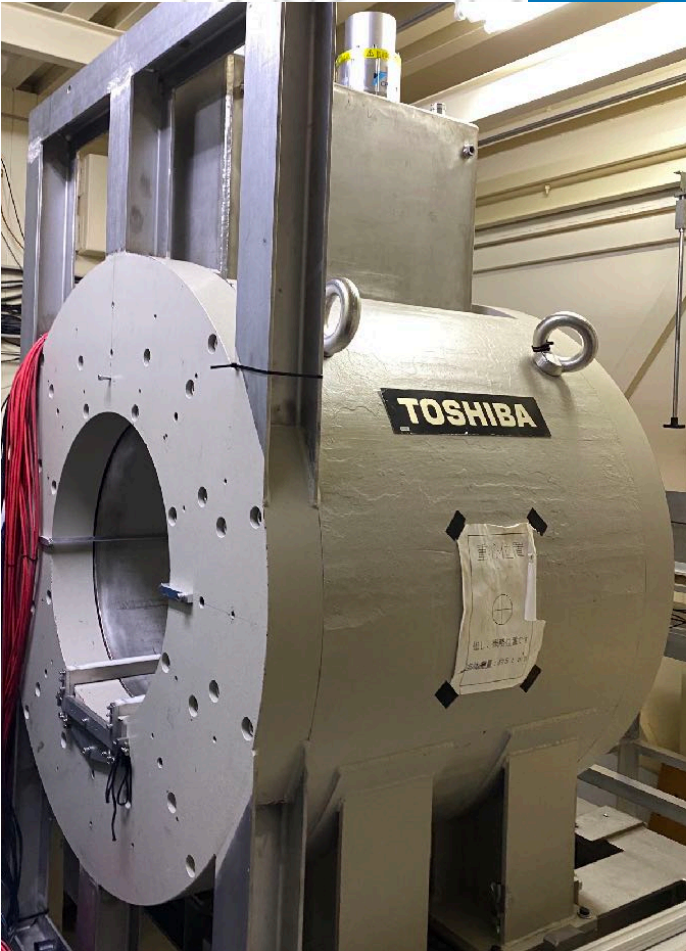
Property of RCNP, The University of Osaka

Comparison of WASA2 with other systems

Specifications	WASA2	WASA	J-PARC E15
Max Field	2.6 T	1.0 T	0.7 T
Bore diameter	60 cm	49 cm	118 cm
Length	100 cm	55 cm	117 cm
Weight	5.4 ton	~ 10 ton	21 ton
Comments	4K fridge attached (to be updated in Toshiba)	KEK made solenoid Helium consumption large Conflict with other exp.	NEC TOKIN Normal conducting

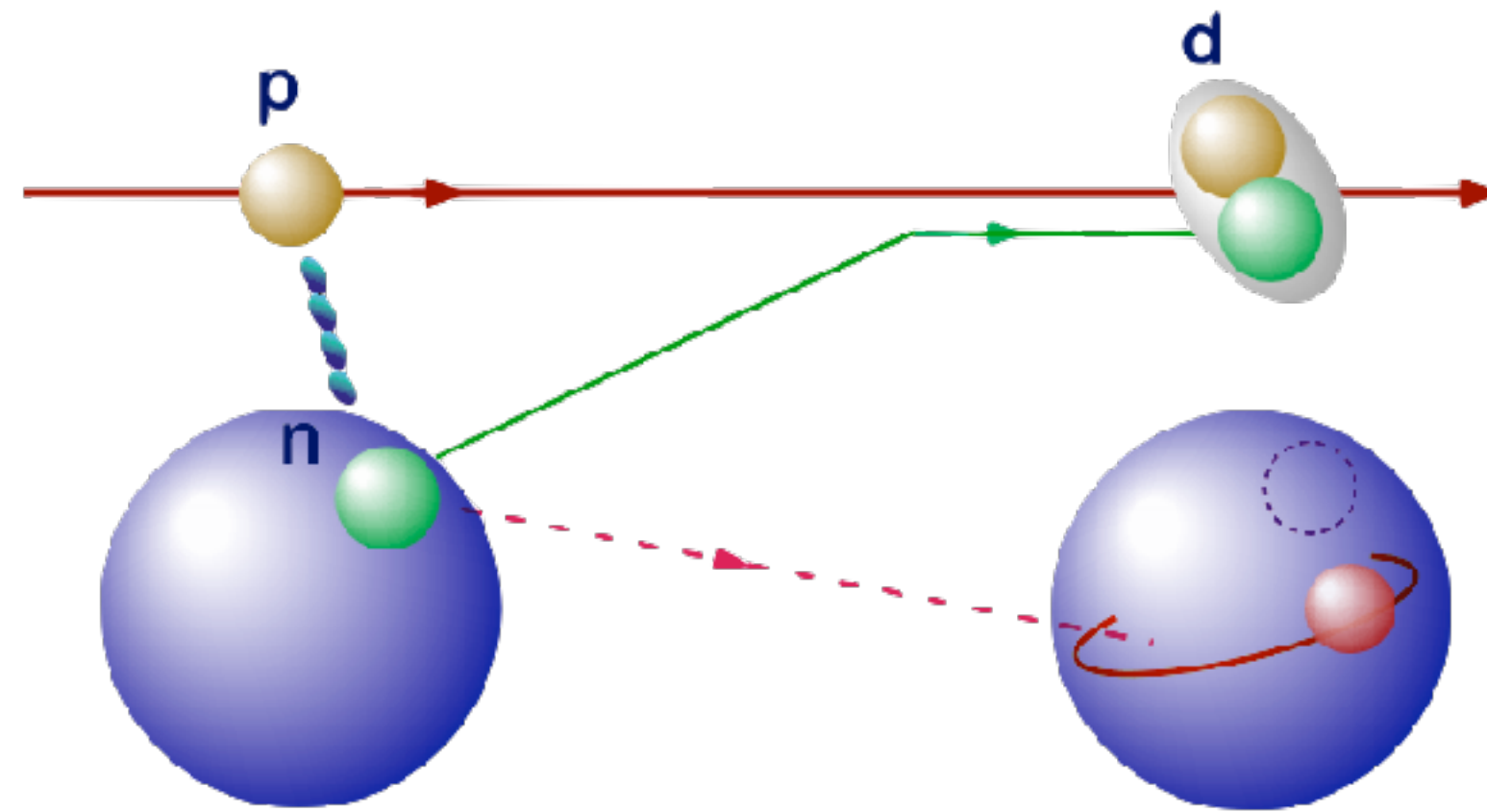


0 mm

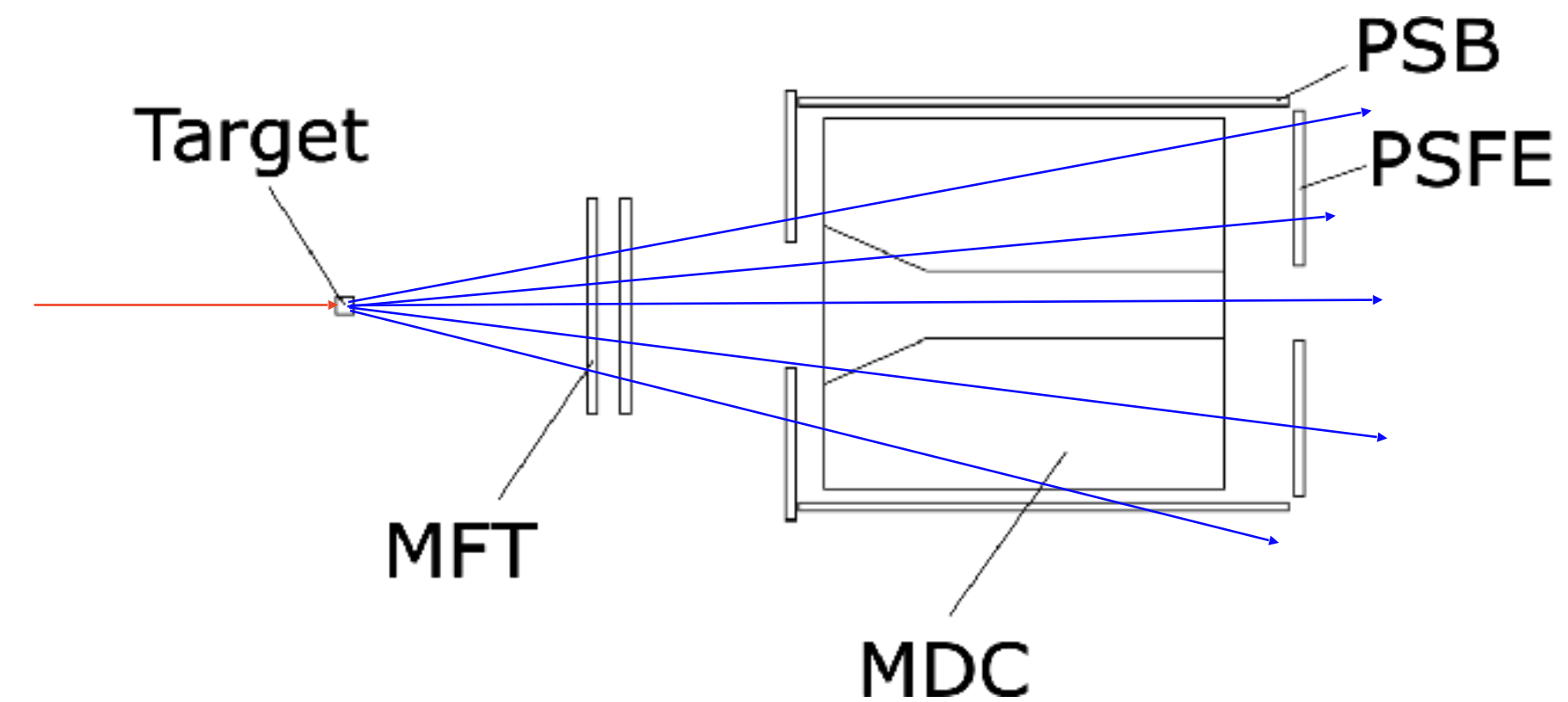


Personal view : physics cases with WASA2 at (Super-)FRS

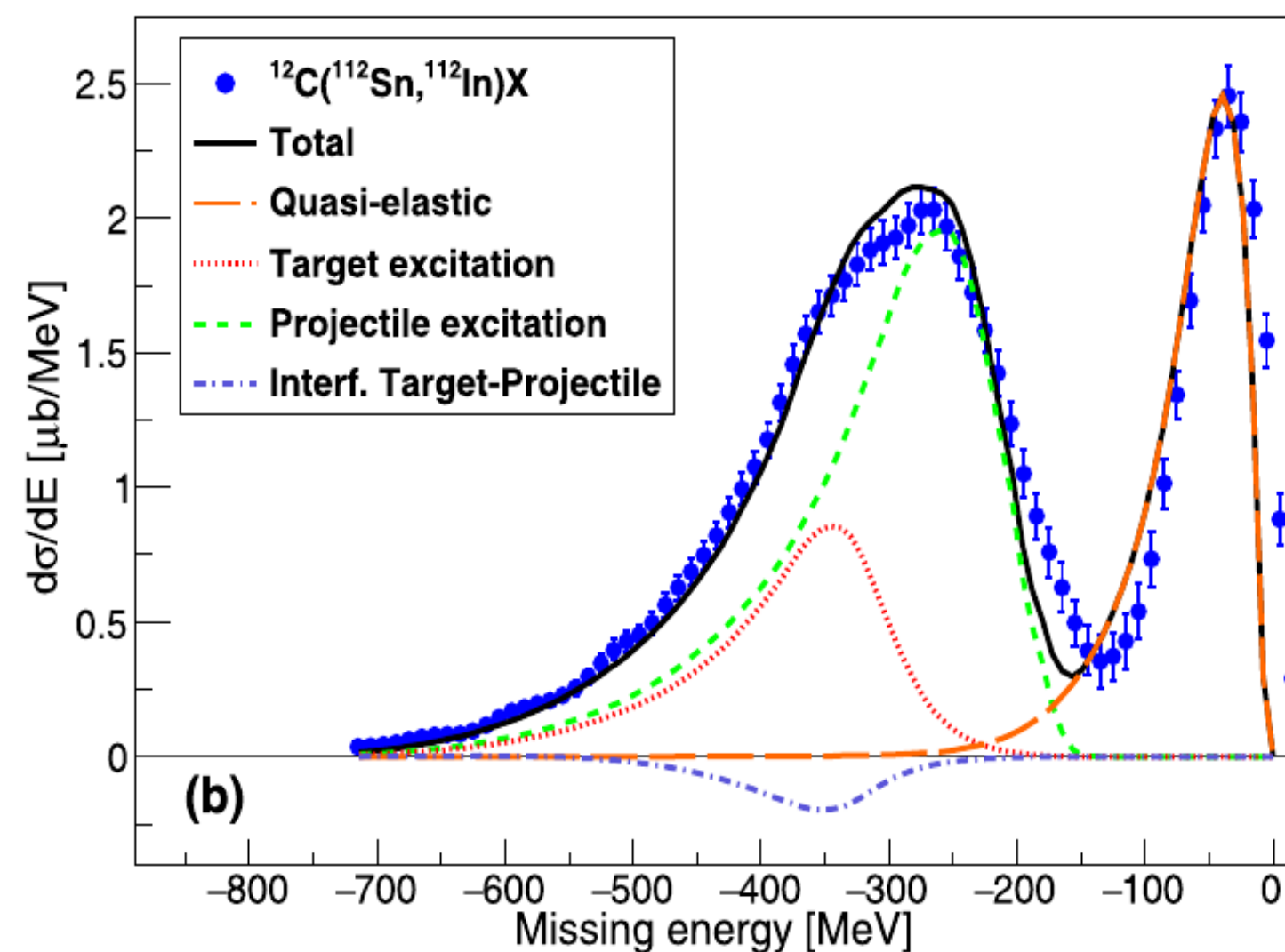
Mesic nuclei spectroscopy



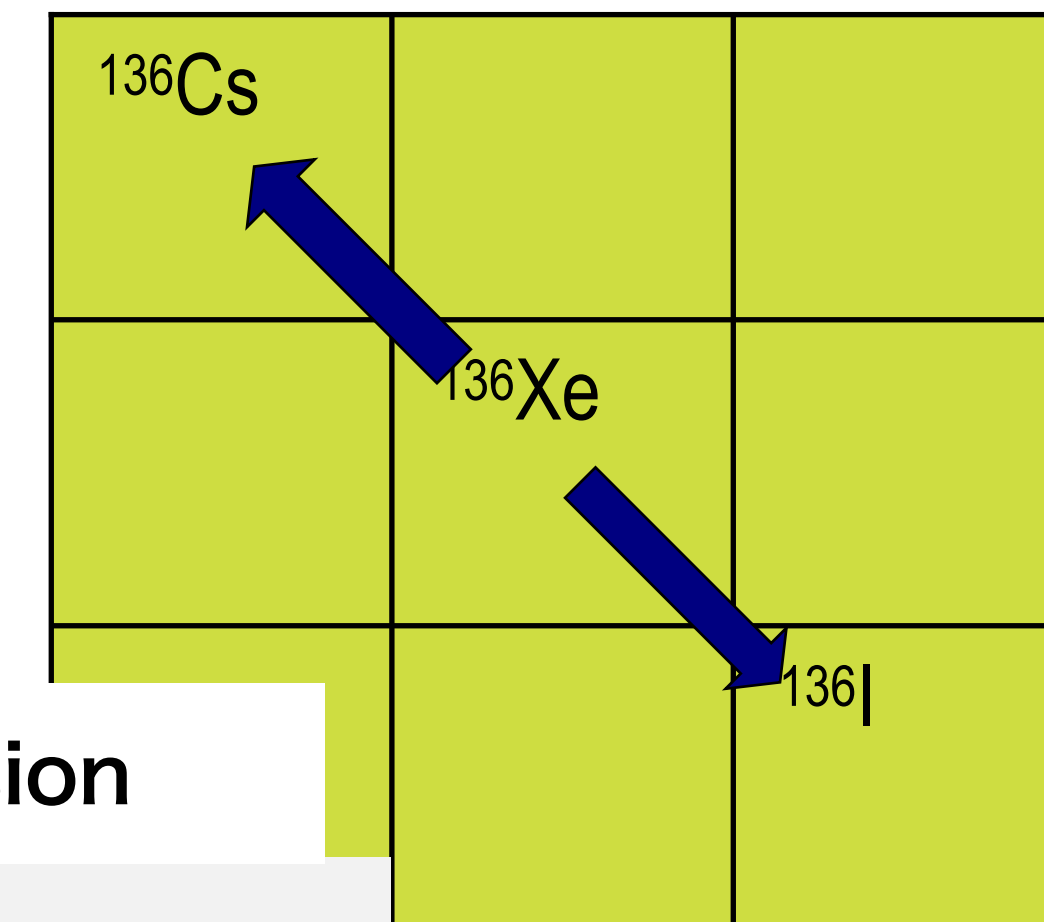
Hyper nuclei spectroscopy



$\Delta(1232)$ and Roper(1400) in neutron rich nuclei



Density dependence of symmetry energy

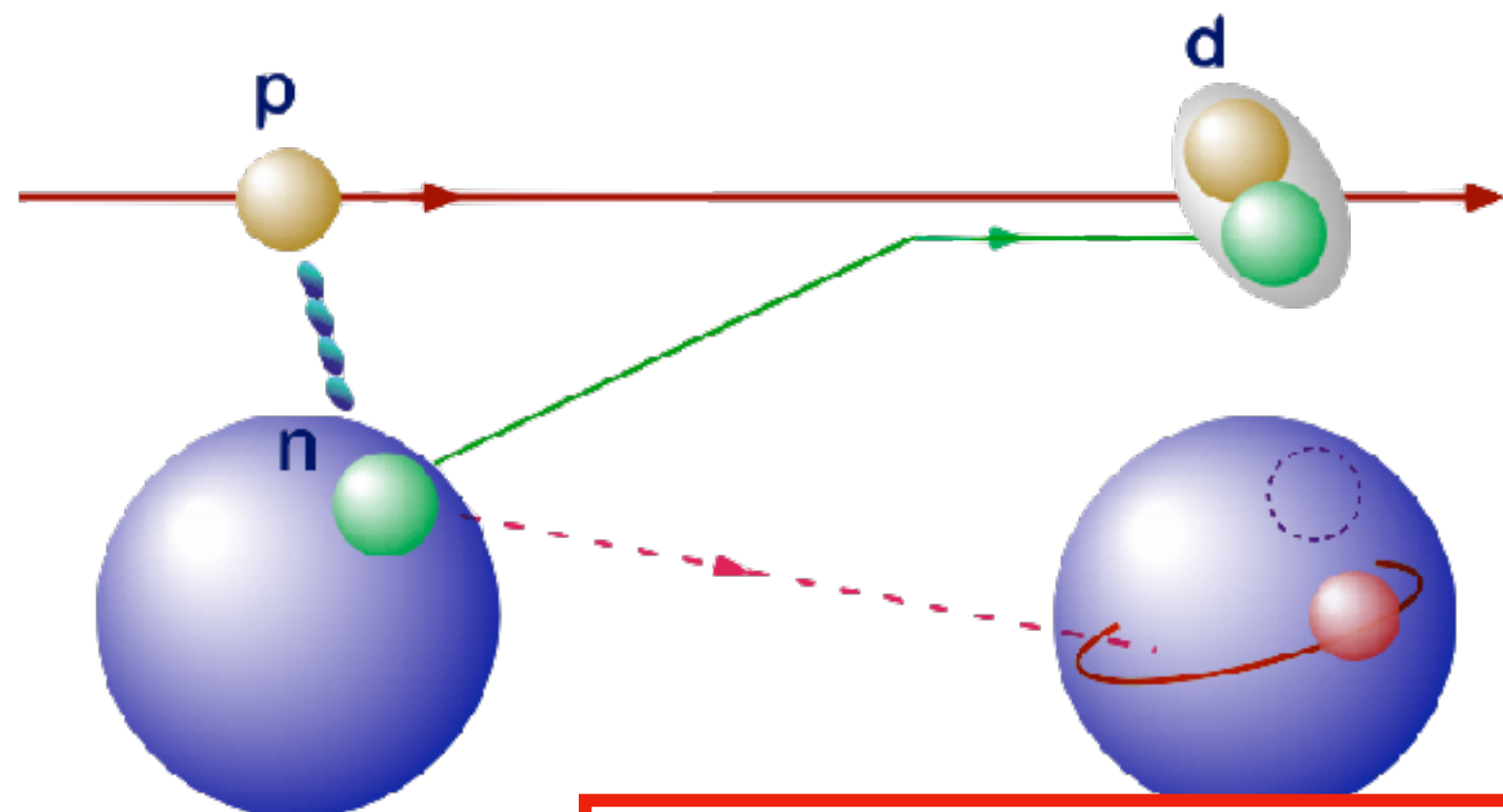


π^\pm emission

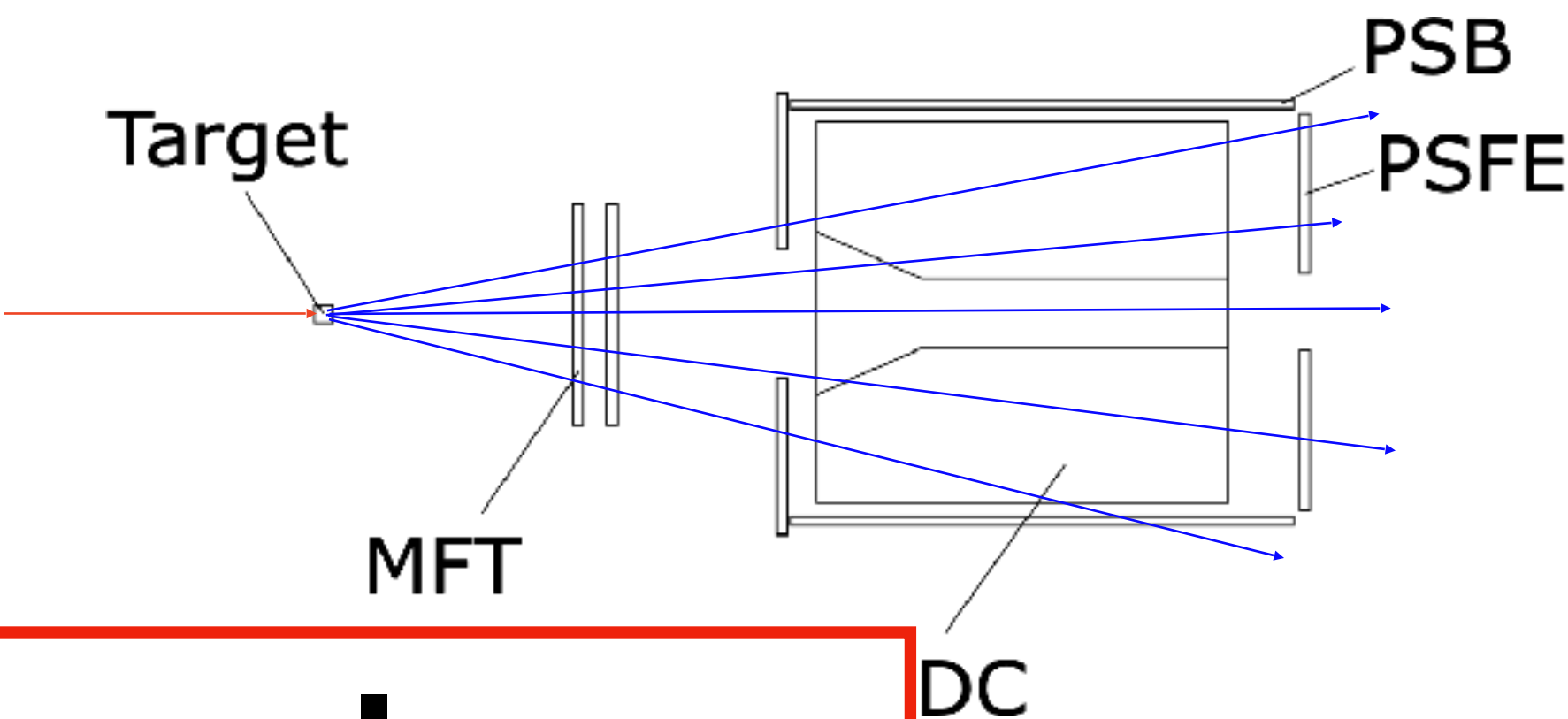
$$\frac{\sigma_{(A,Z,A(Z+1))}}{\sigma_{(A,Z,A(Z-1))}} = \frac{N_n}{N_p} \frac{\sigma_{np \rightarrow pp\pi^-}}{\sigma_{pp \rightarrow np\pi^+}}$$

Personal view : physics cases with WASA2 at (Super-)FRS

Mesic nuclei spectroscopy

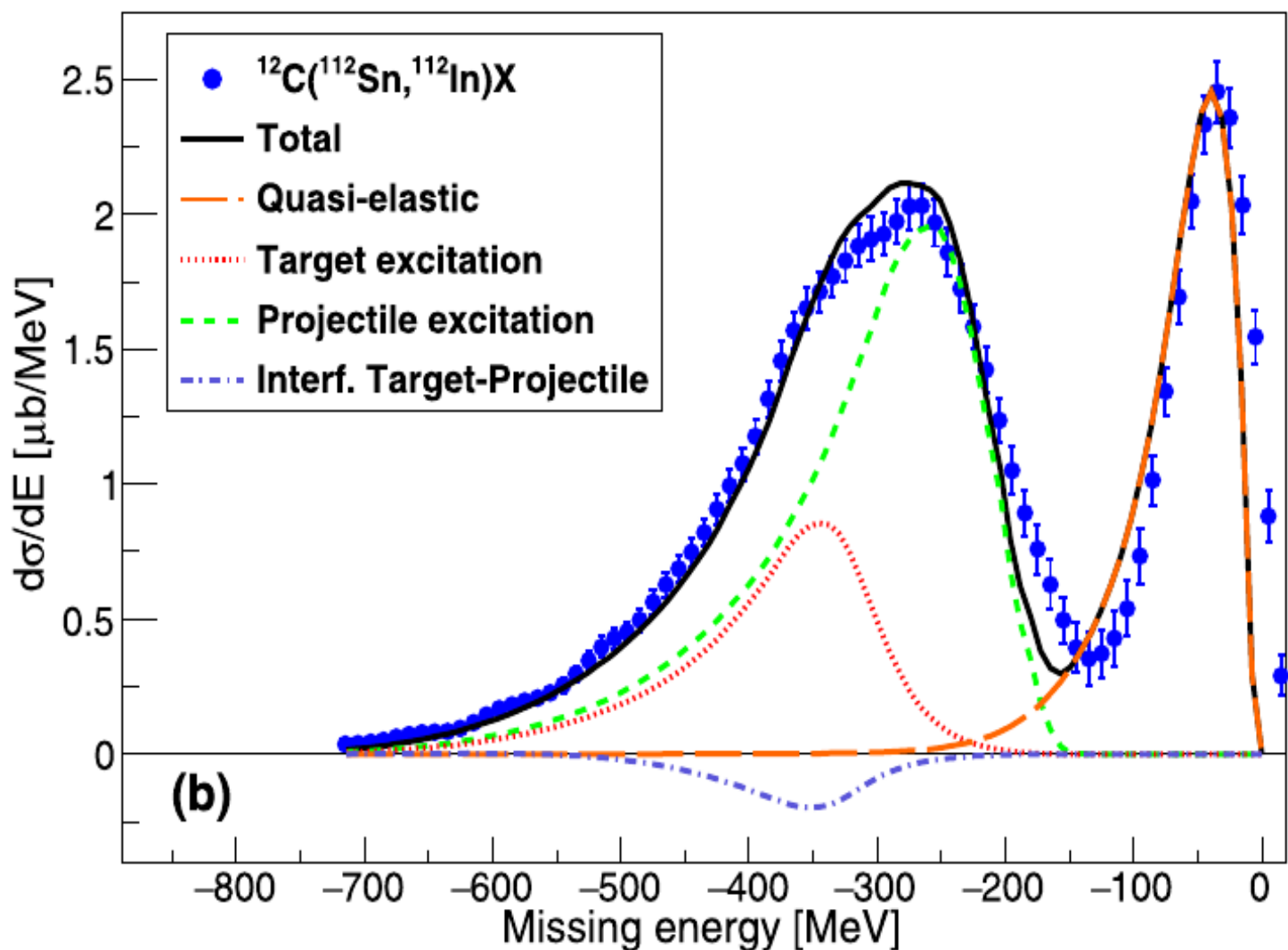


Hyper nuclei spectroscopy

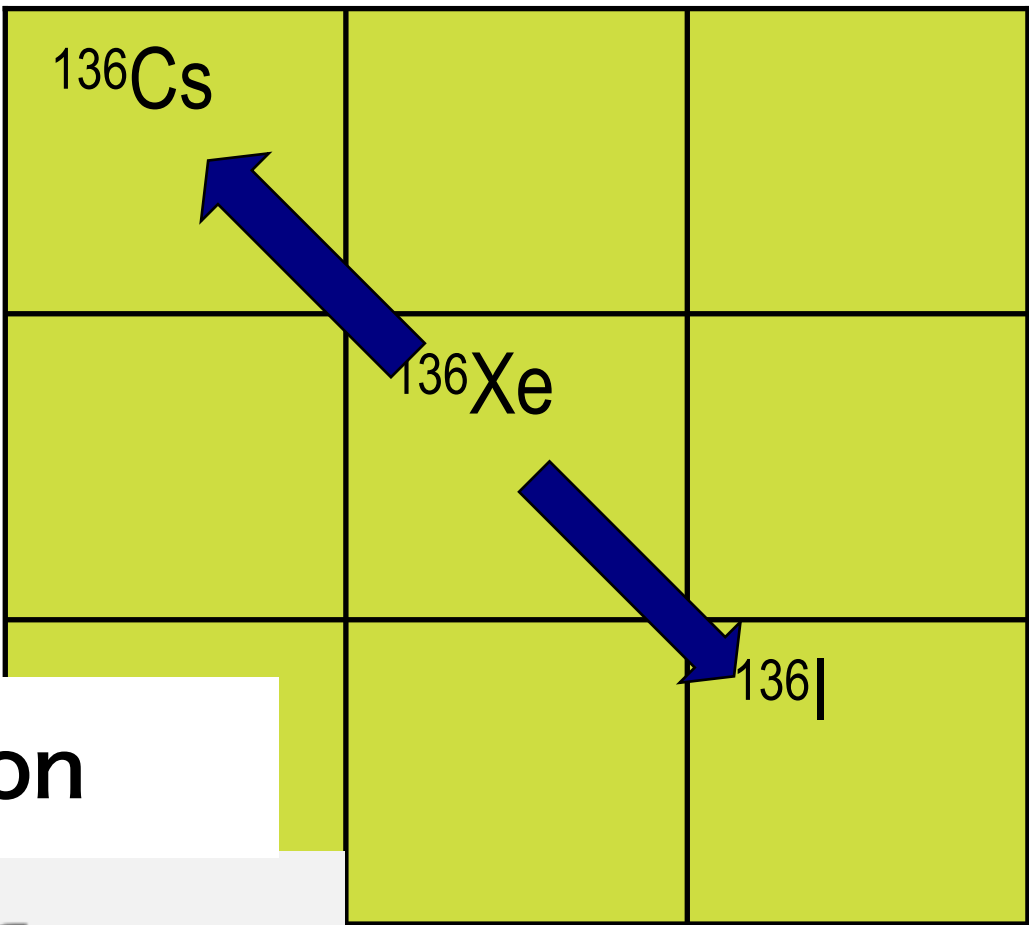


New ideas are welcome

$\Delta(1232)$ in neutron rich nuclei



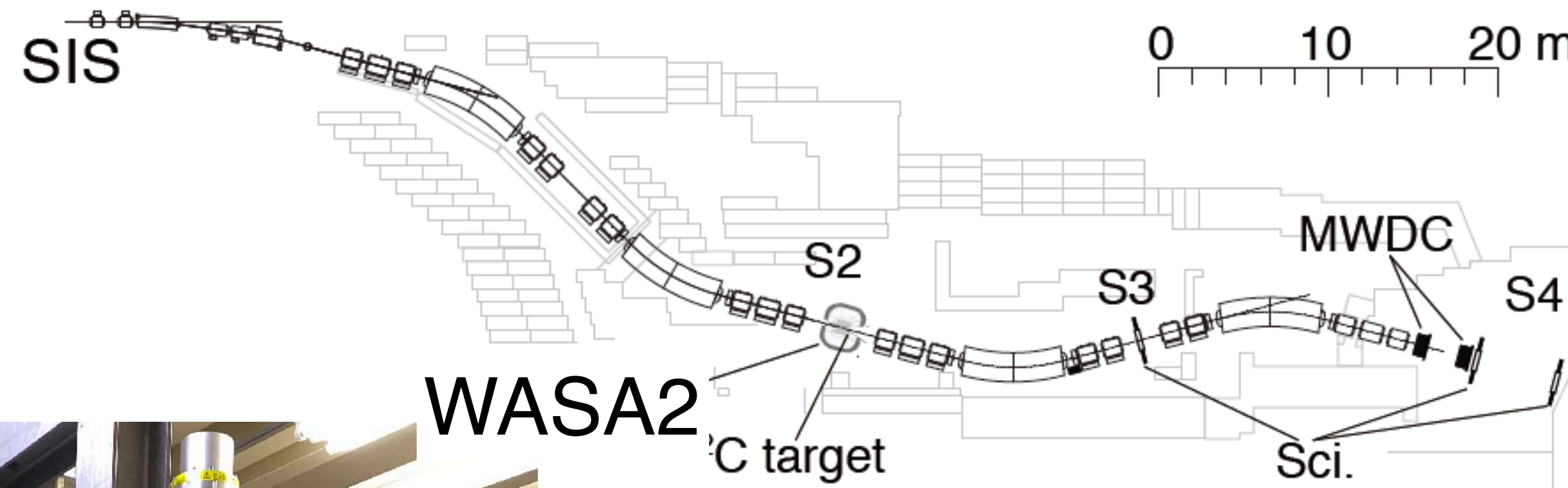
Density dependence of symmetry energy



π^\pm emission

$$\frac{\sigma_{(A,Z,A(Z+1))}}{\sigma_{(A,Z,A(Z-1))}} = \frac{N_n}{N_p} \frac{\sigma_{np \rightarrow pp\pi^-}}{\sigma_{pp \rightarrow np\pi^+}}$$

WASA2 at FRS for η PRiME



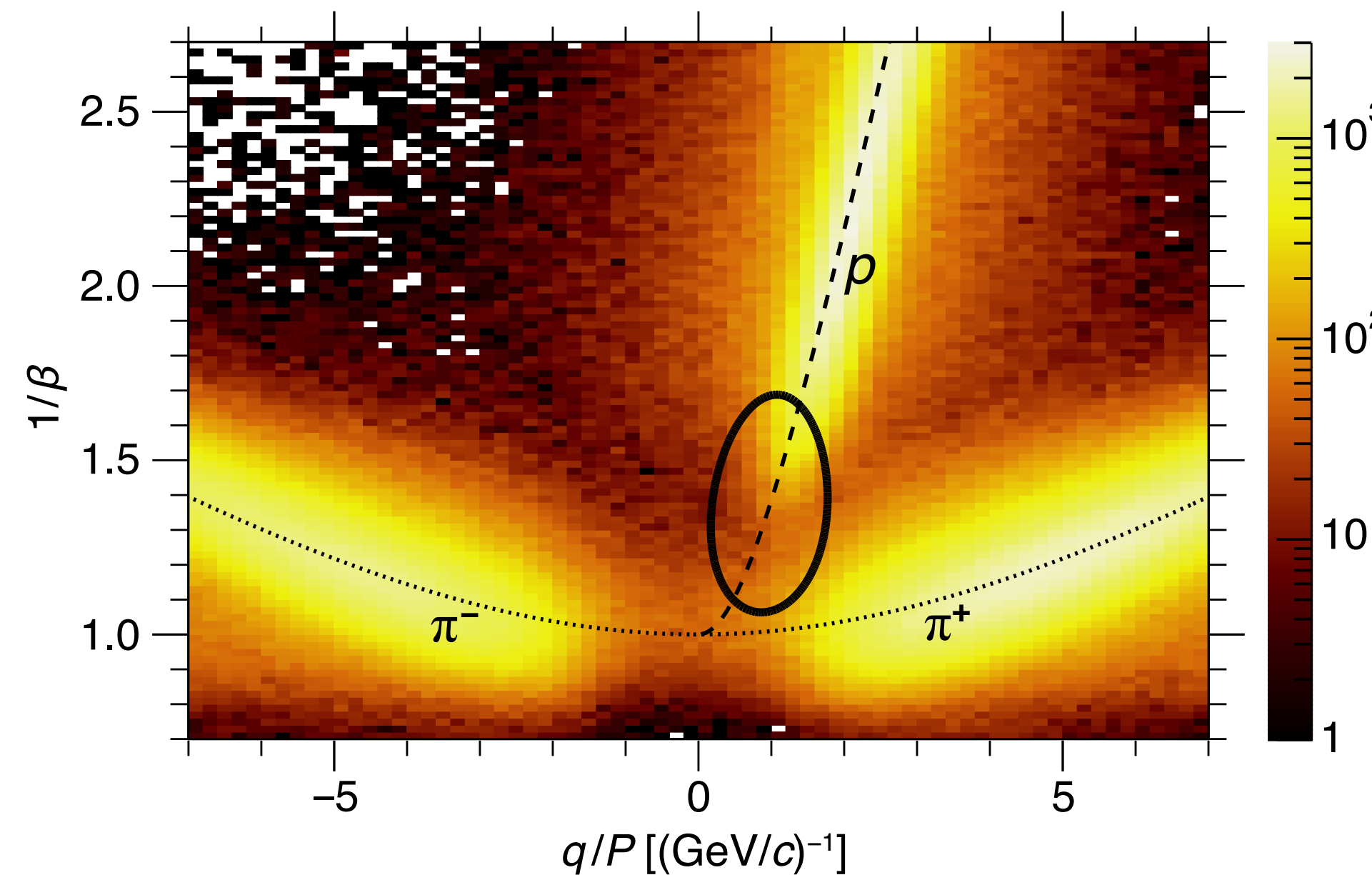
What we expect are...

better PID to reduce pion contamination
and better momentum resolution.
With larger detectors, back-to-back
coincidence of particles is in sight.

WASA2

C target

Sci.



WASA2

WASA

2.6 T

1.0 T

60 cm

49 cm

100 cm

55 cm

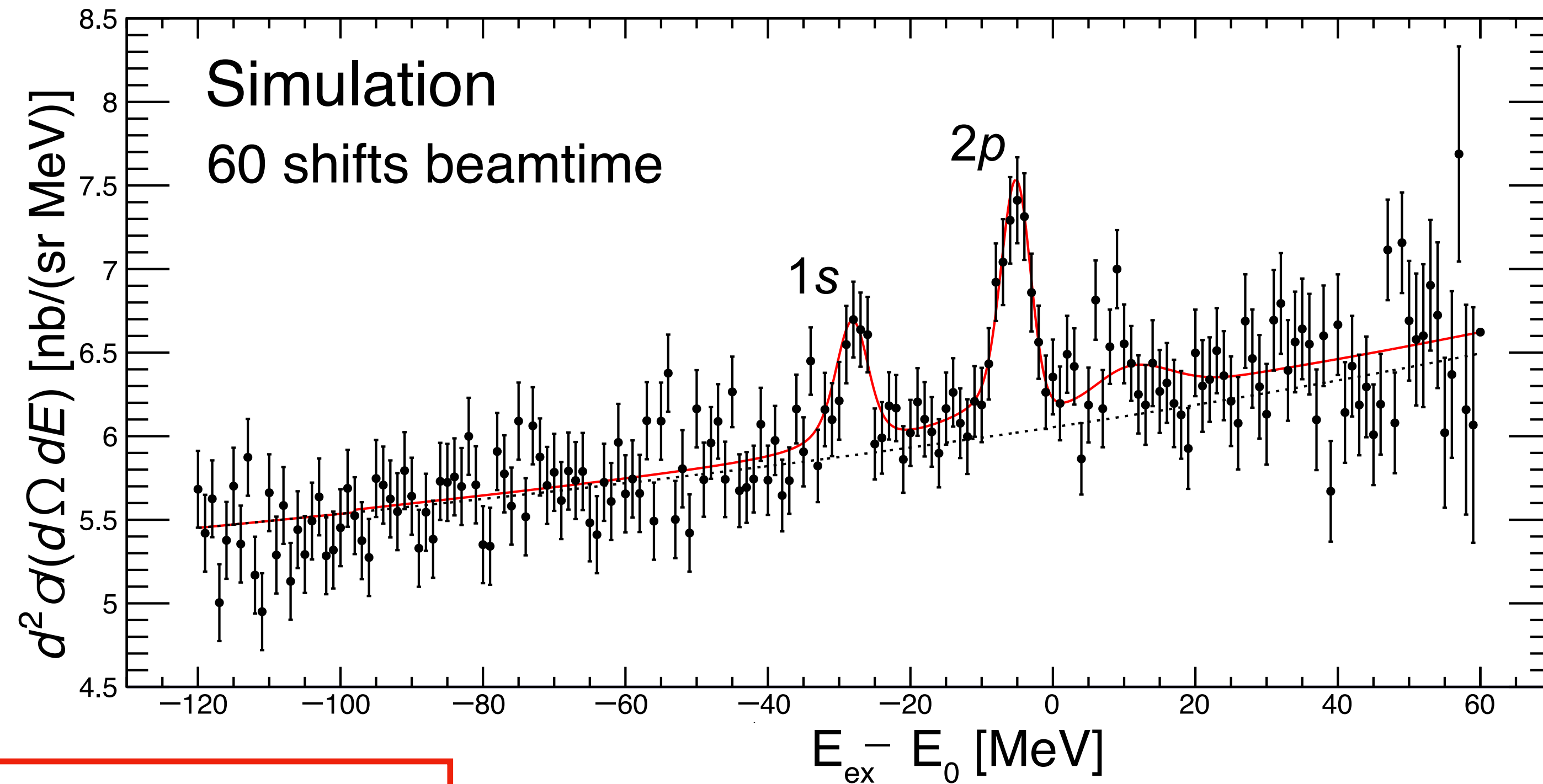
5.4 ton

~ 10 ton

4K fridge attached

Helium consumption large
Conflict with other exp.

WASA2 at FRS for η PRiME



See GSI-S490 (Thursday 18 Sep.)

arXiv: 2509.07824

submitted to PRL

Statistical significance 2.1σ (global)

Fit indicates $V_0 = -62$, $W_0 = -2$ MeV

First indication of η' -mesic nuclei

Assuming same potential, we expect 2 peaks
to be observed and statistical significance $> 5\sigma$ (global)

Goal: discovery of η' -mesic nuclei

Summary

- WASA2 is upper-compatible WASA for charged particle measurement.
- Joint usage/research program approved by owner RCNP, Osaka University
- WASA2 is transported to Toshiba company for cryogenic system replacement (→ next Take's talk)
- WASA2 can accommodate many physics cases
- Let us know your new idea of physics using this unique combination of high-resolution spectrometer FRS + WASA2
- η' -mesic nuclei project will realize “production phase” using WASA2
- We will prepare TDR and hope to submit a proposal to next G-PAC