Current status and plans of FFA at KURNS

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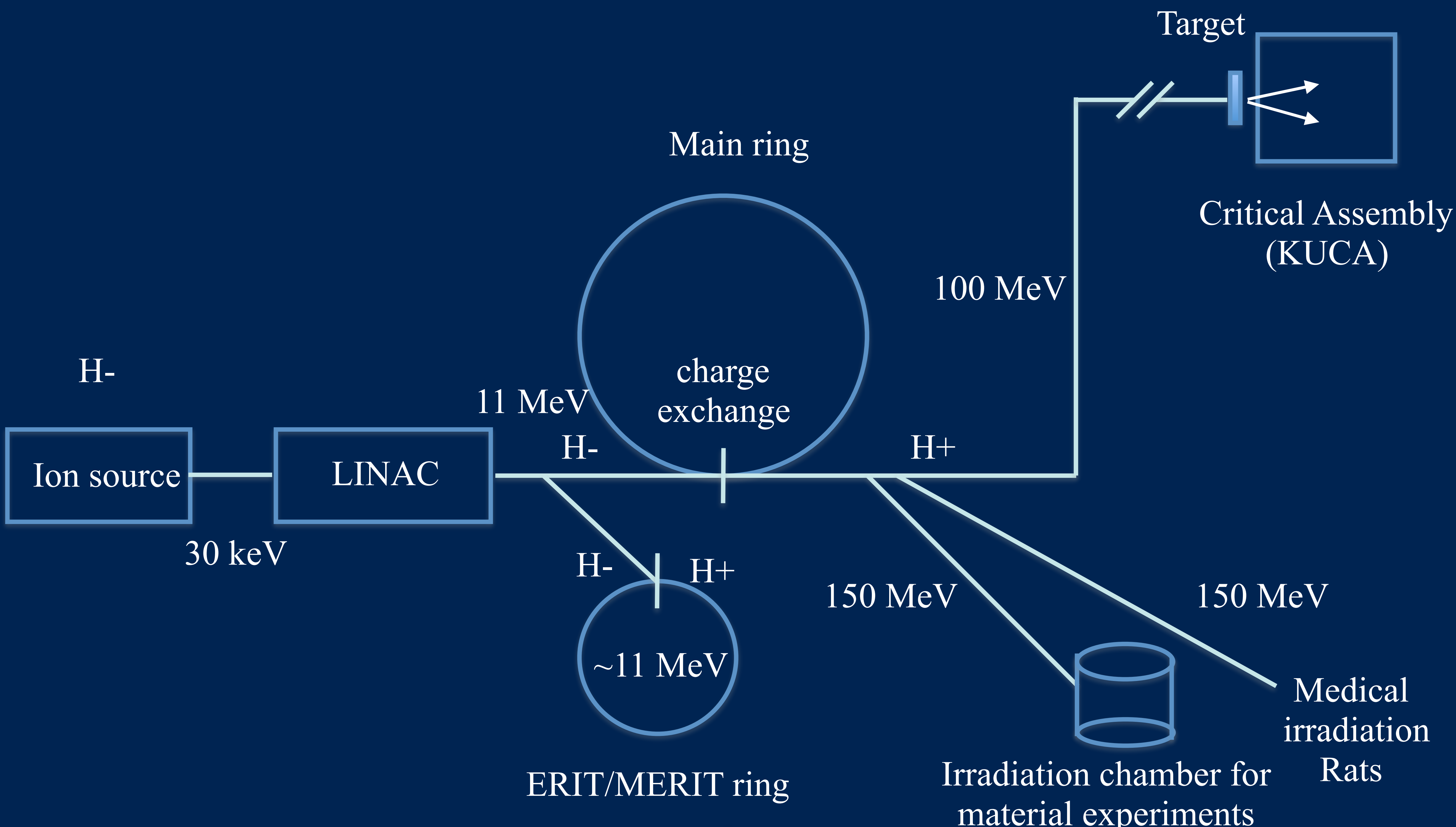
FFA 19 at Paul Scherrer Institute. 19 Nov. 2019

OUTLINE

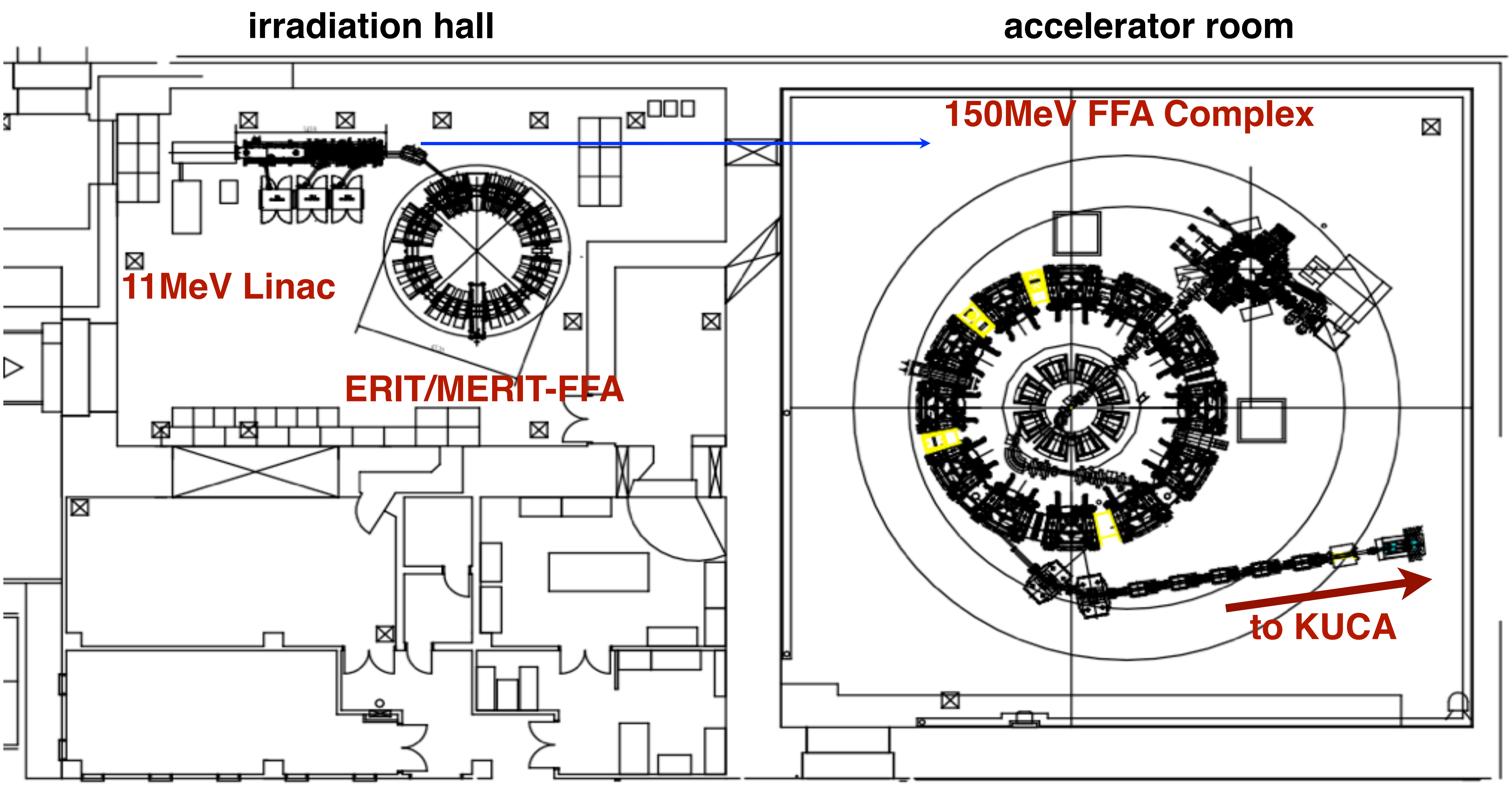
1. Present status of the KURNS FFA facility
    1. Overview of the Complex
    2. User’s experiments
2. First evidence of MA transmutation in the ADS
3. Modification plan of the main ring to the PPR
4. Summary

Overview of the Complex

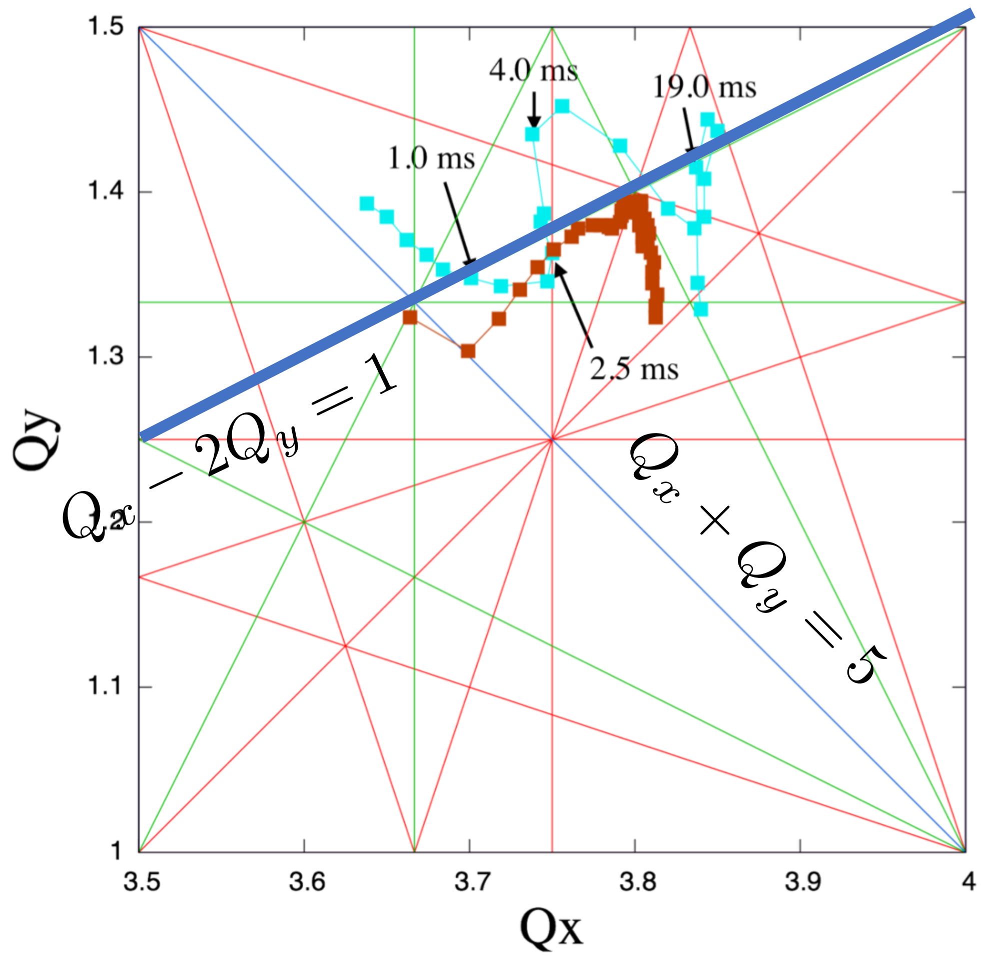
Schematic Diagram of the KURNS FFA Complex



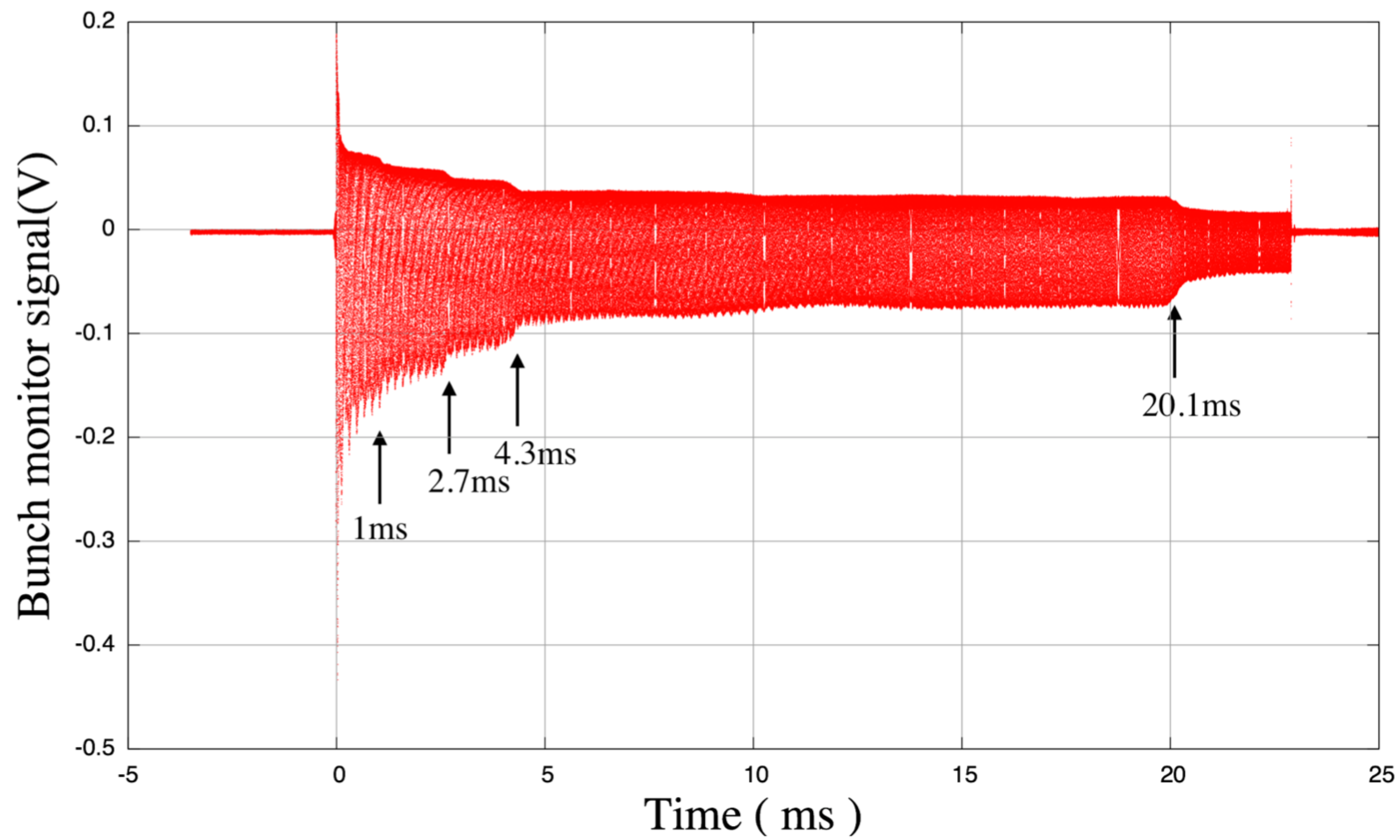
Layout of accelerator complex in the Innovation Research Lab.



MAIN RING tune excursion

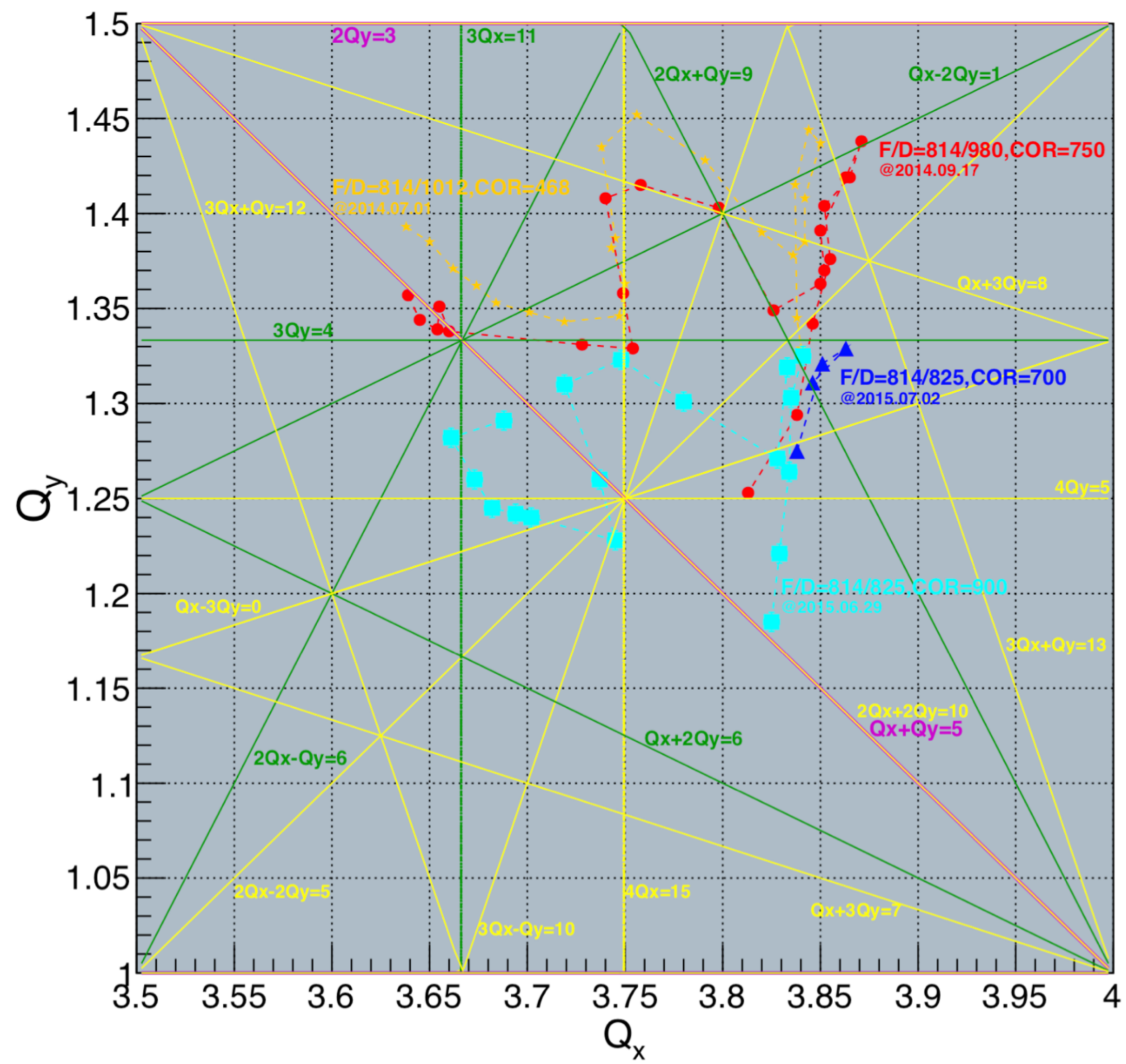


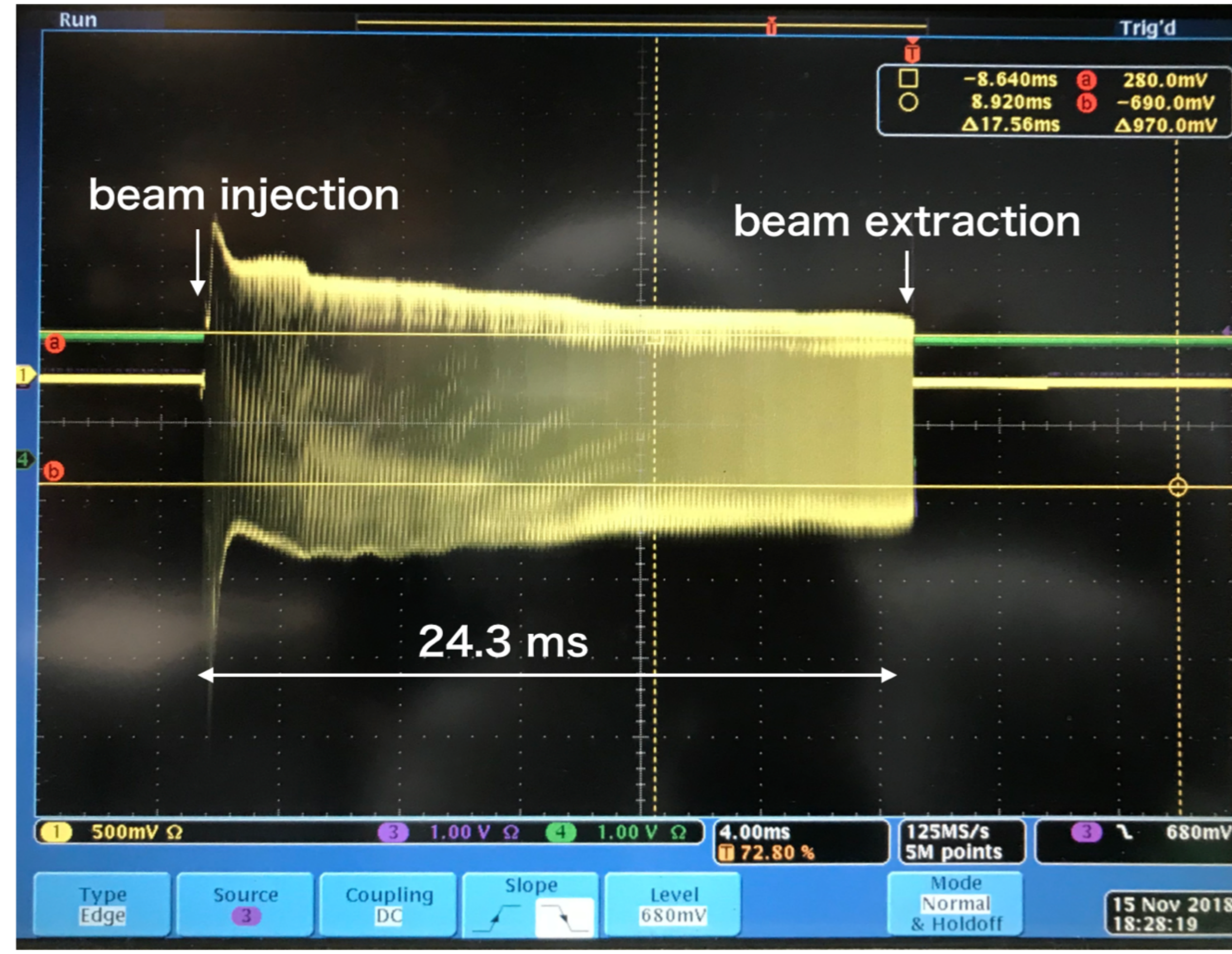
MAIN RING tune footprints.
Blue: measured
Brown: simulated



MAIN RING bunch monitor signal.

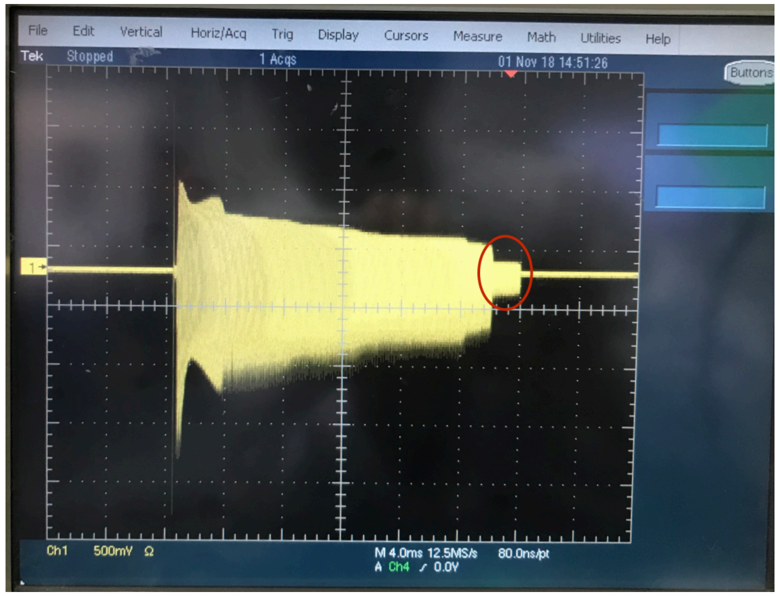
MAIN RING tune optimization

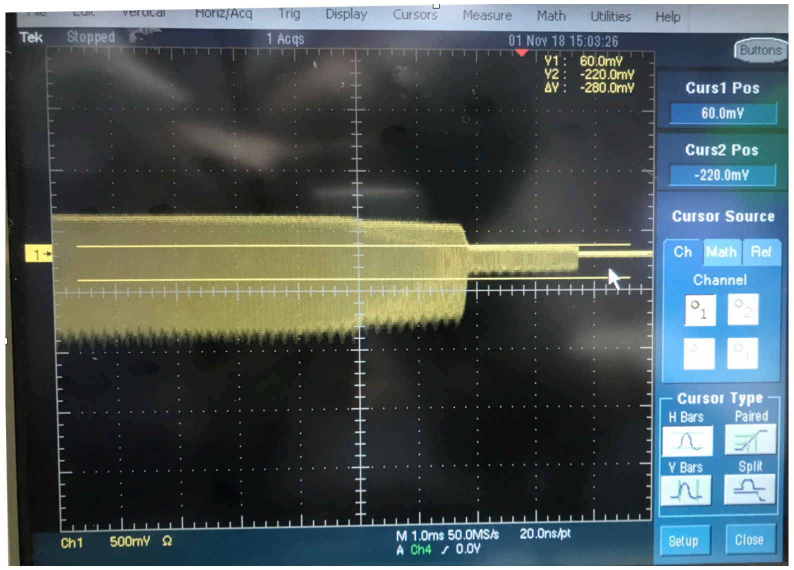




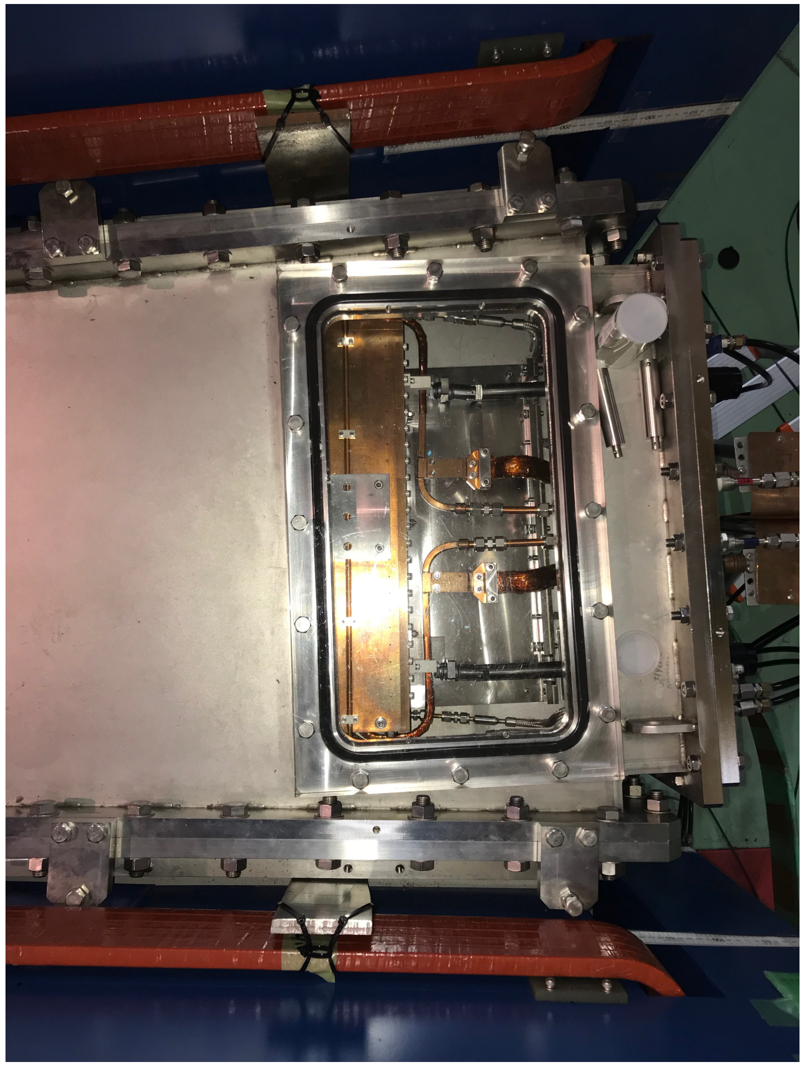
Bunch monitor signal with (F,D)=(814,814) A

Cure of beam loss before extraction

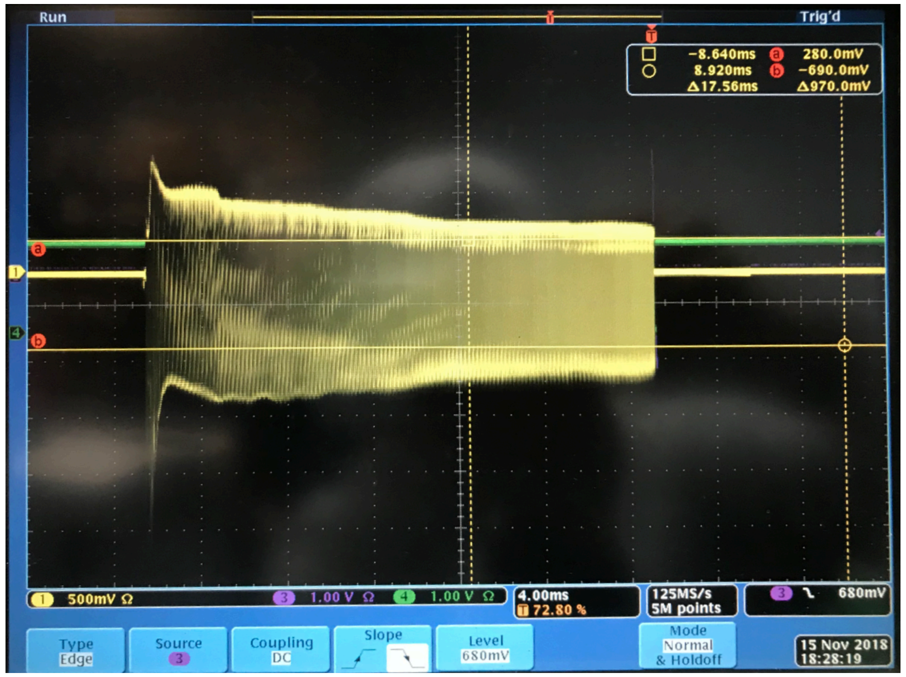




Large beam loss around 20 ms



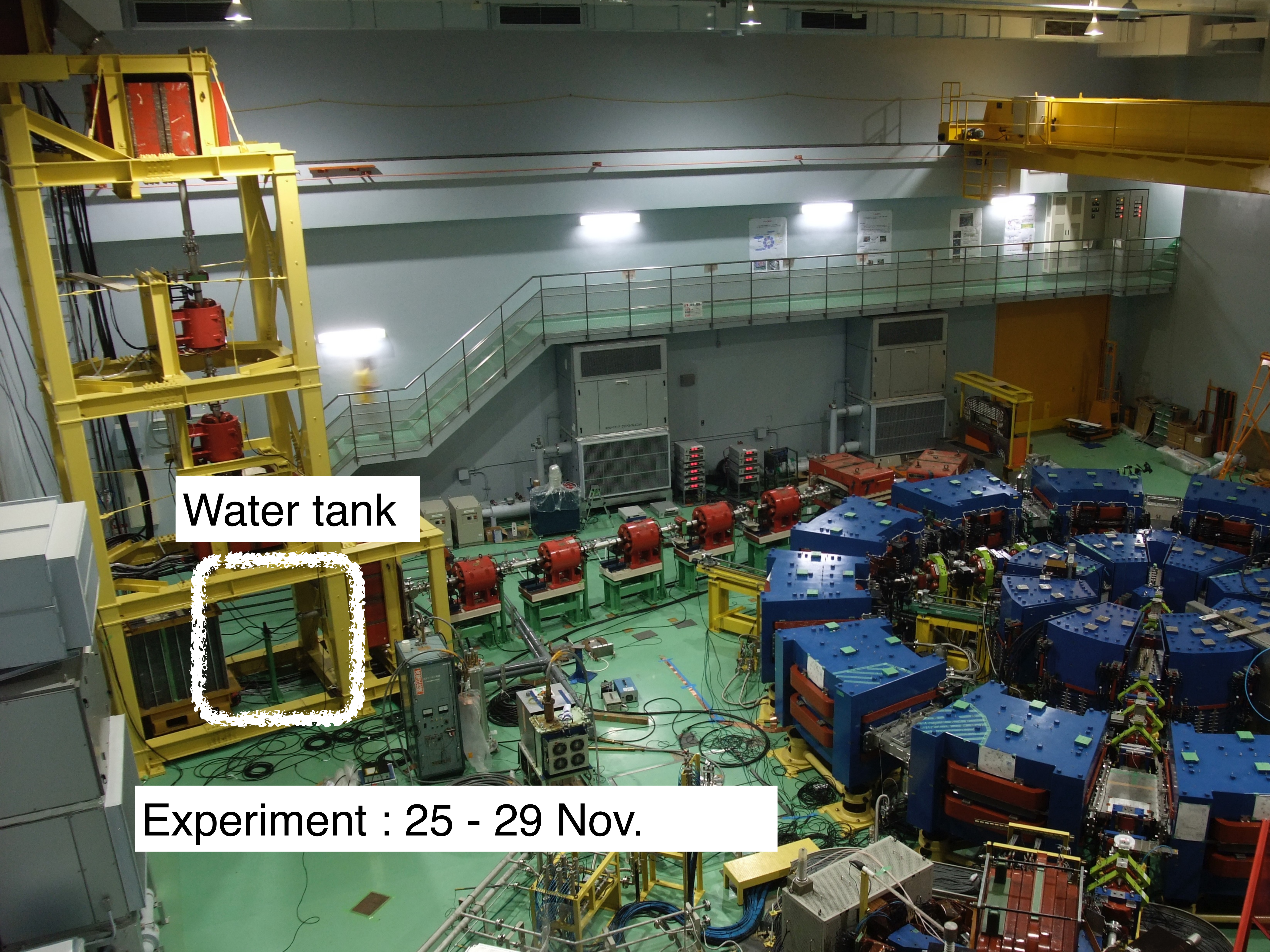
Patch relocated at proper position i.e. the inner edge of the patch has been located at the same position in R as the edge of the SME



The beam loss disappeared!

Beam users

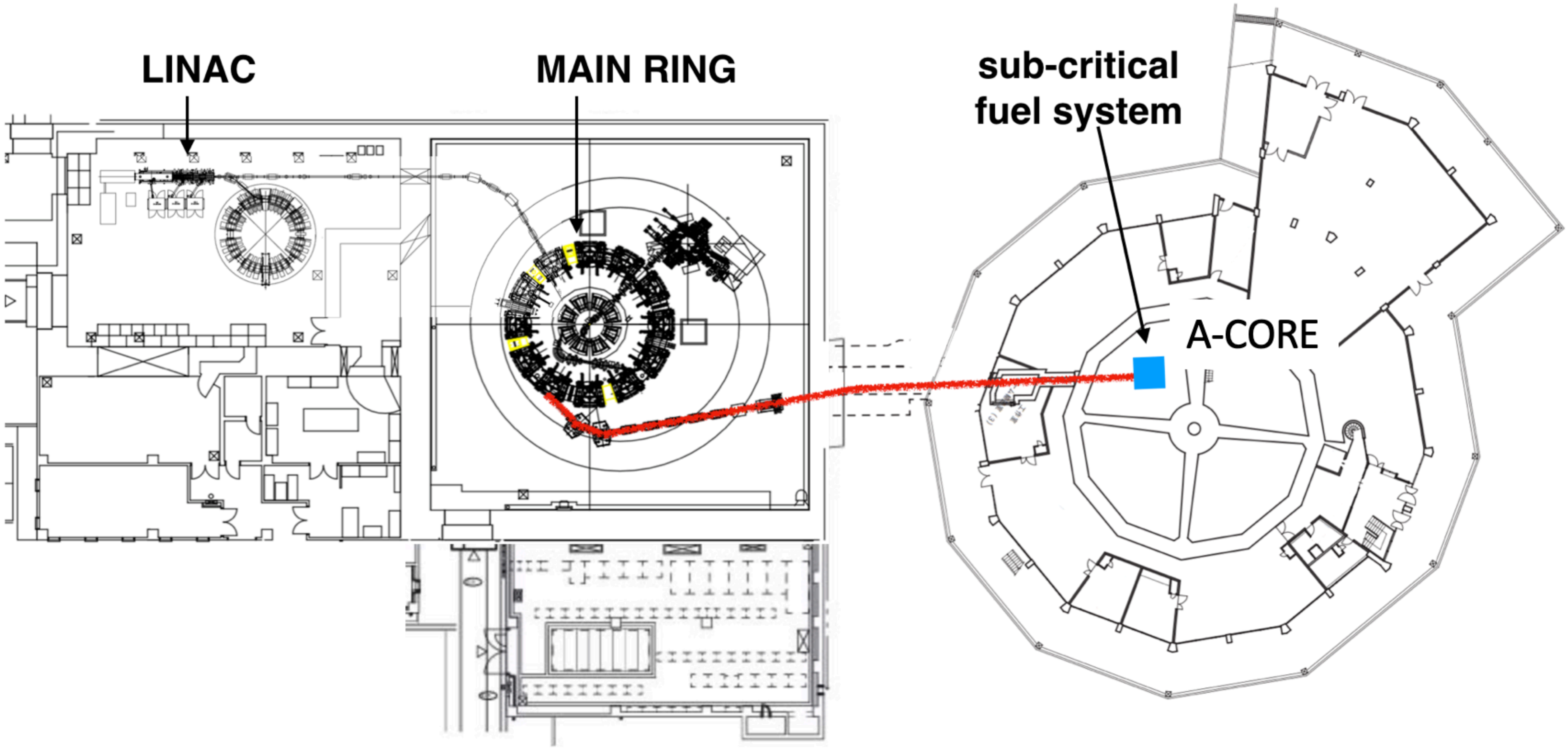
- Reactor physicist : ADS experiment
- Detector calibration for high energy physics
  - extremely low intensity :
    one proton / bunch (11 MeV H- LINAC)
- Medical purpose
  - 100 MeV short bunch -> ultra sonic from metal marker in the water phantom


Water tank
Experiment : 25 - 29 Nov.

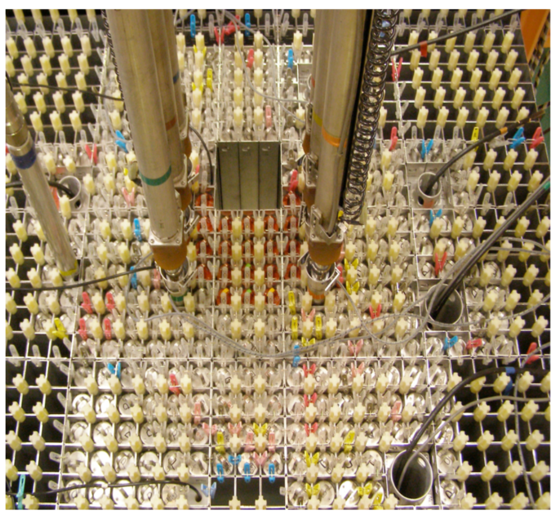
ADS experiment

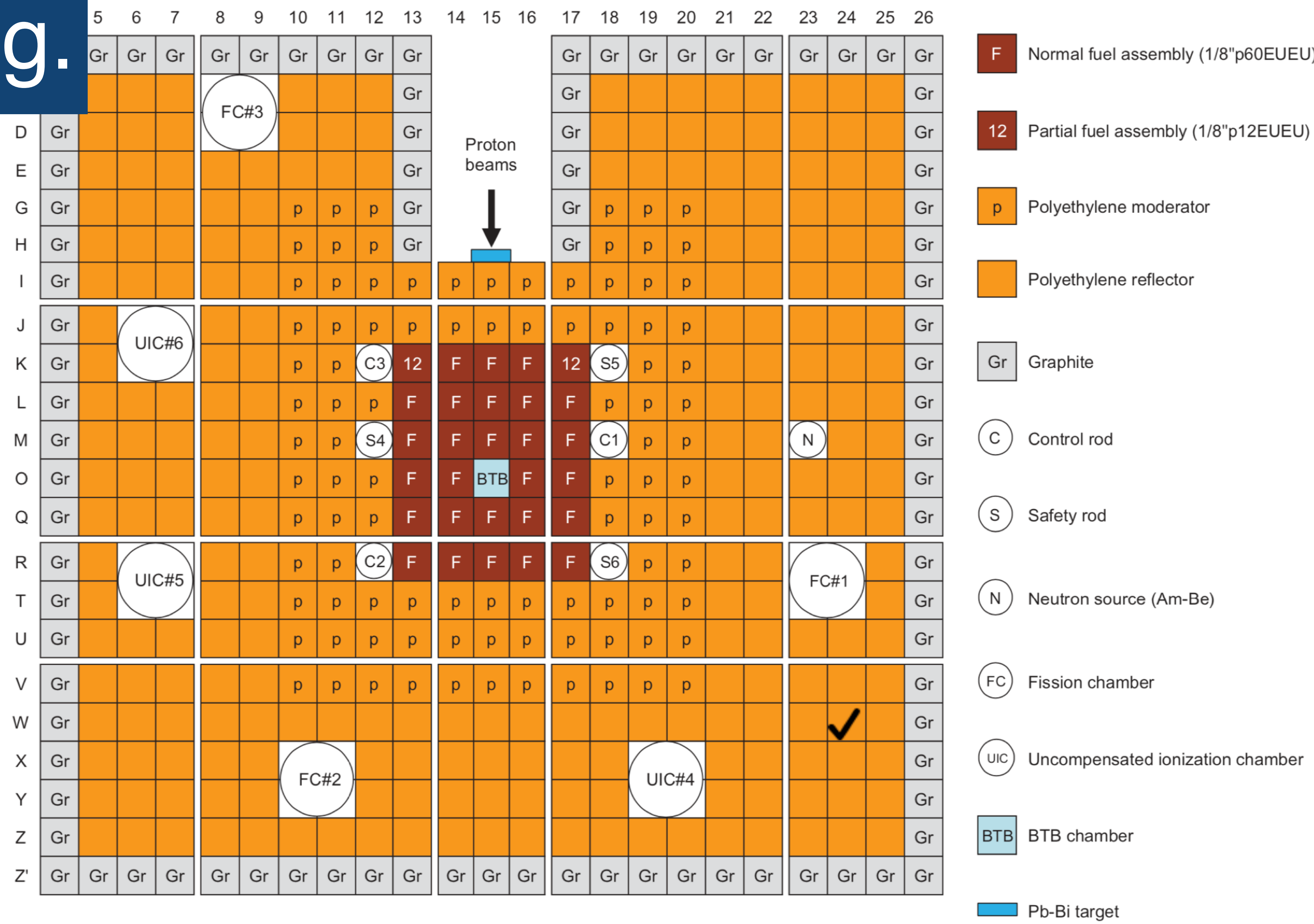
First evidence of MA transmutation in the ADS

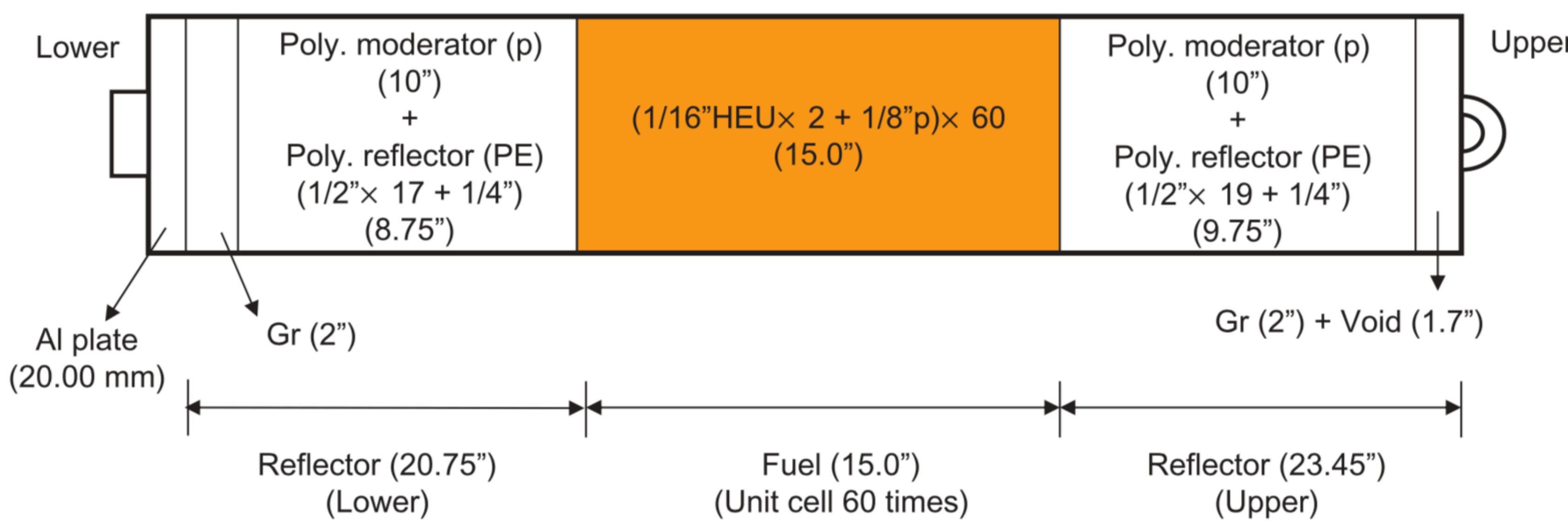
ADS Experimental Facilities at KURNS



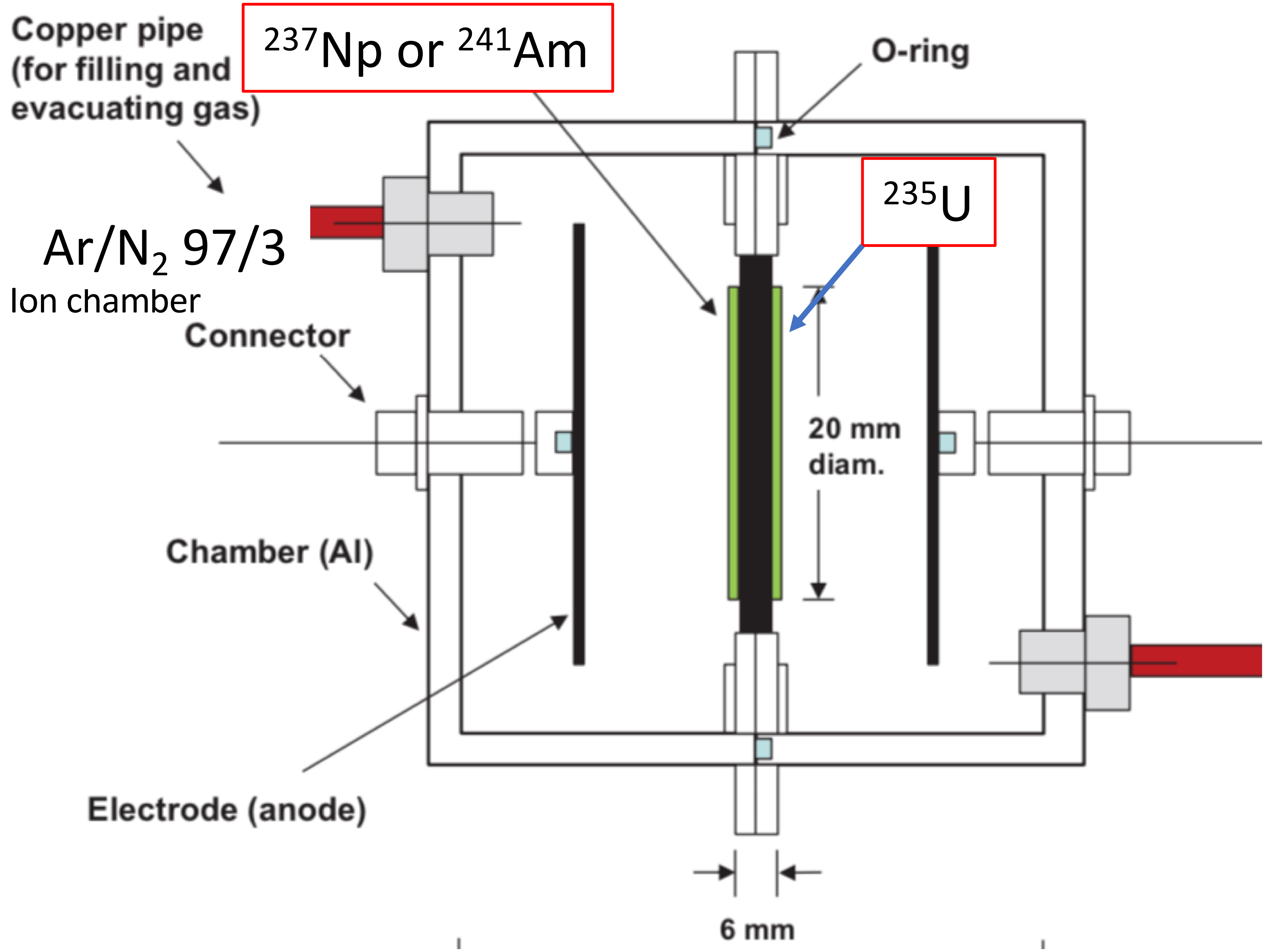
Core config.

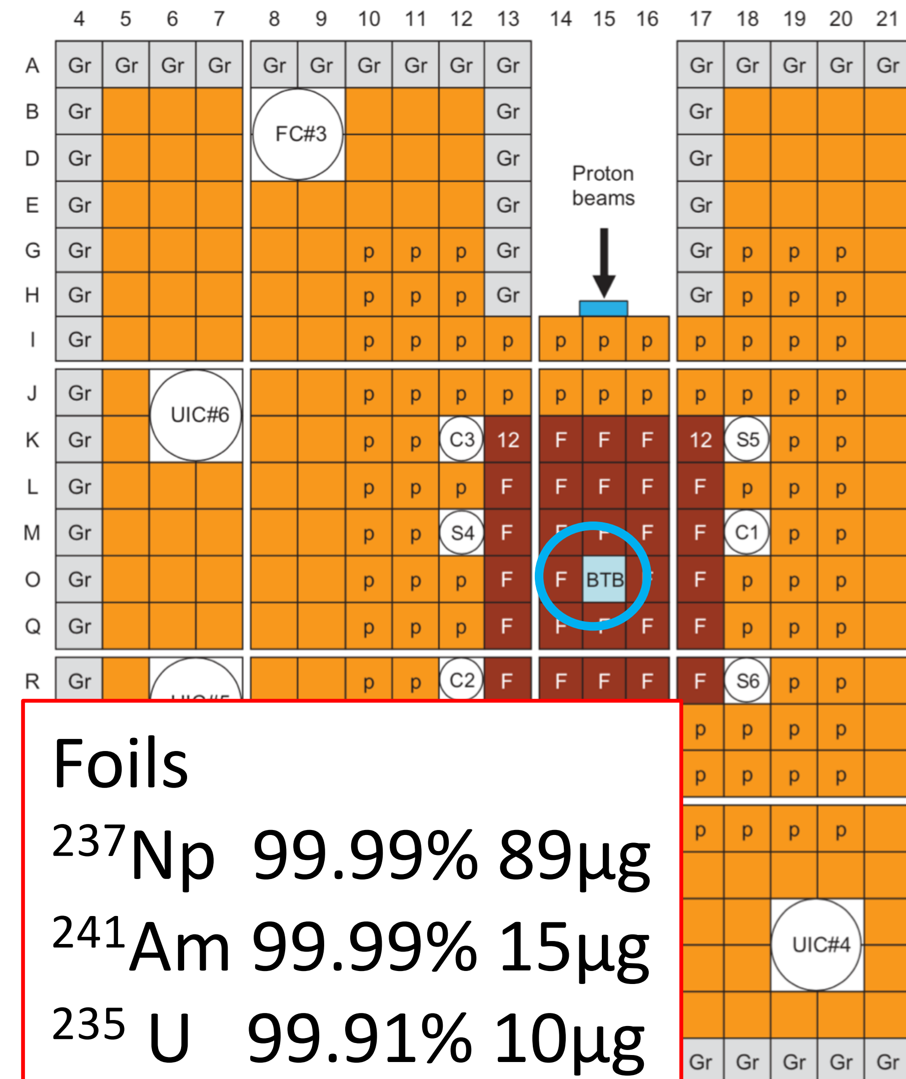



5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
D E G H I J K L M O Q R T U V W X Y Z Z'
FC#3
Proton beams
UIC#6
C3
S5
S4
C1
N
BTB
UIC#5
C2
S6
FC#1
FC#2
UIC#4
F Normal fuel assembly (1/8"p60EUEU)
12 Partial fuel assembly (1/8"p12EUEU)
p Polyethylene moderator
Polyethylene reflector
Gr Graphite
C Control rod
S Safety rod
N Neutron source (Am-Be)
FC Fission chamber
UIC Uncompensated ionization chamber
BTB BTB chamber
Pb-Bi target


Lower
Upper
Poly. moderator (p)
(10")
+
Poly. reflector (PE)
(1/2"× 17 + 1/4")
(8.75")
(1/16"HEU× 2 + 1/8"p)× 60
(15.0")
Poly. moderator (p)
(10")
+
Poly. reflector (PE)
(1/2"× 19 + 1/4")
(9.75")
Al plate
(20.00 mm)
Gr (2")
Gr (2") + Void (1.7")
Reflector (20.75")
(Lower)
Fuel (15.0")
(Unit cell 60 times)
Reflector (23.45")
(Upper)

BTB (Back-to-back fission chamber)





Foils

^{237}Np 99.99% 89μg

^{241}Am 99.99% 15μg

^{235}U 99.91% 10μg

Special cell contains the back to back or BTB fission chamber.

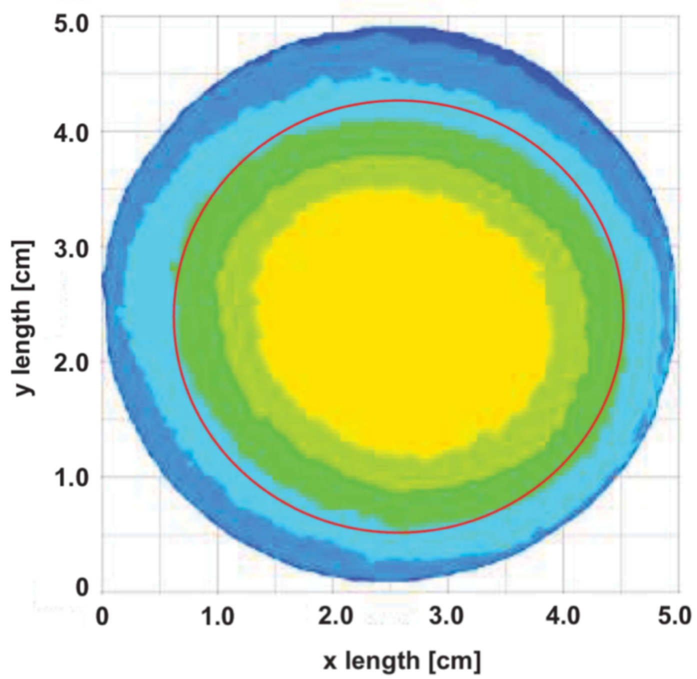
The sample foil of 237Np or 241Am was set on this plate back to back of the uranium reference foil.

BTB chamber is an ion chamber. The gas is argon nitrogen 97 to 3.

Signals from MA and uranium can be accumulated in the same run of experiment.

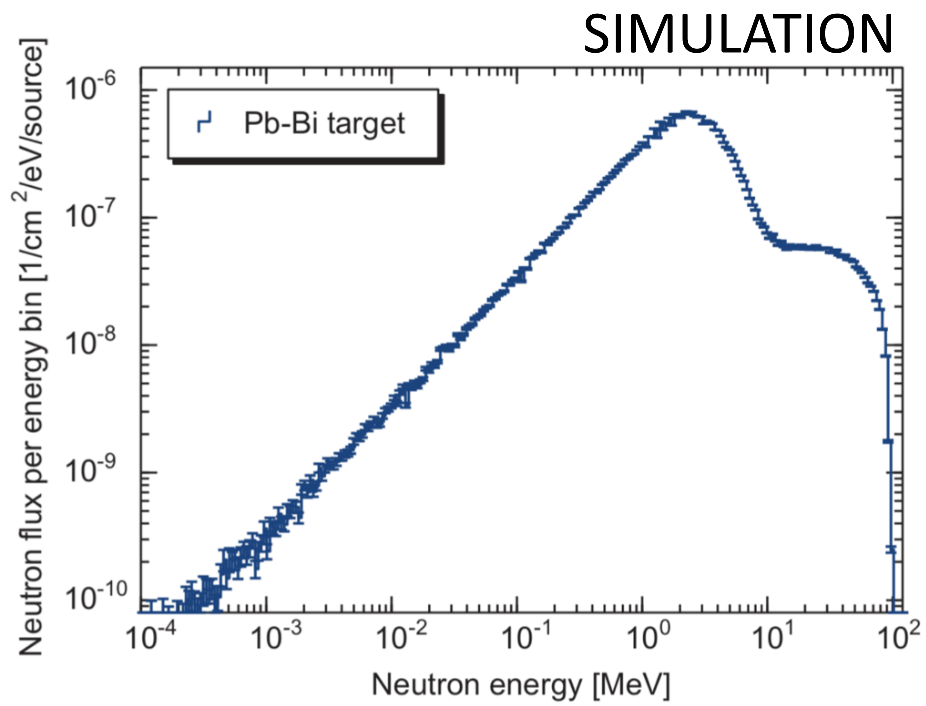
These are not taken as coincidence.

Proton beam profile and neutron energy spectrum at the target

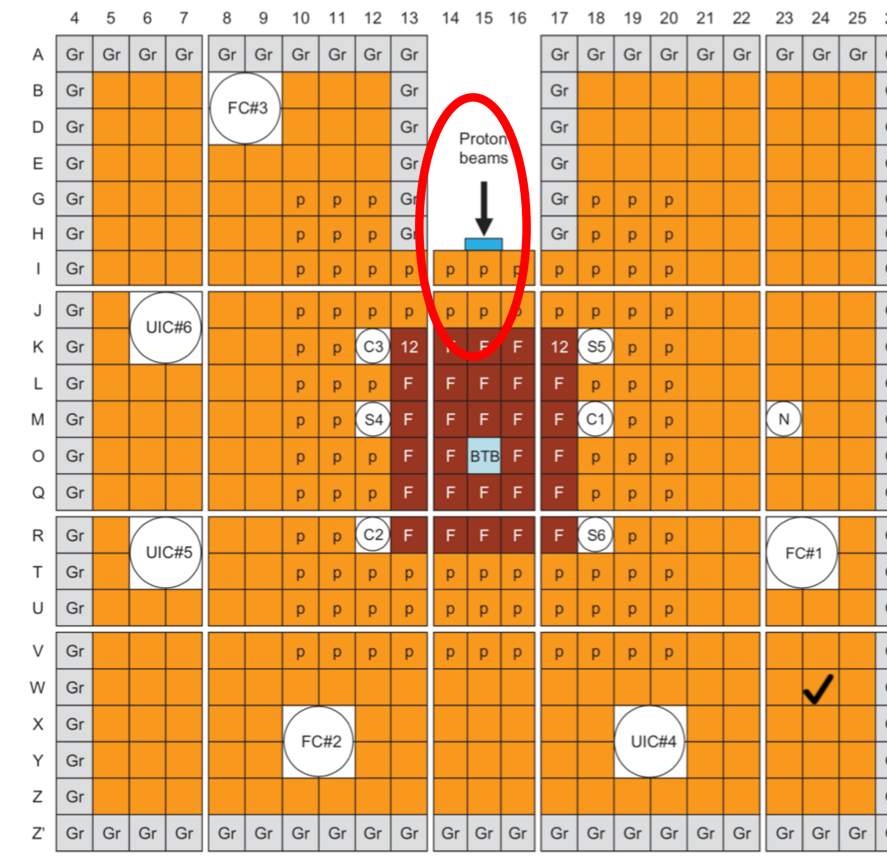


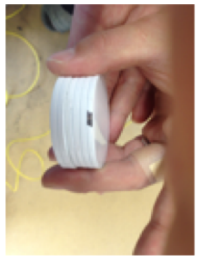
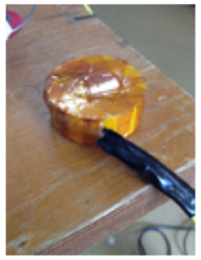
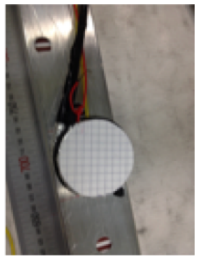
Proton beam profile at the Pb-Bi target measured by Gafchromic film.

6.3×10^{9} protons/s
1.3×10^{8} neutrons/s



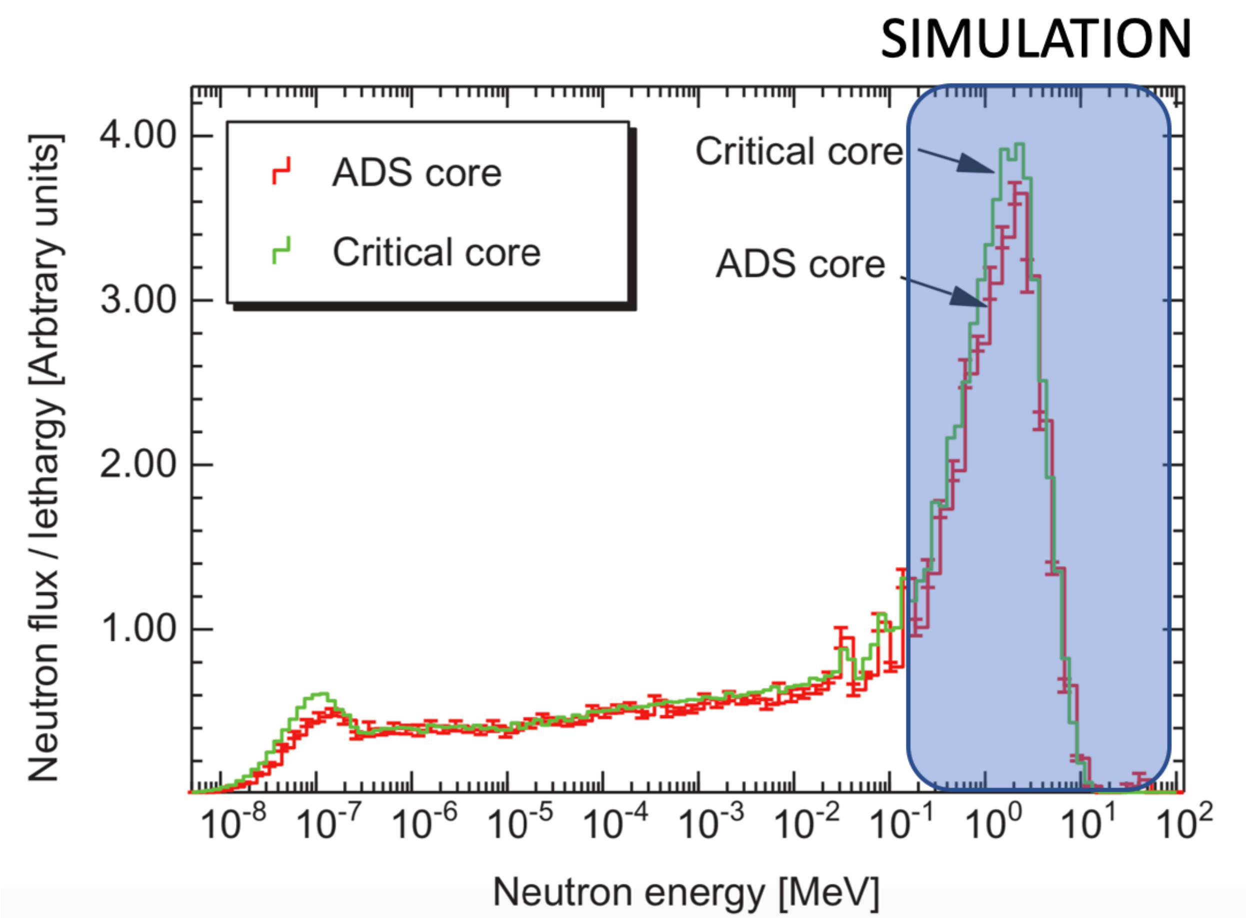
Neutron energy spectrum at the target calculated by PHITS, using the proton beam profile on the left.

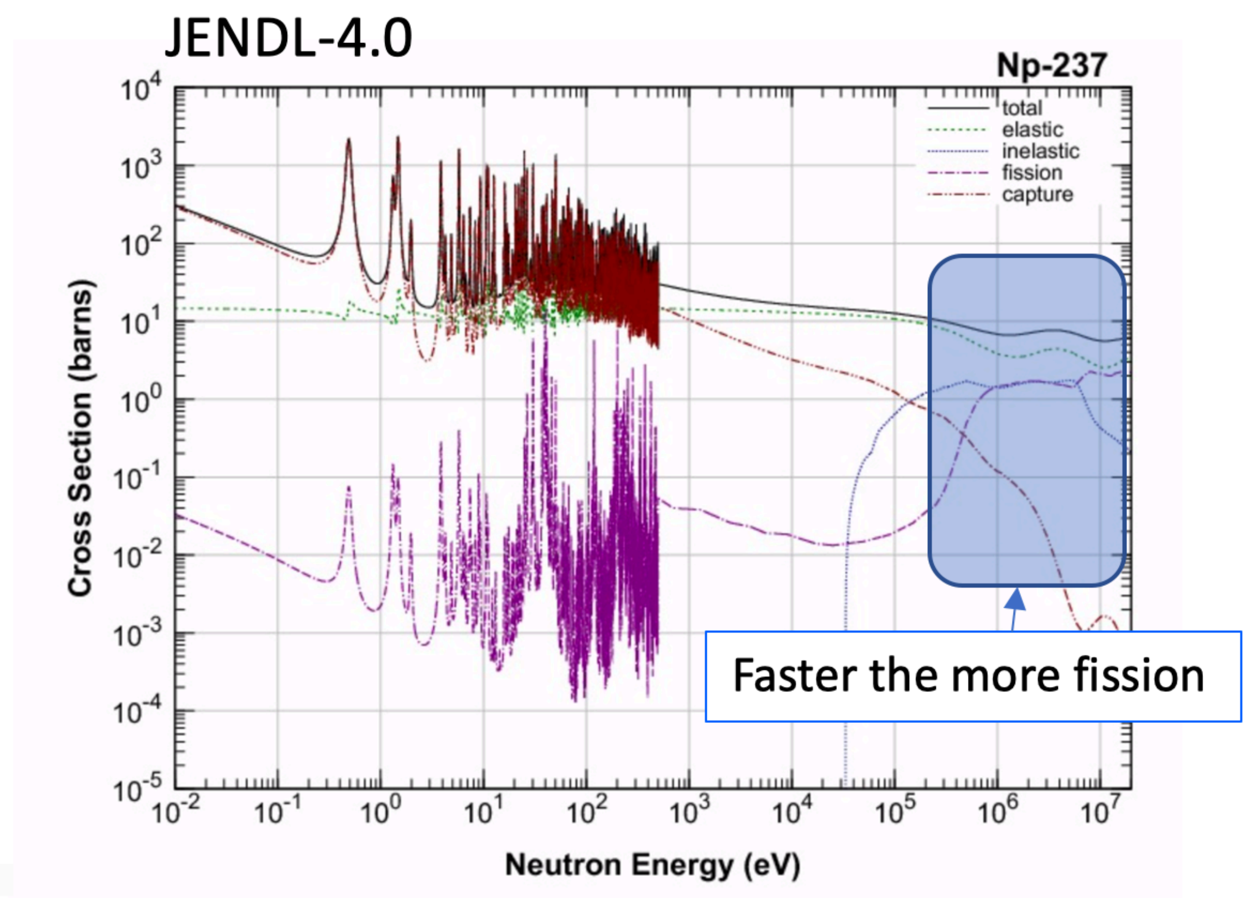


Prior to experiments, a beam profile at the target was measured by using Gaphcromic film.
The neutron energy spectrum at the target was obtained by simulation by using PHITS code.

Neutron energy spectrum at the BTB





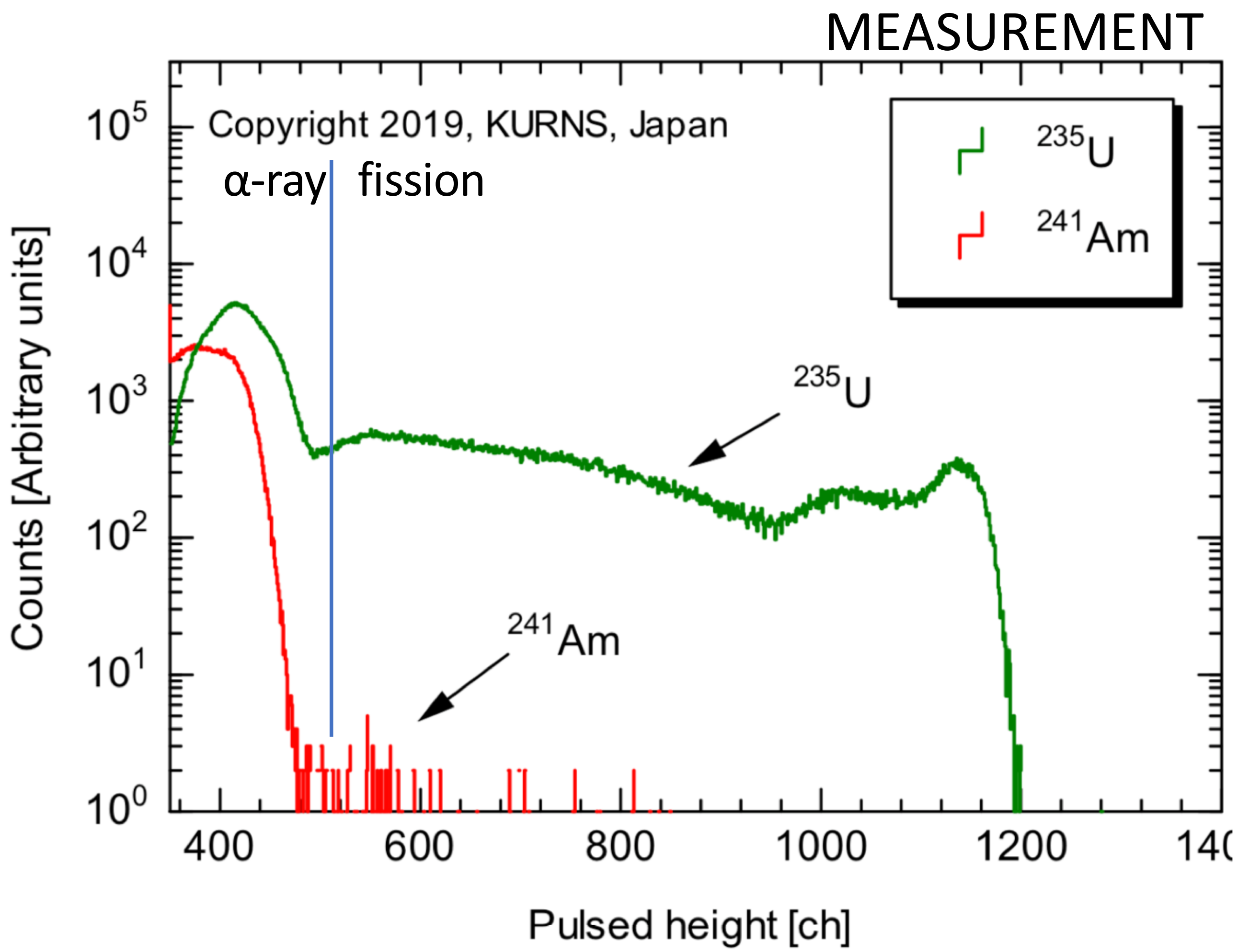
Neutron energy spectrum at the BTB calculated by PHITS, using the proton beam profile.

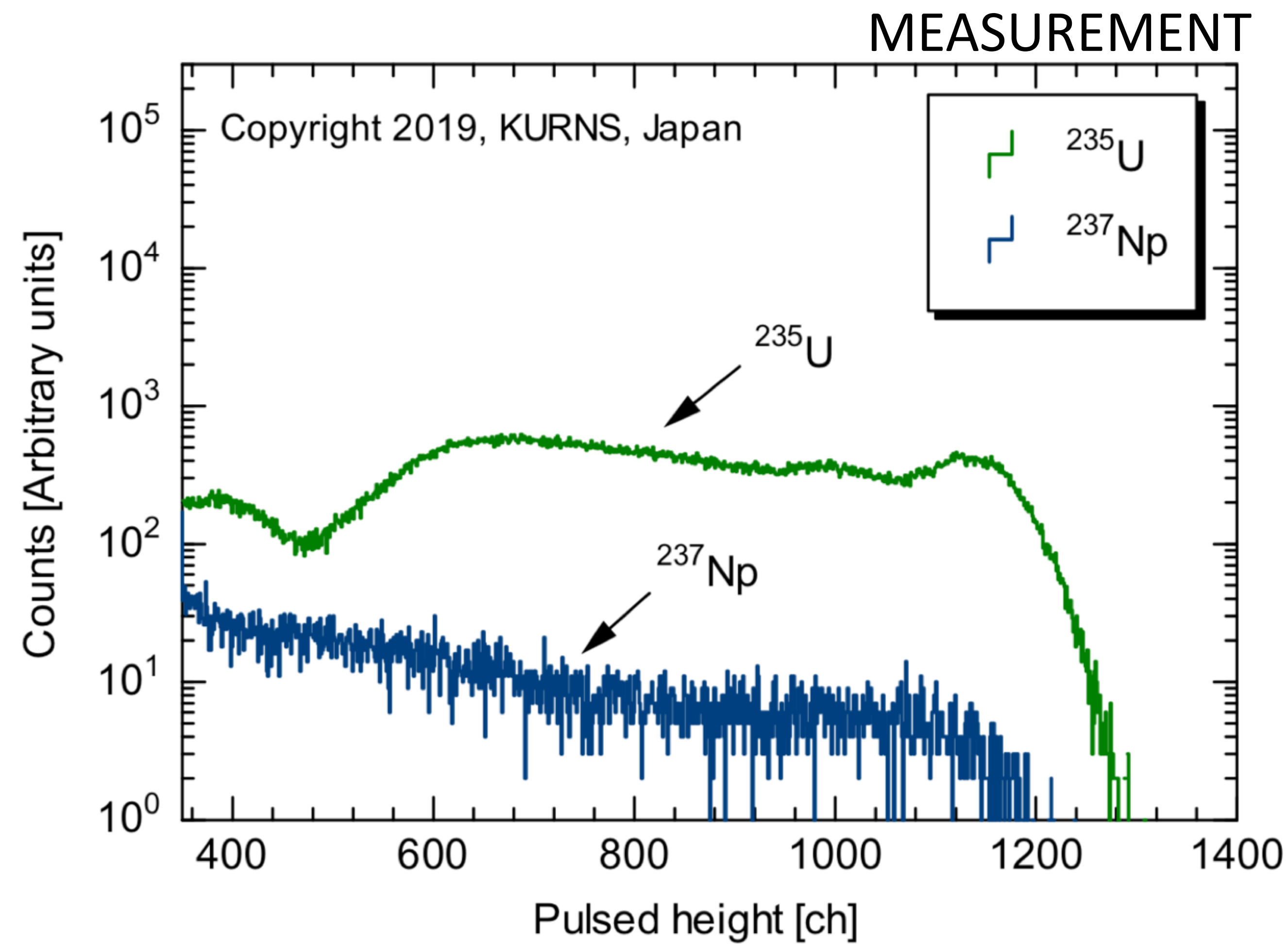
Neutron cross section by JENDL-4.0

Neutron energy spectrum at the BTB was also calculated using PHITS.
The energy spectrum for critical core without initial neutron from the target.

Fission reaction of ^{241}Am and ^{237}Np

Np-237→Mo-102 + I-133





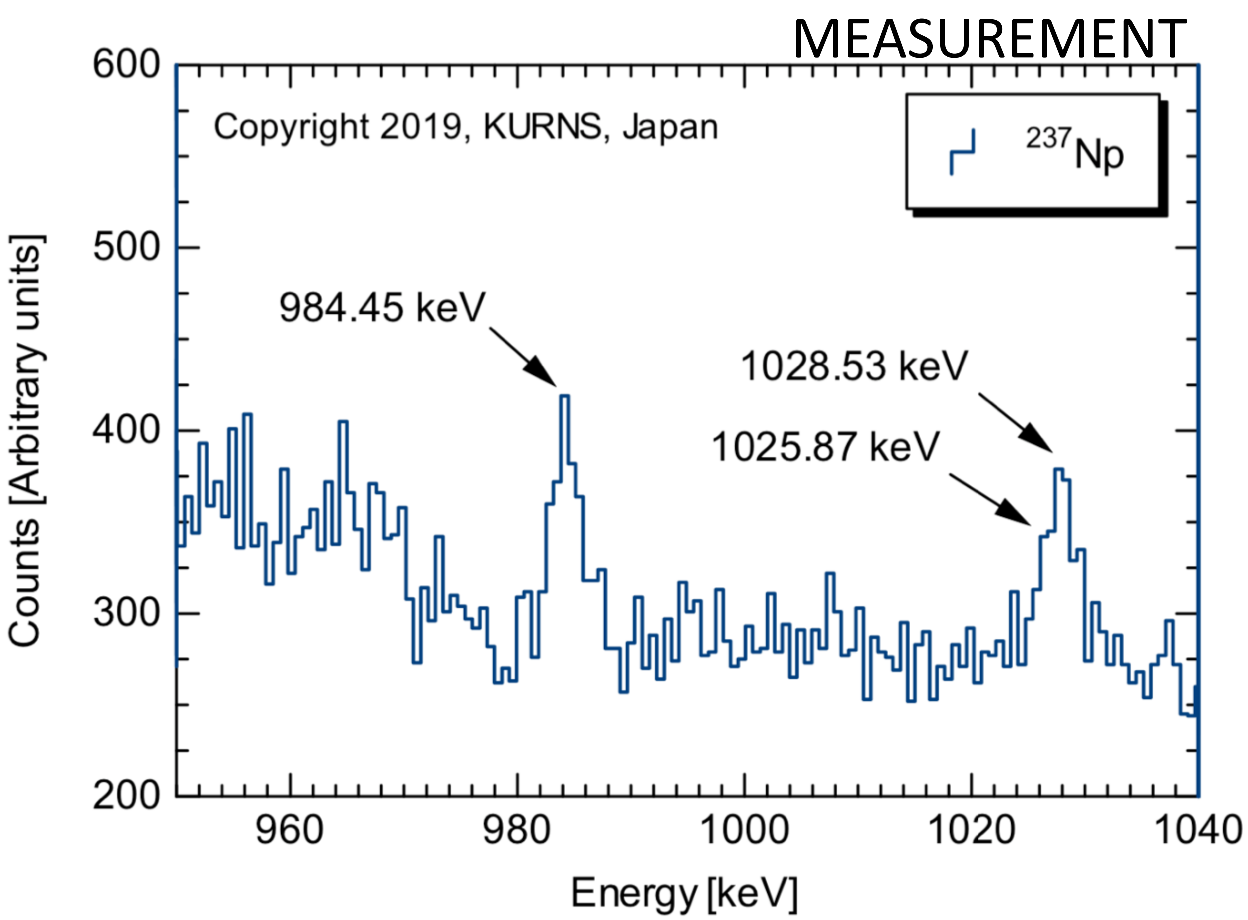
The left plot is the pulse height distribution from BTB chamber for americium. In the lower energy region less than 480 ch (1.2 MeV), there are lots of alpha contamination. Although the number of signals is very small, we see the clear signal in this region. These are from the fission reactions.

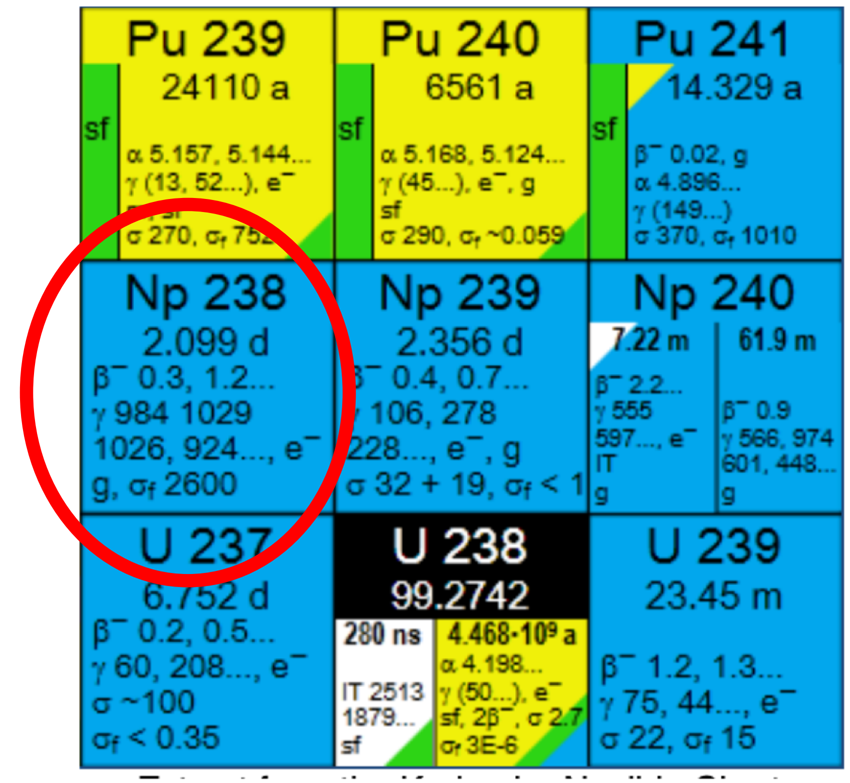
On the right, the same plot for neptunium. It has a large number of signals from the fission events.

These measurement were done during the beam irradiation.

Capture reaction of ^{237}Np

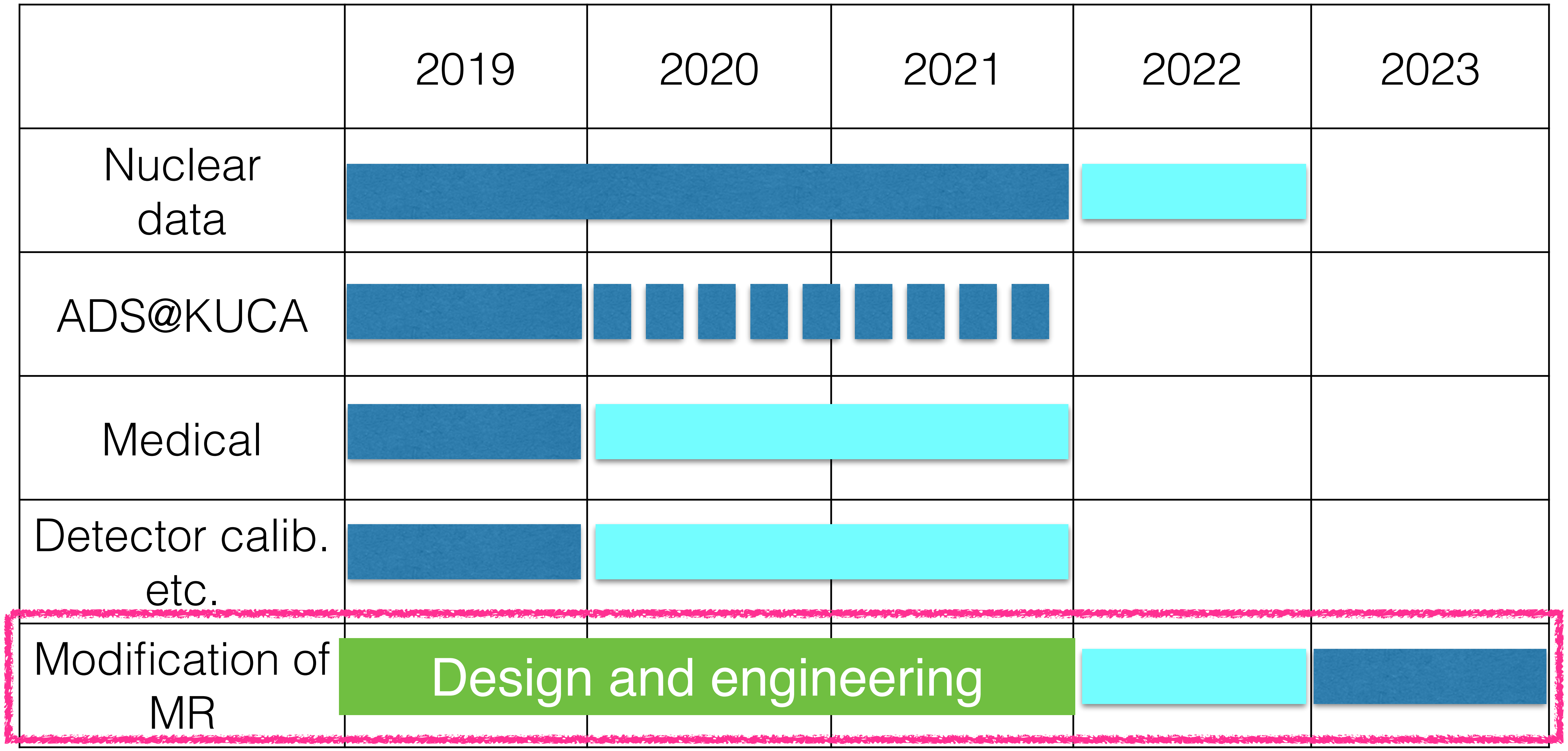
$$n + {}^{237}Np \longrightarrow {}^{238}Np \xrightarrow{\text{B decay(2.1 days)}} {}^{238}Pu$$





For the capture reaction.The measurement was done by detecting gamma ray spectrum by using germanium detector after extracting the sample foil.It shows a clear signal around 984 keV which is from beta decay of 238Np produced by neutron capture process of 237Np.

Plans


2019
2020
2021
2022
2023
Nuclear data
ADS@KUCA
Medical
Detector calib. etc.
Modification of MR
Design and engineering

Modification of MR

Main Ring → PPR (Pion Production Ring)

(for the case of moving MR to RIKEN)

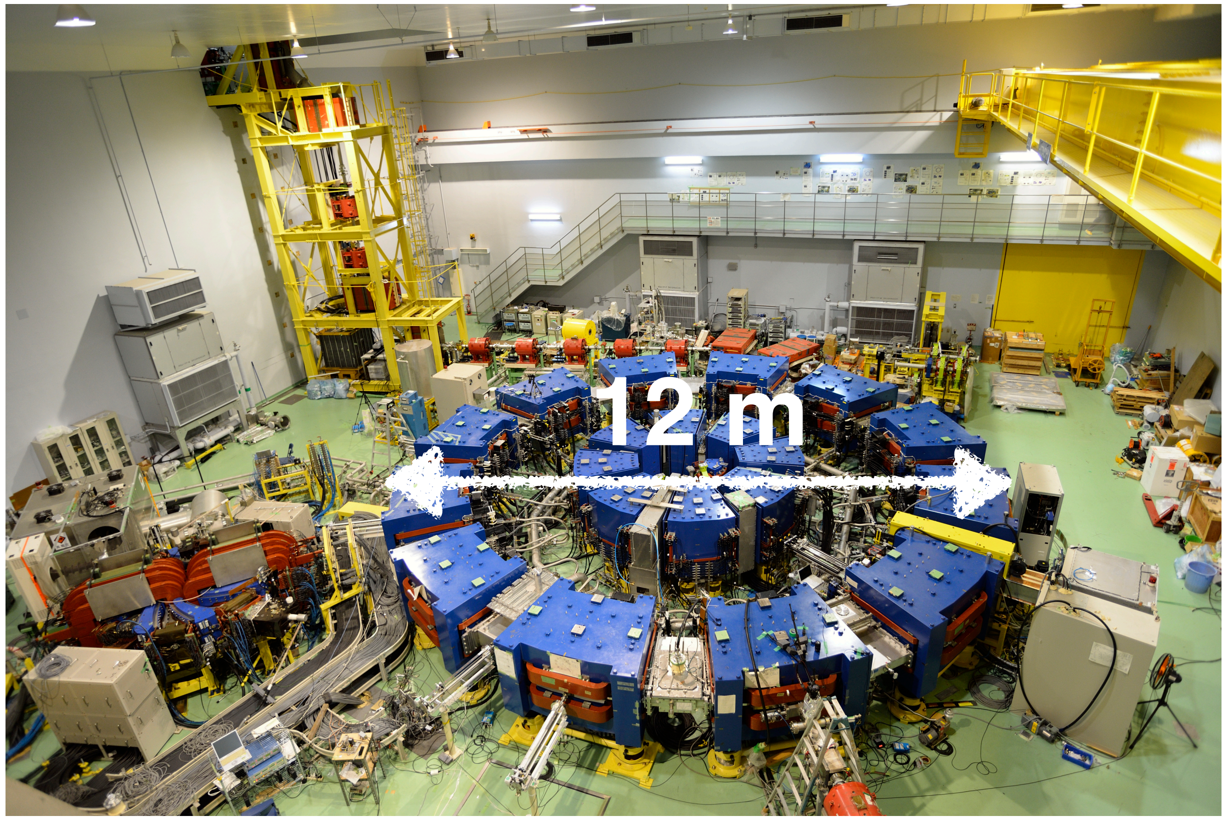
330 MeV proton FFA / AVF CYC.

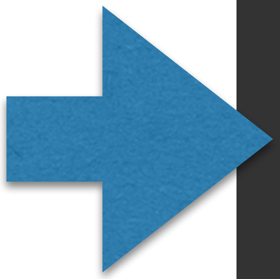
Designed by K. Suga and H. Okita

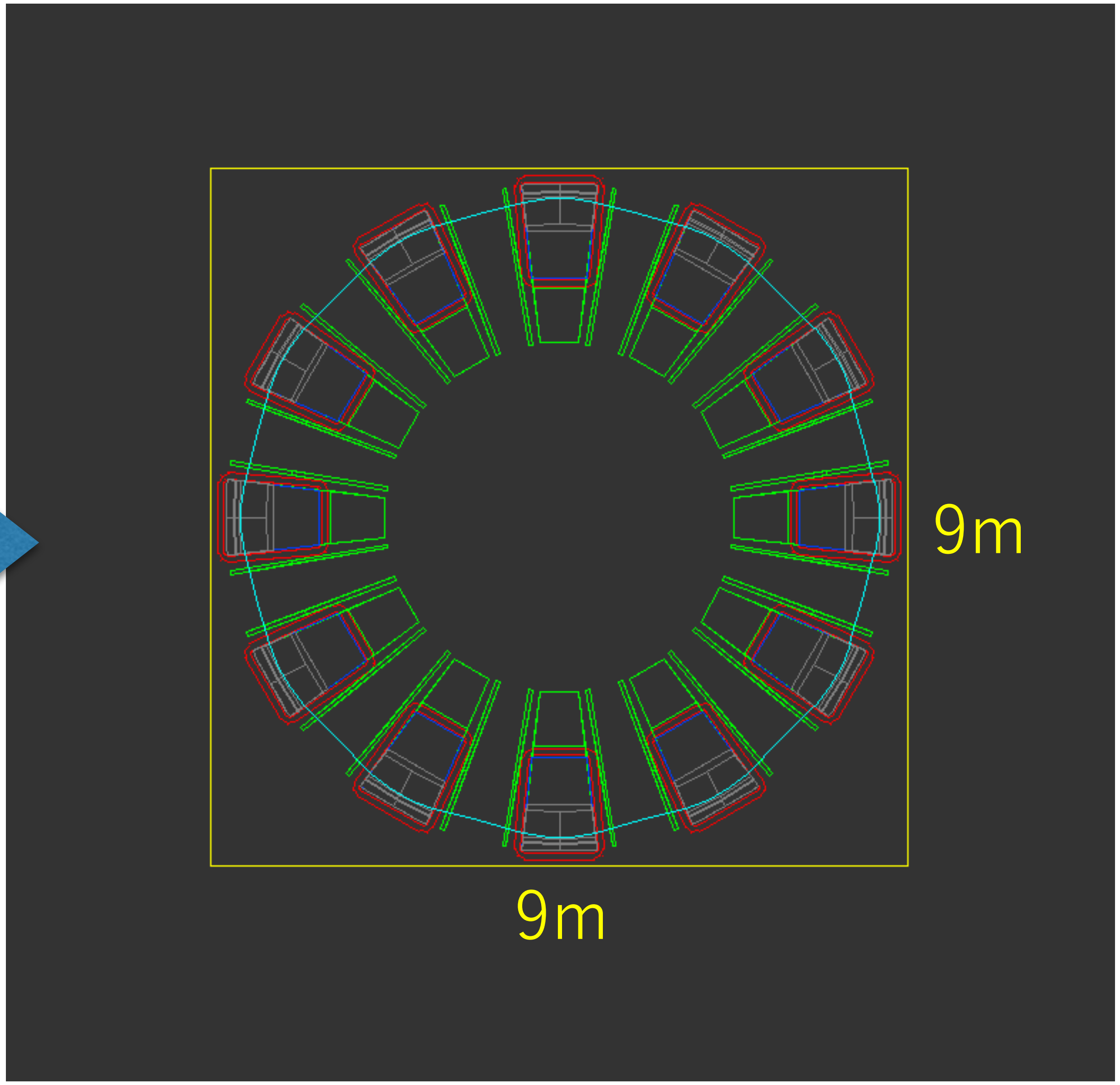
Concept and constraints

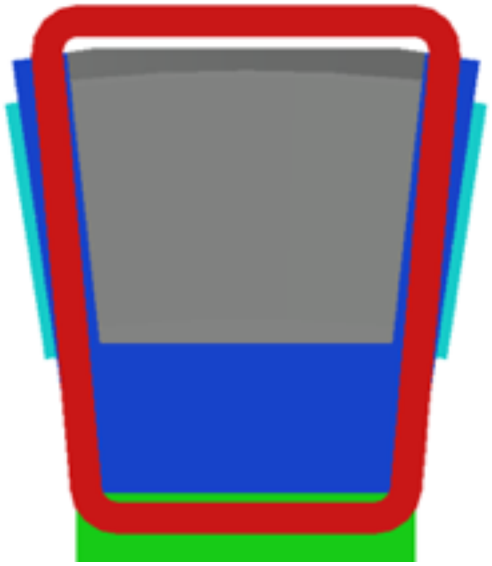
1. Dedicated to pion production
2. Use ERIT scheme i.e. no acceleration
3. Inject 330 MeV proton from AFV cyclotron at RIKEN
4. Fit to the existing building at RIKEN $R_{\mathrm{footprint}}$ < 5 m
5. No reverse bending
    1. Use only F magnets
    2. Low k for the horizontal focusing
    3. Edge angle for the vertical focusing
6. Aiming design at a perfect-scaling and COD-free ring

Squeeze the footprint





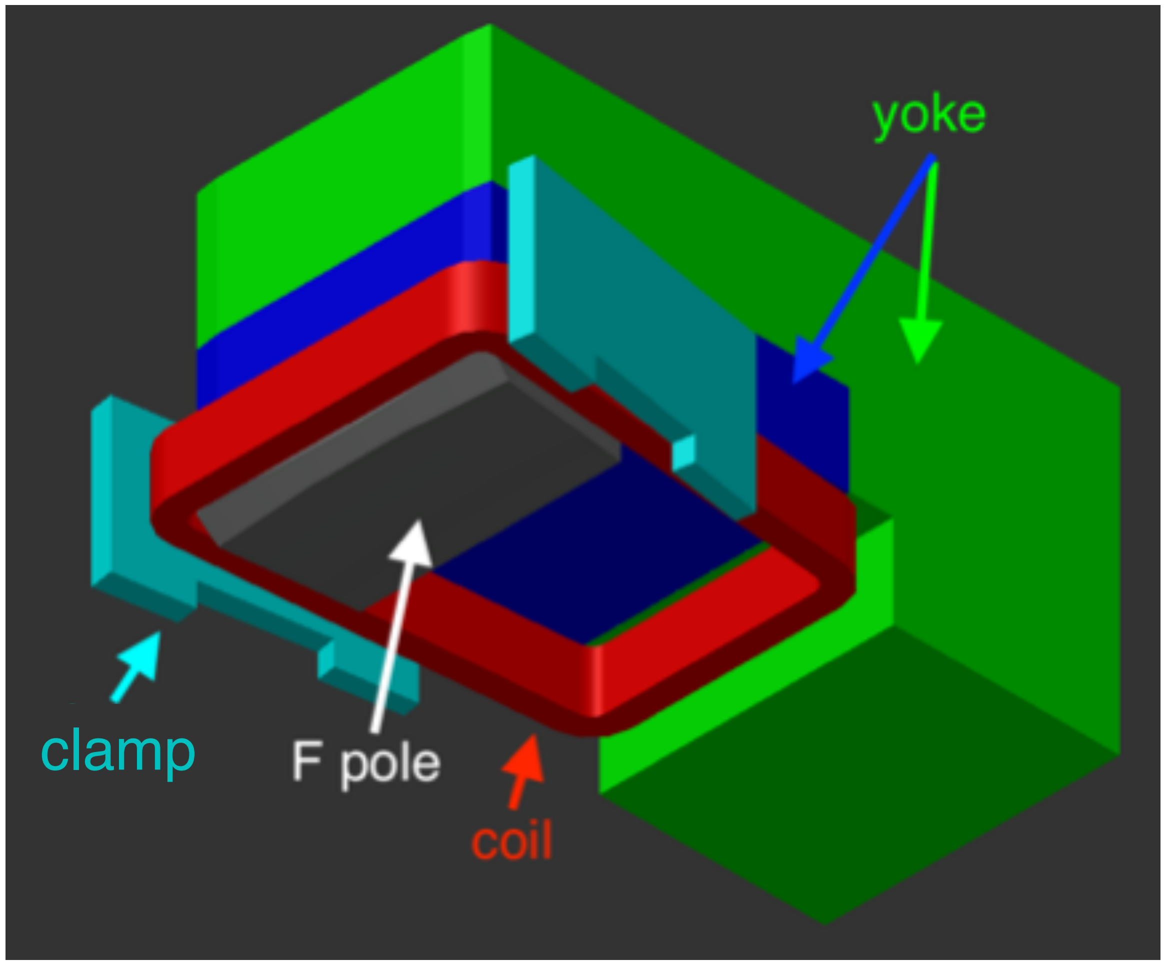


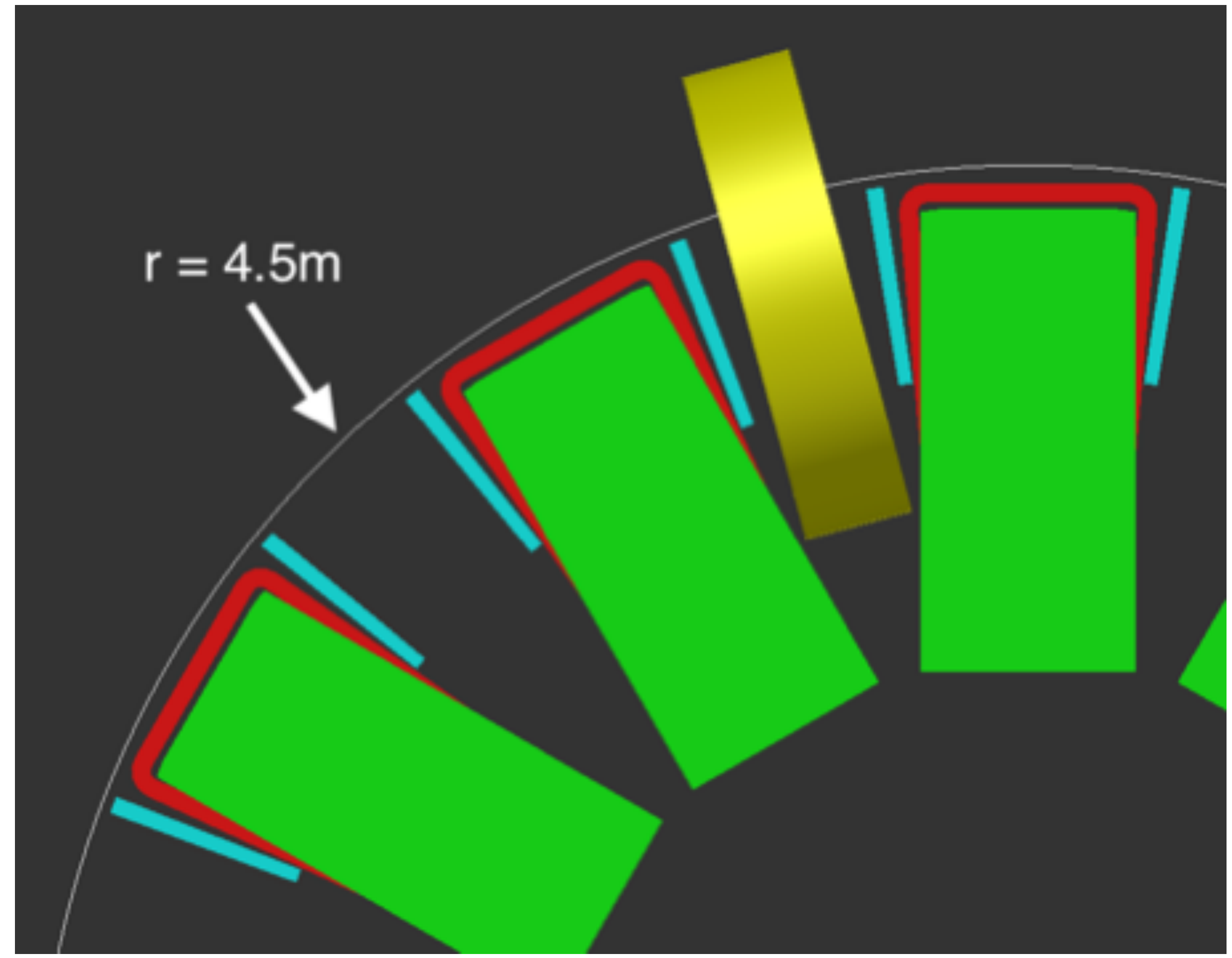


squeeze in R keeping
the opening angle fixed

small gap between
coil and pole

Remodeling of the main magnet



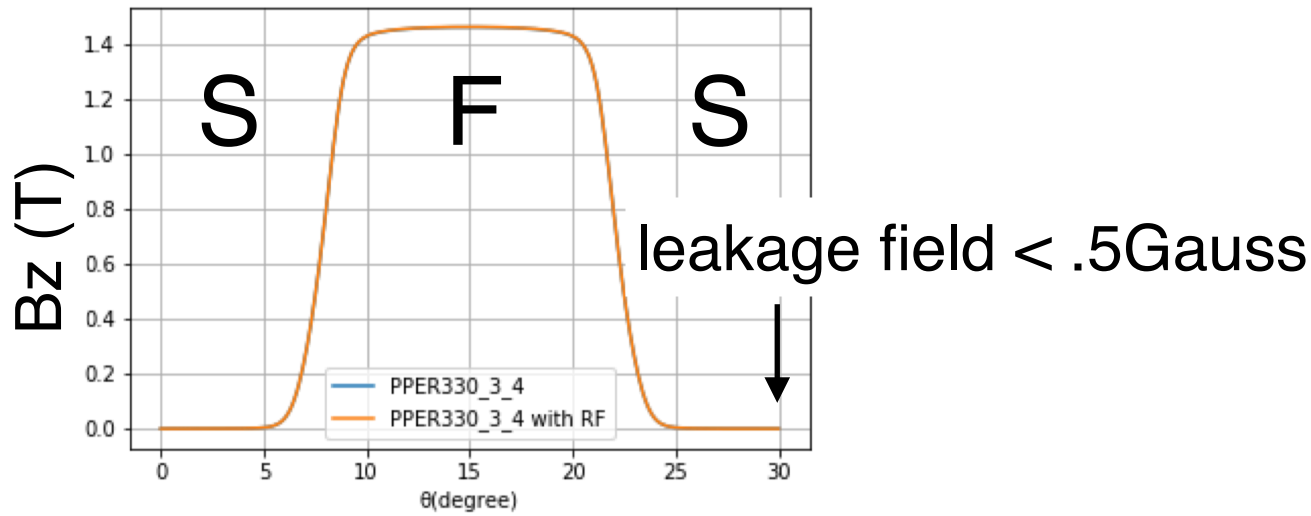


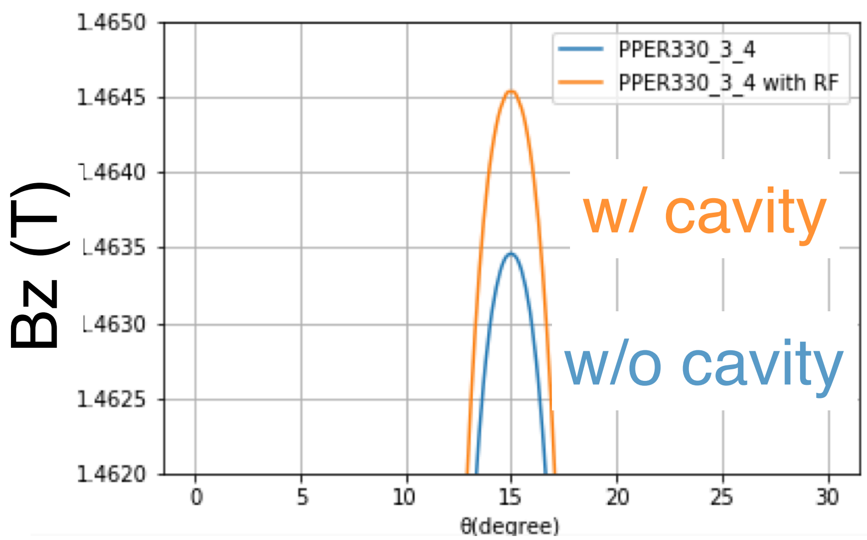
Reuse: F-yoke(blue) and coil

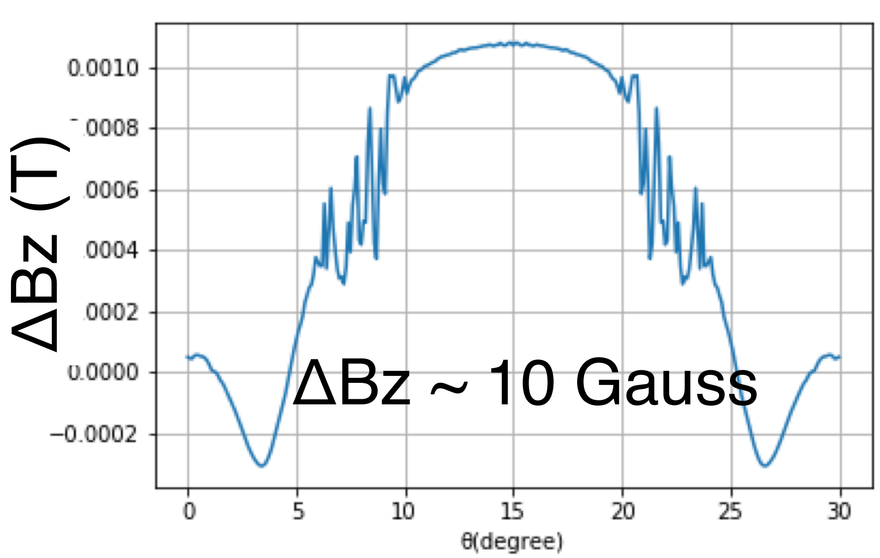
Newly fabricate: return yoke(green), F pole and clamp

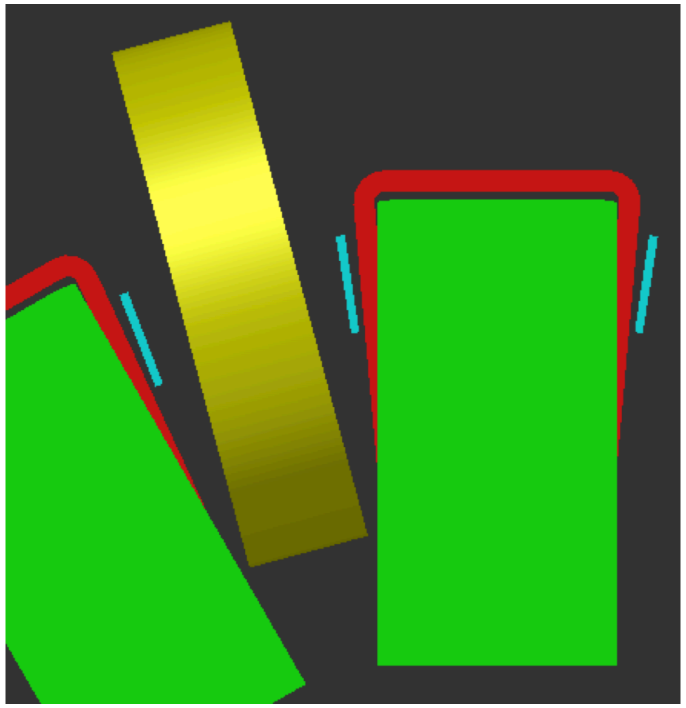
Cut way: D pole and shunt yoke

Effect of the cavity

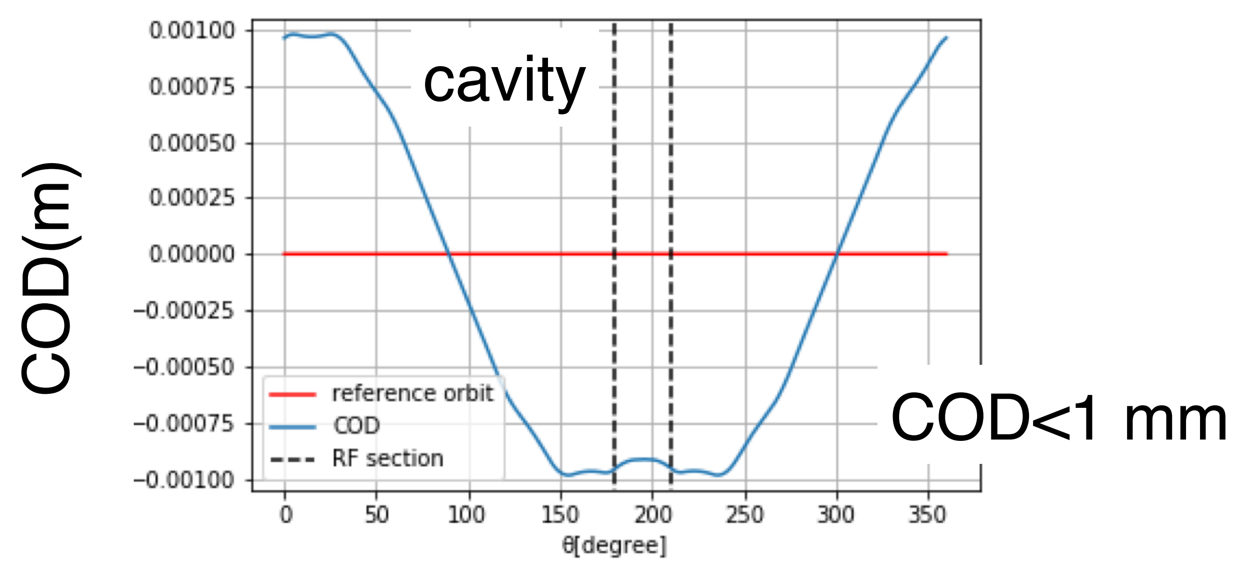




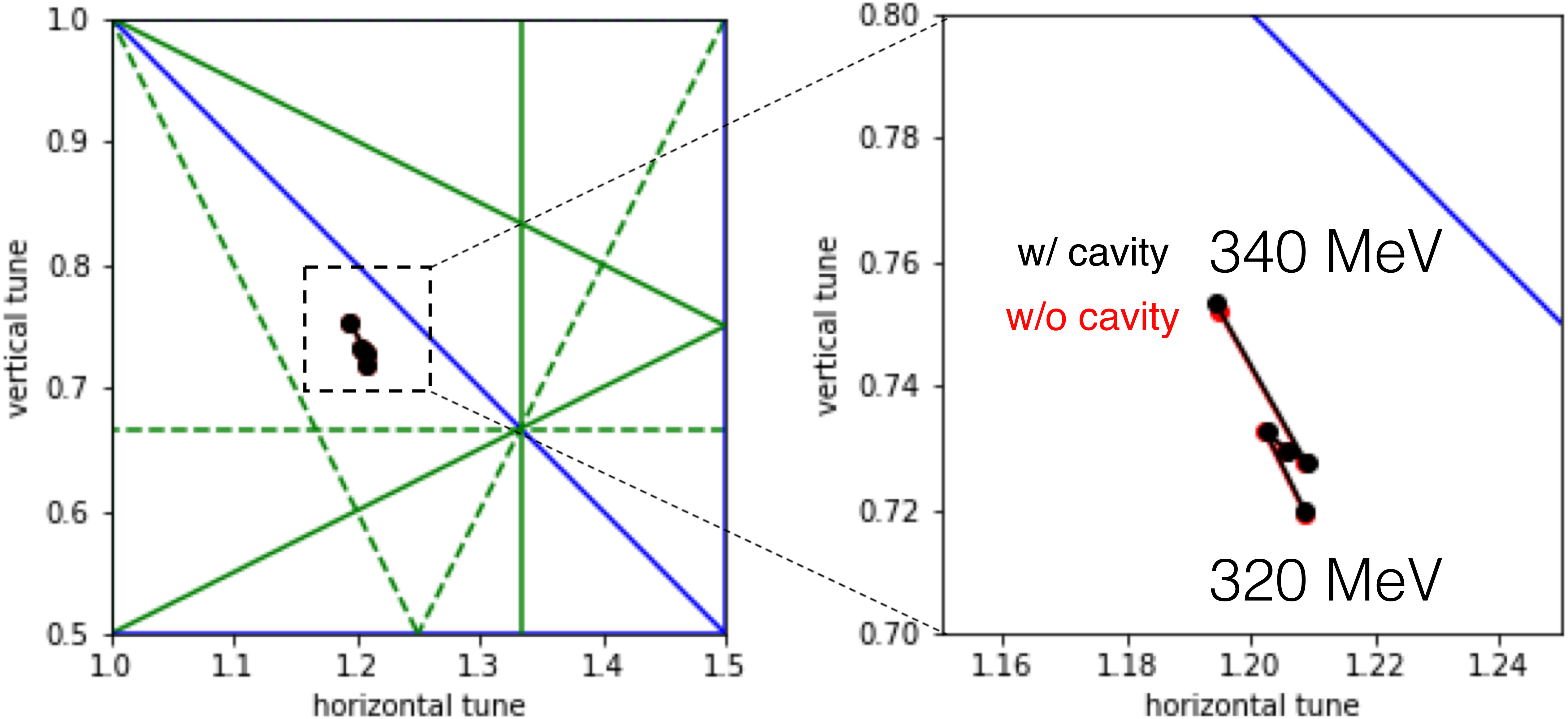




Calculation model:
insert thick iron disc at every straight section mocking the cavity

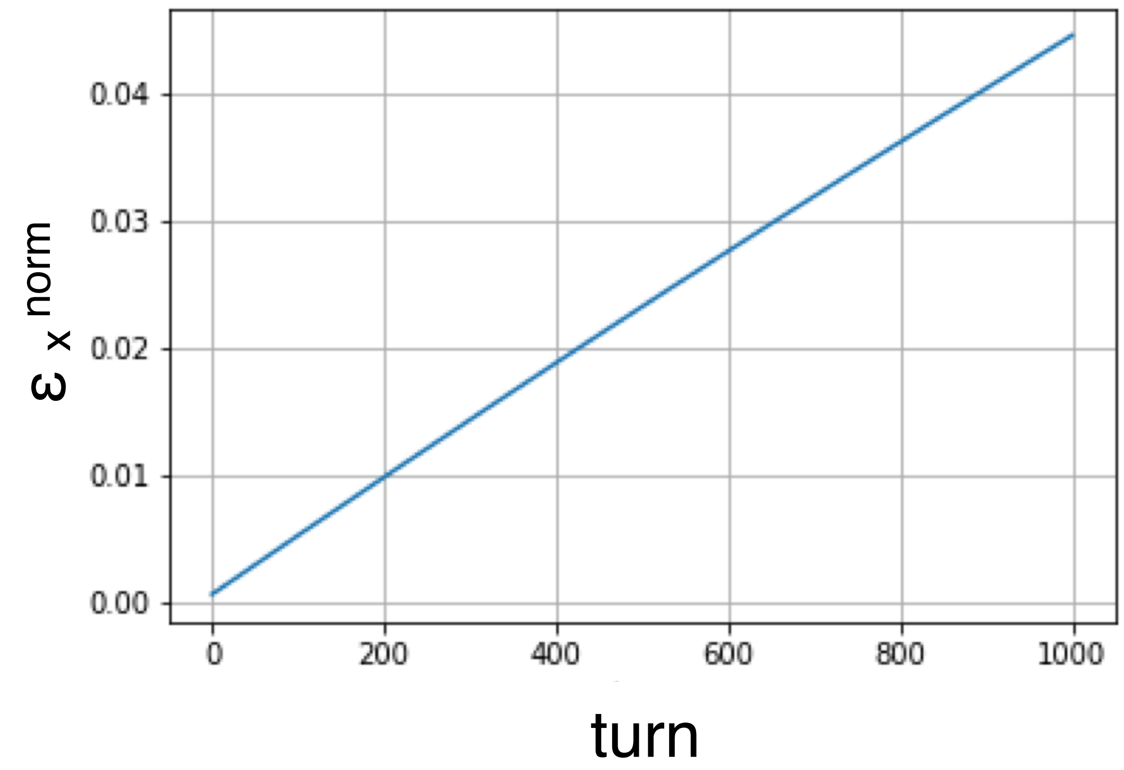


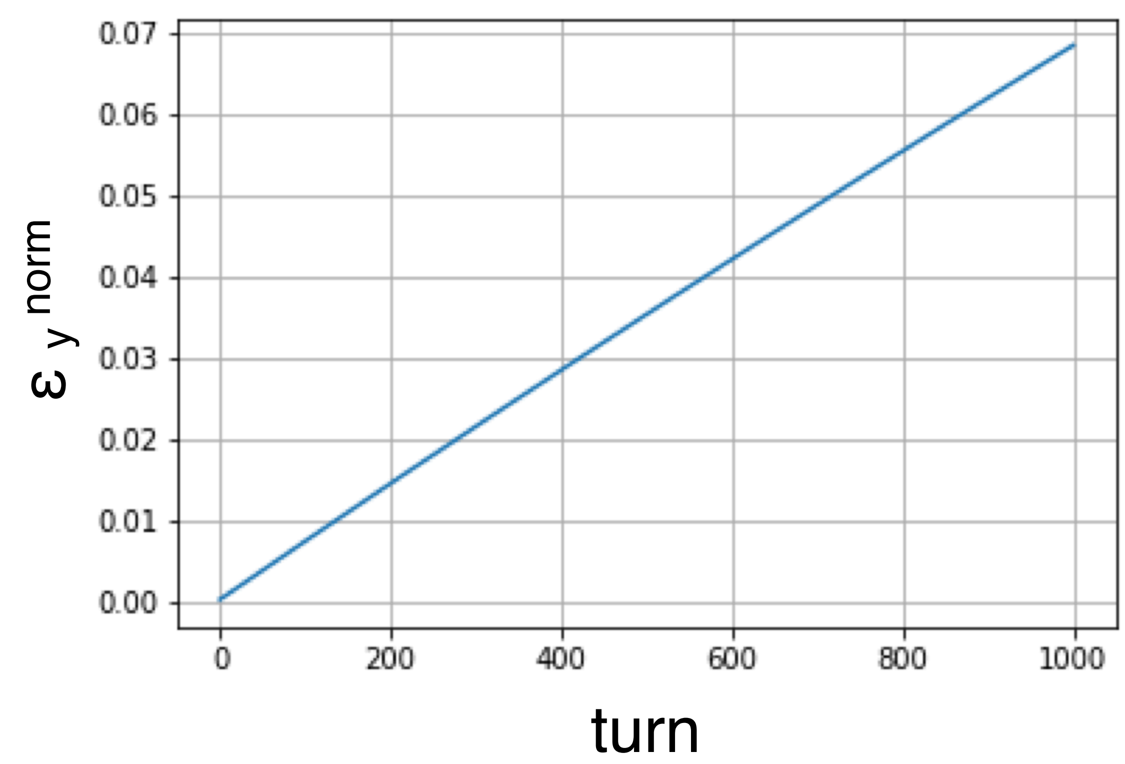
Tune variation



Summary of parameters of PPER

beam species	proton
energy	330 MeV
Radius of central orbit	4.07 m
tune	(1.21, 0.73)
β@ center of F	(3.5 m, 5.5 m)
minimum gap	142 mm
B field @ central orbit	1.48 T
I_{beam} from injector	1 pA
target thickness	100 μm
survival	100 turn
injected beam size	5 mm
production rate	200/s π^- (1000/s π^+)





Summary

1. First results of transmutation of MAs in ADS have been obtained in this February.

2. Redesigning of Main ring to a pion production merit ring PPER is going on.

Thank you for your attention.