The muon linac project at J-PARC

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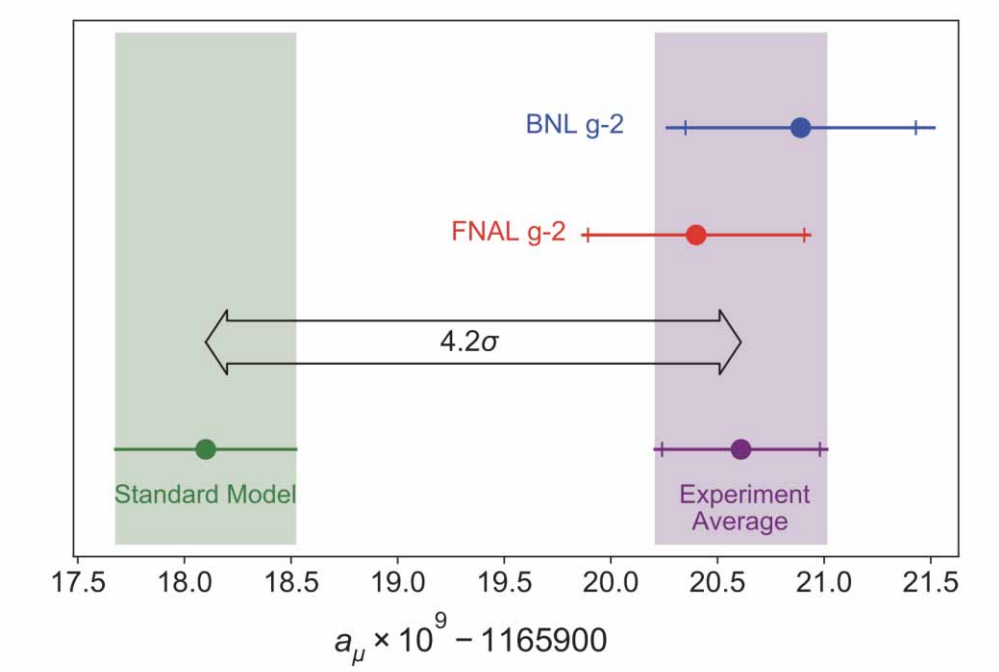
Contents

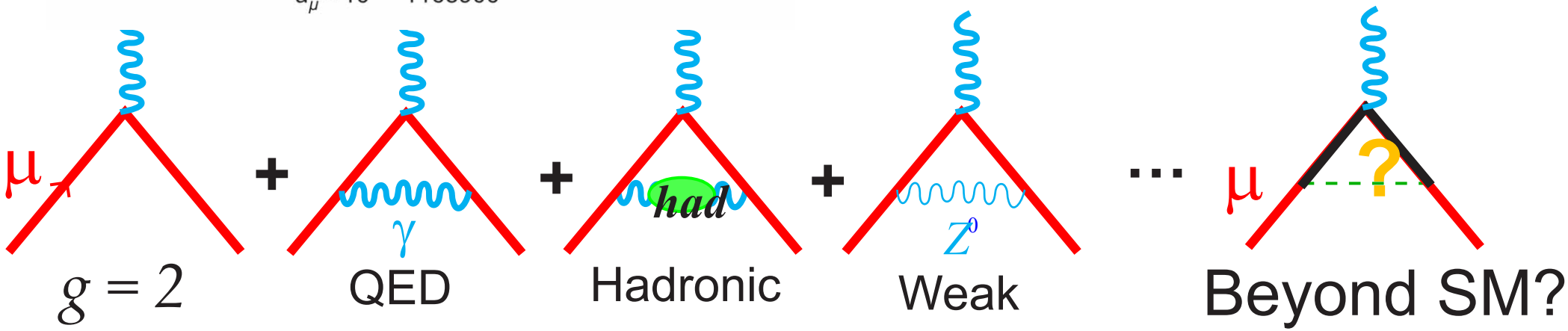
- Physics motivation
- Experimental setup
- Accelerating structures
- Plan
- Summary

Beyond the Standard Model? – muon g-2



$$\vec{\mu} = g\left(\frac{q}{2m}\right)\vec{S}$$

$$a_\mu = \frac{g-2}{2}$$



Muon g-2/EDM experiment J-PARC E34

Prog. Theor. Exp. Phys. **2019**, 053C02

proton (3 GeV)

graphite target

μ+(4 MeV) Surface muon

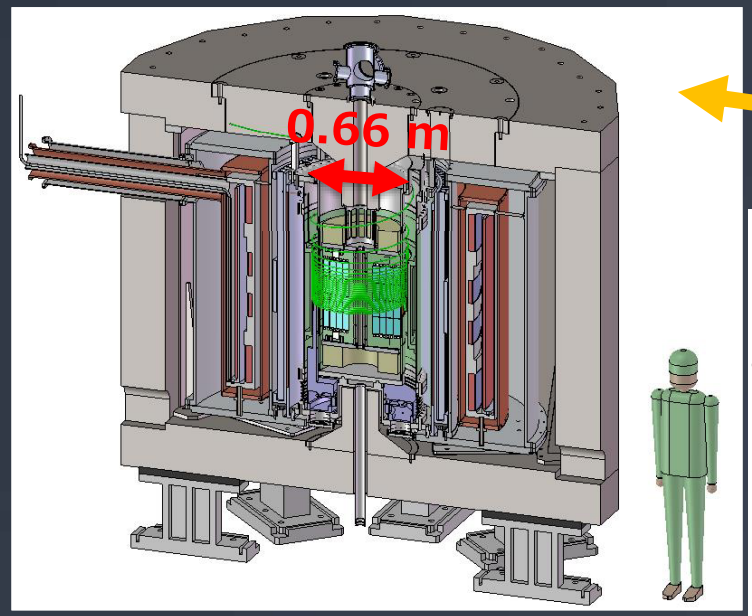
μ+ (25 meV) muon cooling

muon LINAC

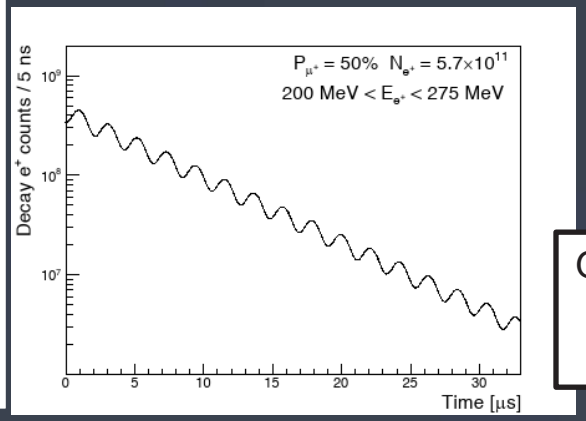
μ+ (212 MeV)

injection

Storage magnet



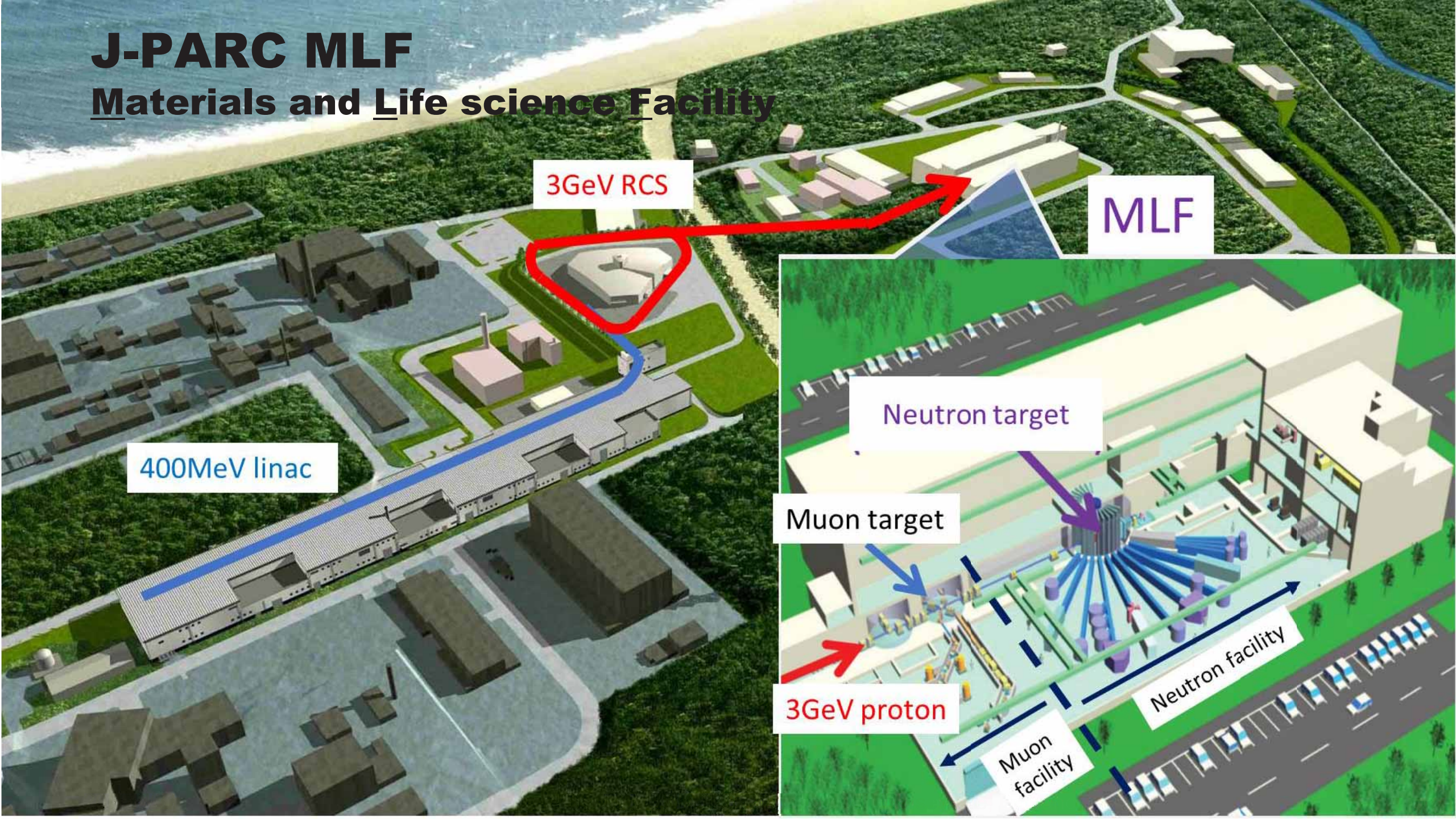
muon storage magnet



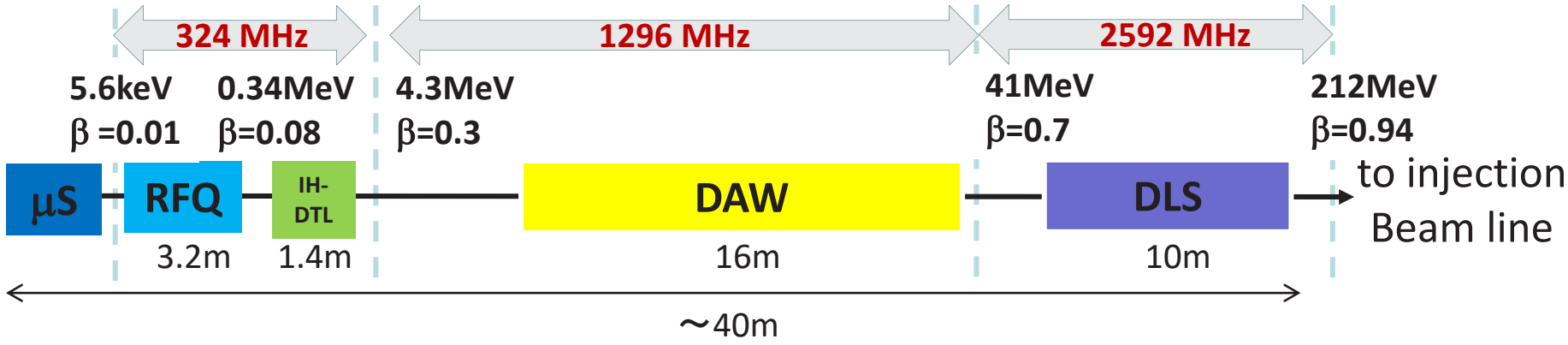
Goals:
- g-2 450 ppb (~ BNL/FNAL run 1)
- EDM 1.5 x 10^{-21} e·cm (x70 better)

J-PARC MLF

Materials and Life science Facility



Configuration of the Muon LINAC

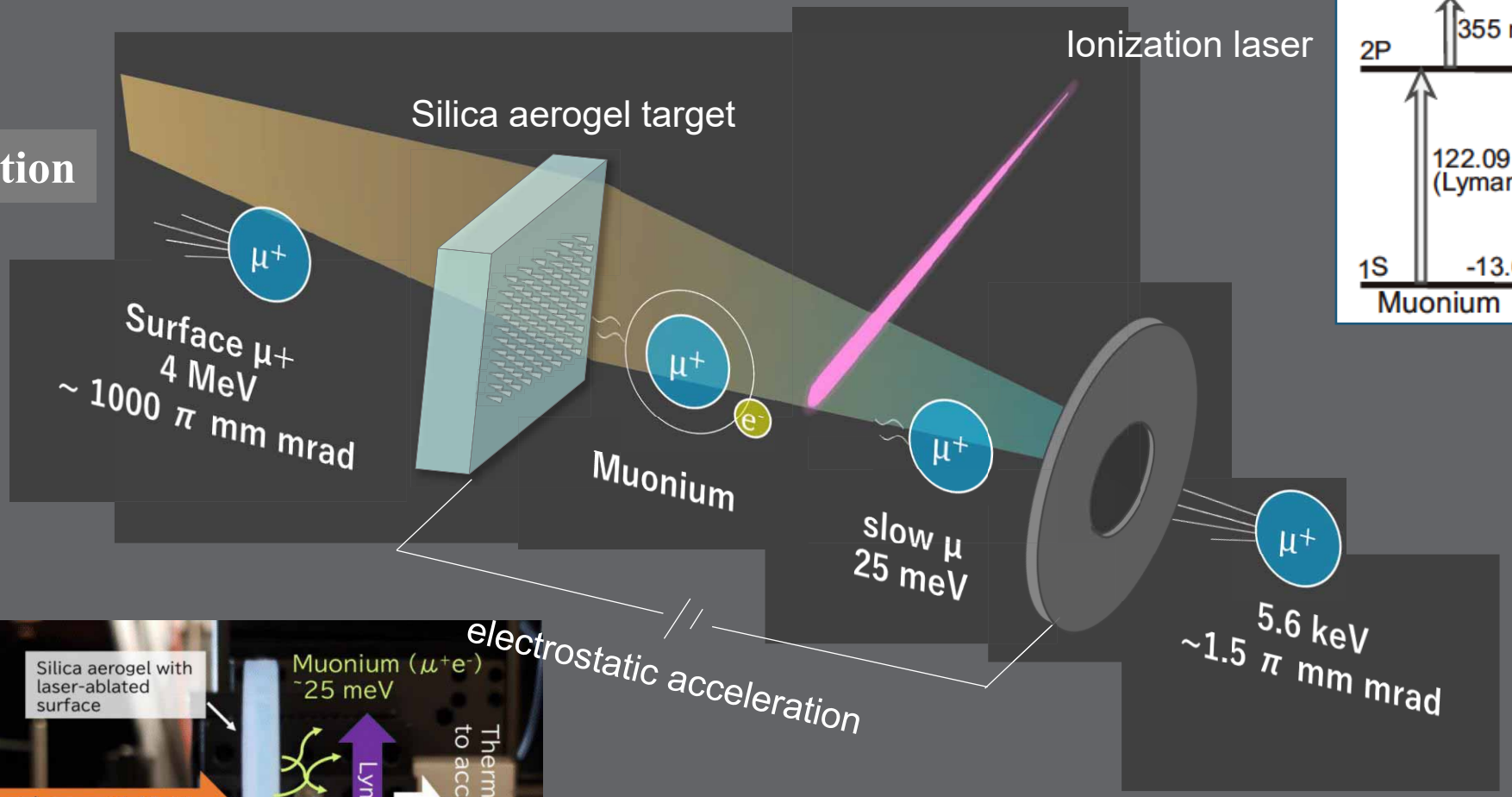


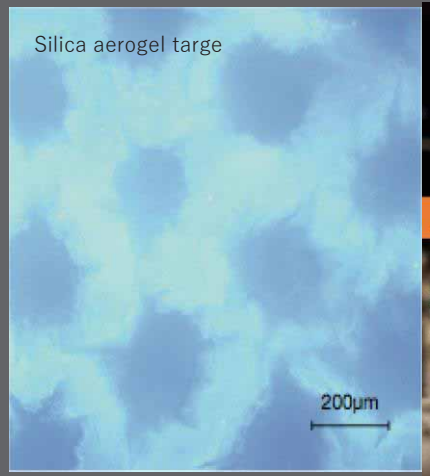
Particle	μ^+
Energy	212 MeV (300 MeV/c)
Intensity	1×10^6 /s
Rep rate	25 Hz
Pulse width	10 ns
Normalized rms emittance	1.5 π mm mrad
Momentum spread	0.1 %

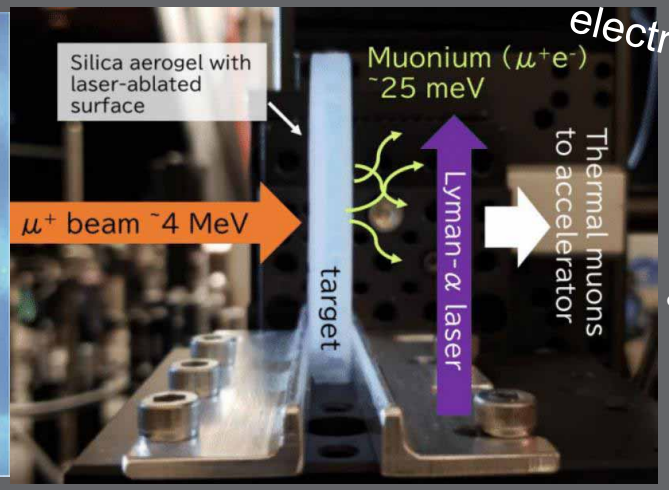
- 3-stage frequency, 4-structures.
- Comparable emittance to p linac, but very low intensity.

Muon cooling for g-2/EDM experiment

USM production

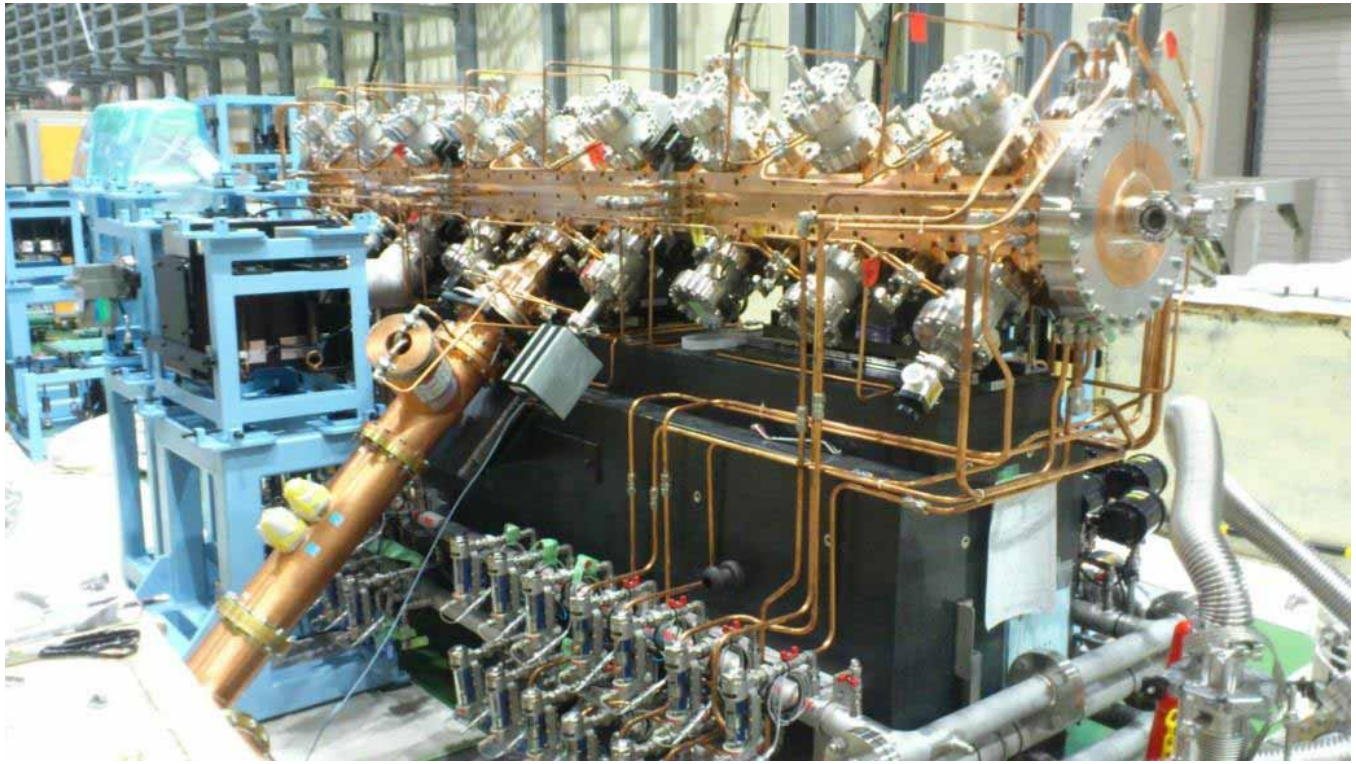






- Thermal muonium production and laser dissociation produce ultra-slow muons (USM) [PTEP 091C01 (2014), PTEP 123C01 (2020)].

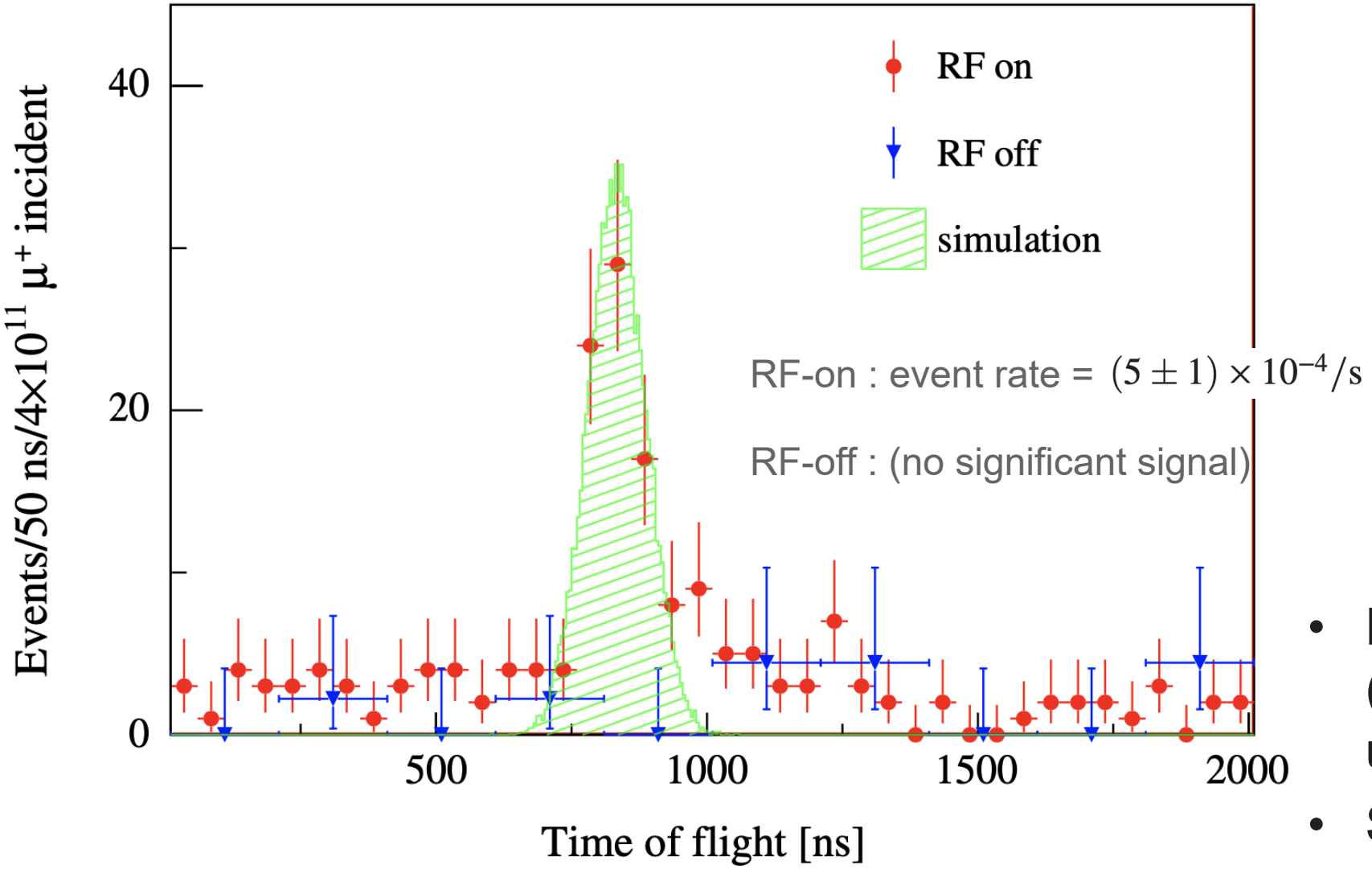
RFQ

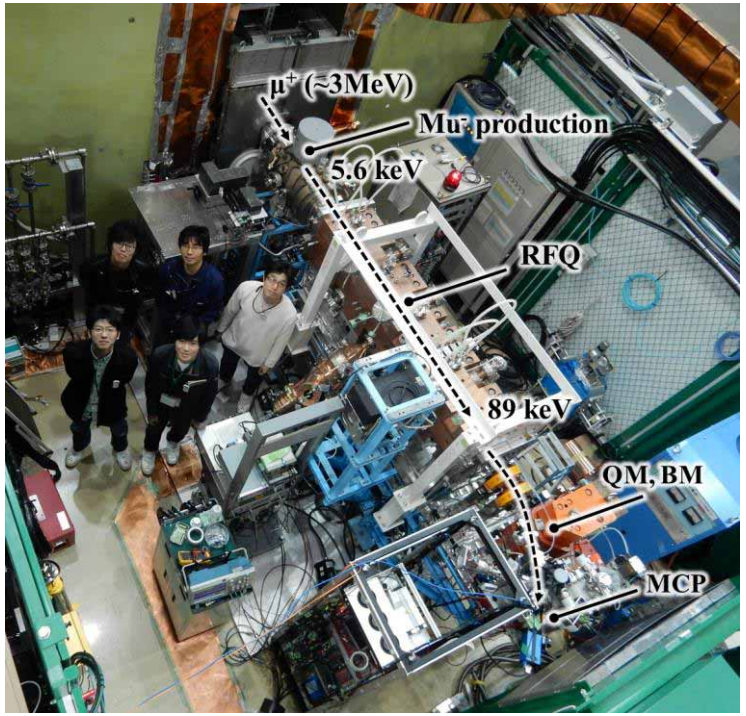


- J-PARC RFQ II (A spare of 30mA RFQ)

Structure	4-vane RFQ
f_0	**324 MHz**
$\mathbf{W_{in}}$	**5.63 keV**
$\mathbf{W_{out}}$	**0.337 MeV**
Vane length	3.172 m
# of cells	294
r_0	3.69 mm
a_{min}	2.11 mm
m_{max}	2.28
$\phi_{s,max}$	-44 ~ 48 deg
V	**9.32 kV**
Max. surface field	3.56 MV/m (0.2 E_k)
Nominal power	**4.18 kW**

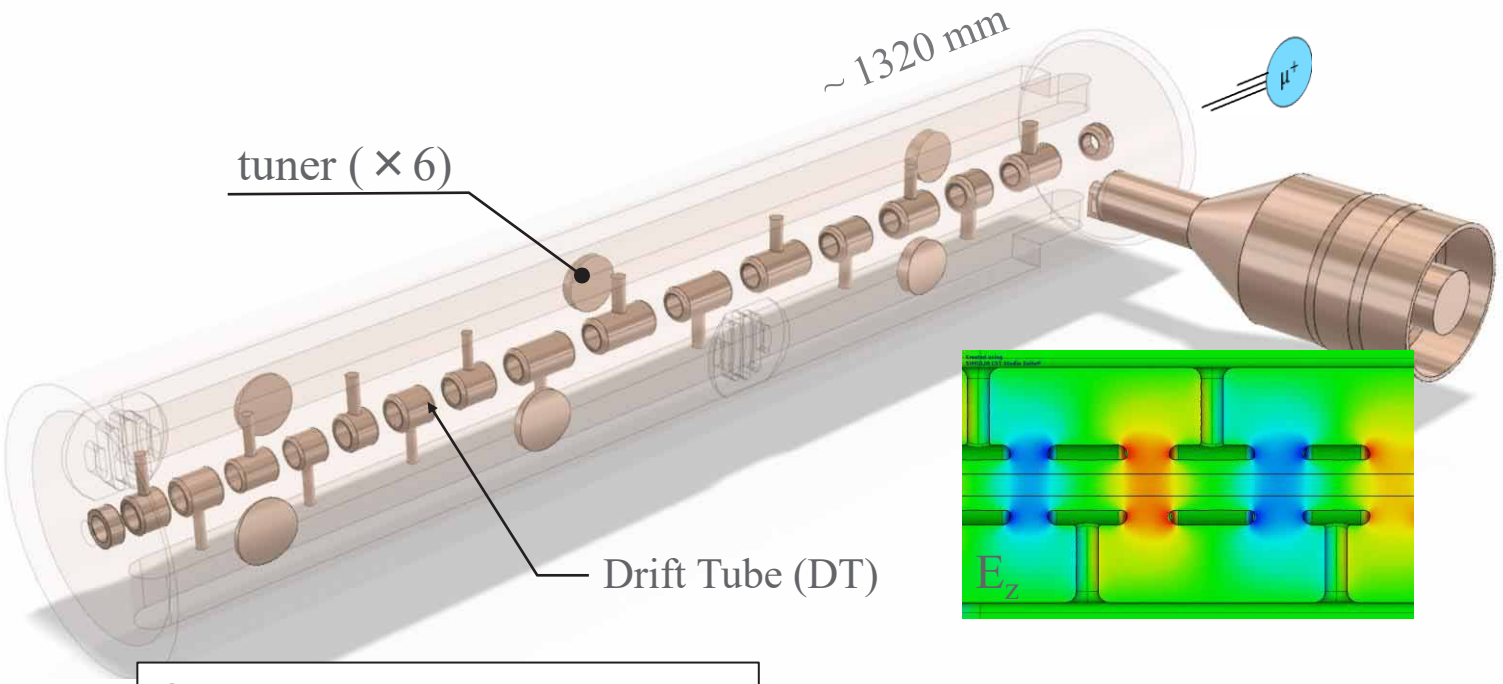
The world's first RF accelerated muons!

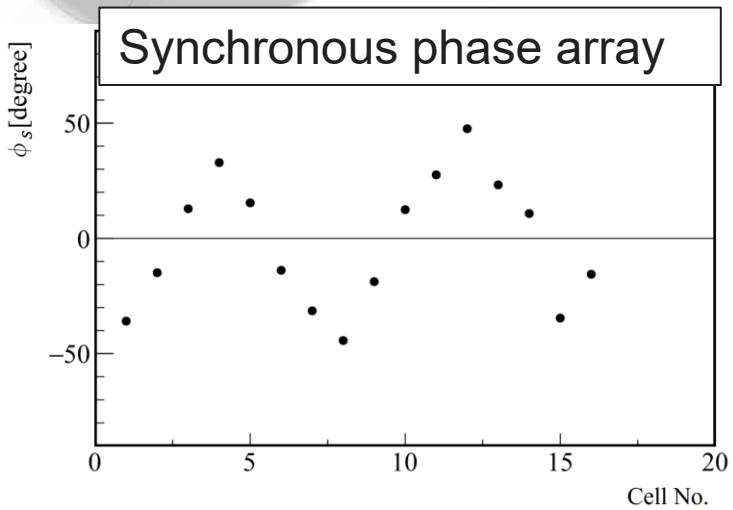




- Epi-thermal Mu^- ($\mu^+e^-e^-$) (not USM) is accelerated up to 89 keV.
- S. Bae et al., PRAB 21, 050101 (2018)

Alternative Phase Focusing IH-DTL

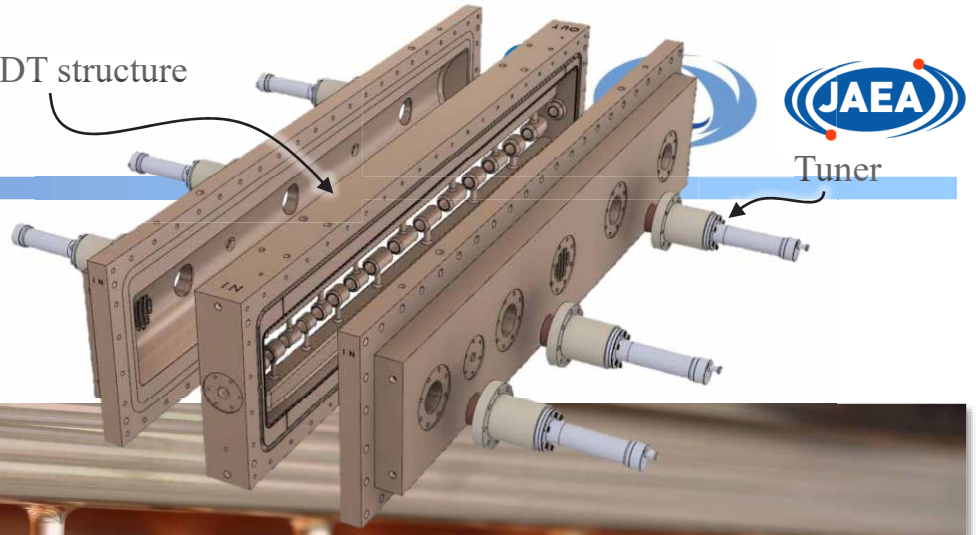




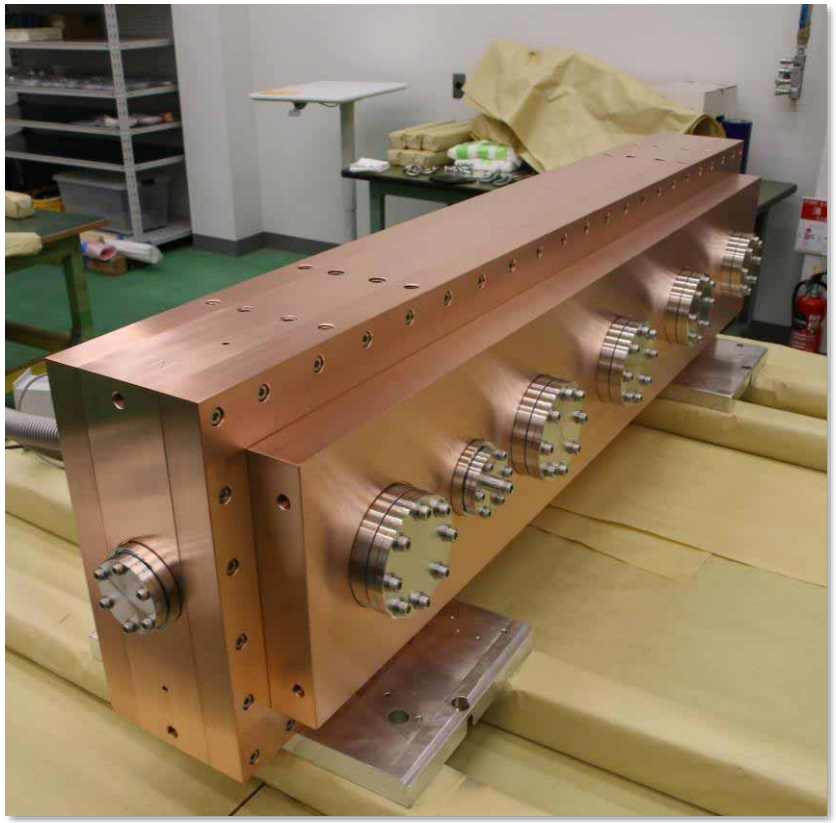
- TE110 mode (H mode) cavity
- π mode operation $\left(l_c = \frac{\beta\lambda}{2}\right)$
- Alternative Phase Focusing (APF)

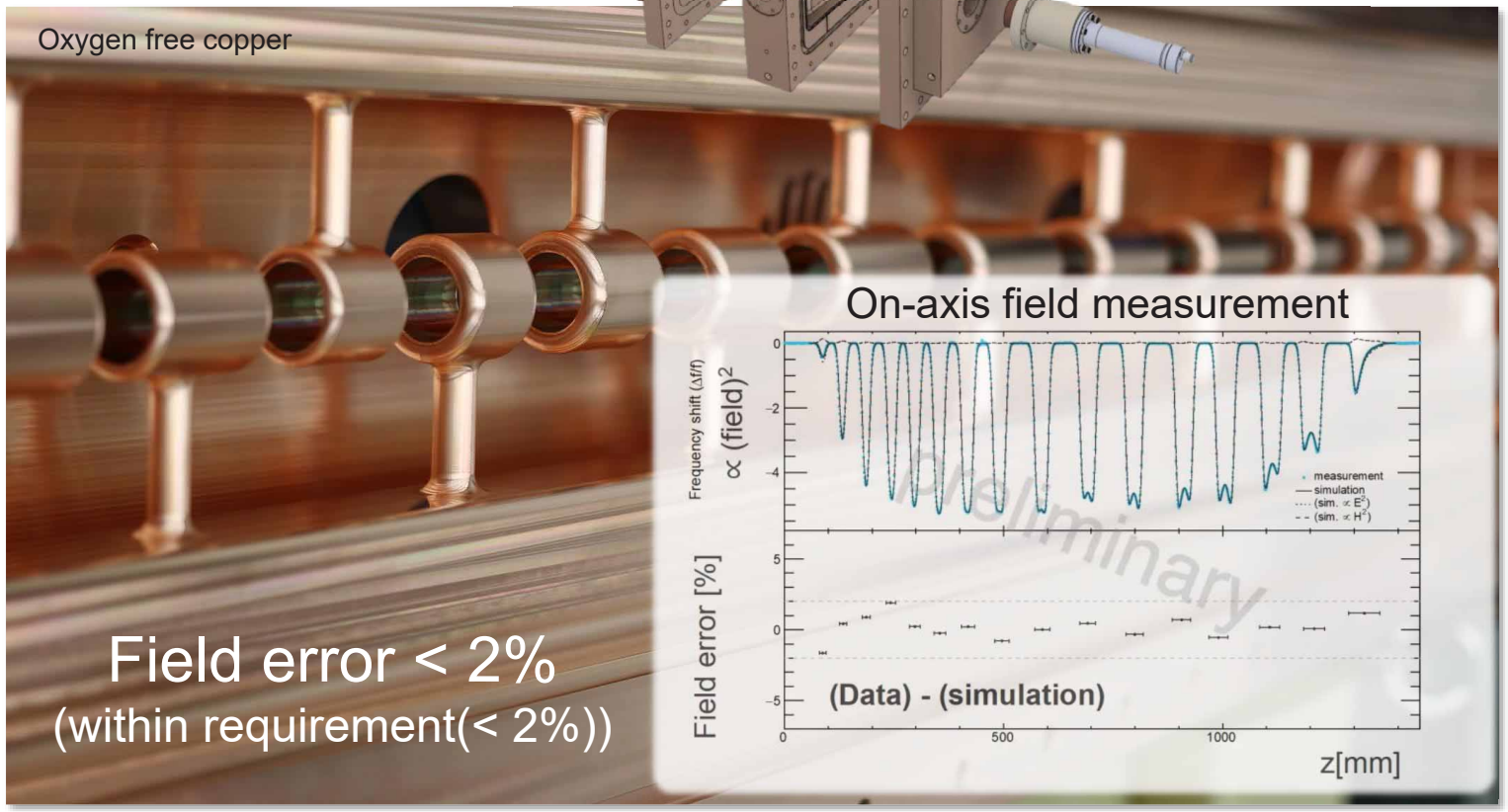
Structure	APF IH-DTL
f_0	324 MHz
Operation mode	**π**
W_{in}	0.337 MeV
W_{out}	4.26 MeV
Cavity length	1.32 m
# of cells	16
Bore radius	11.4 mm
ϕ_s	**-44 ~ 48 deg**
Max. E_0	10 MV/m
ZTT	68 MΩ/m
Max. surface field	35.6 MV/m (2.0 E_k)
Nominal power	310 kW

IH-DTL fabrication

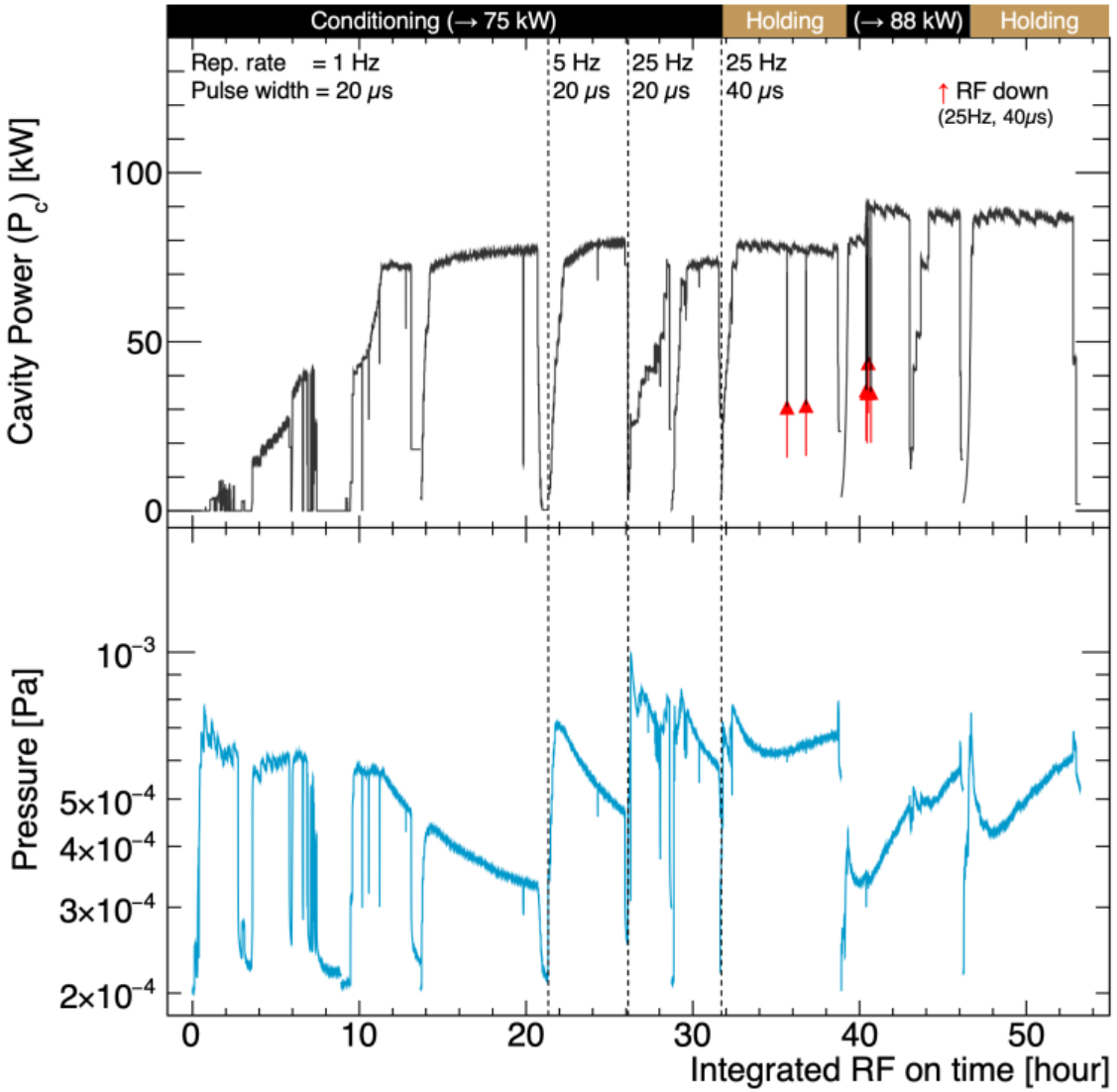


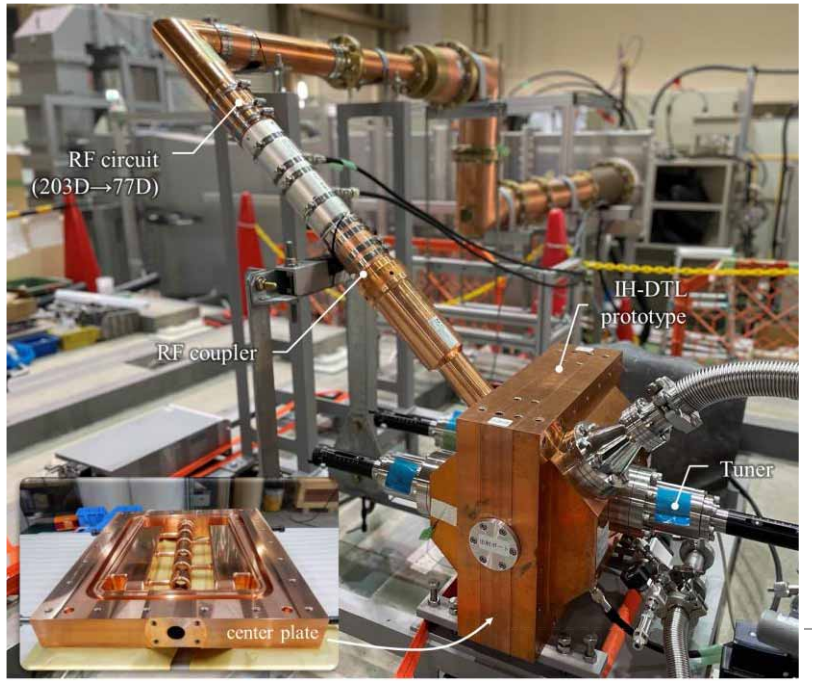
Fabrication of IH-DTL was completed.





High power test of the IH-DTL prototype

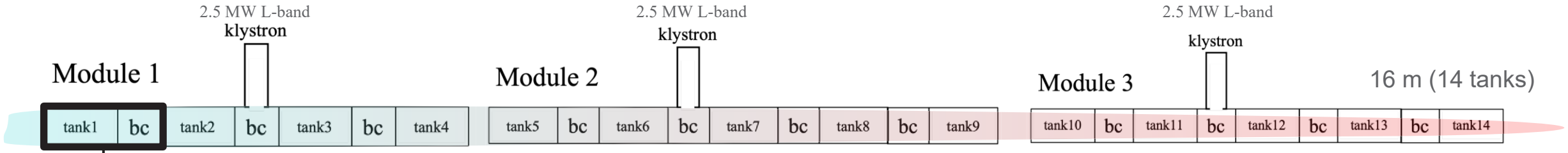




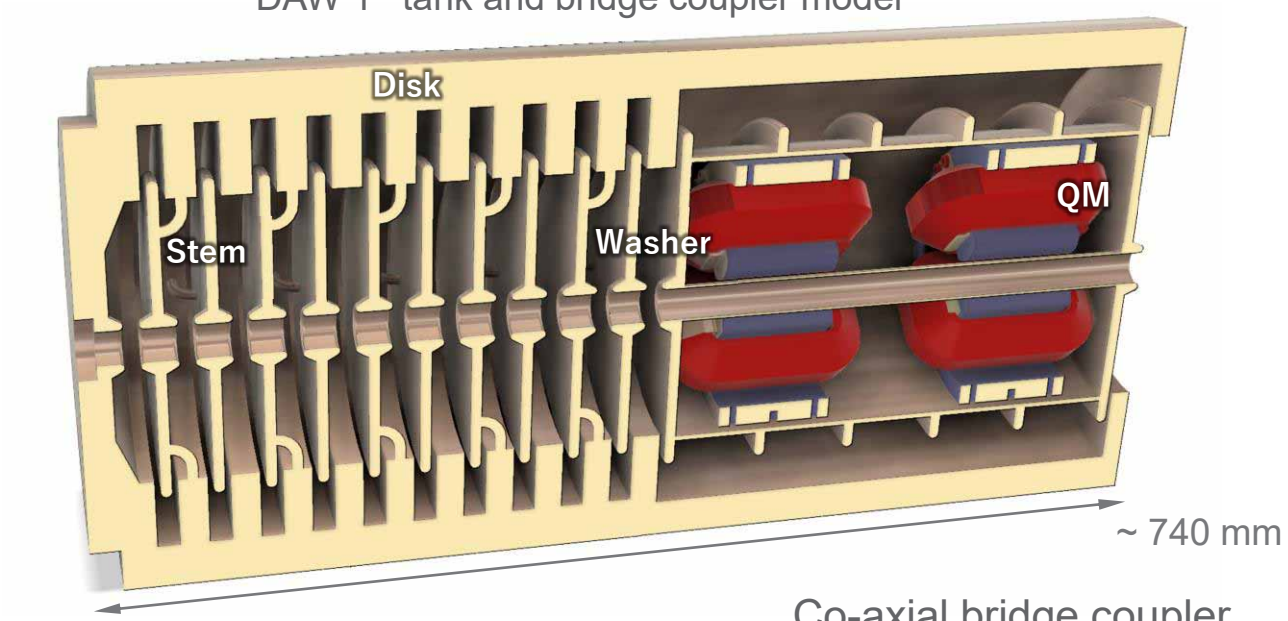
Y. Nakazawa, MOPORI22

- Verify fabrication methodology with 6-cell IH-DTL.
- After 30 hour conditioning, 75 kW, 25 Hz, 40 μs was achieved.
- No trip 88 kW (10% higher voltage)7 h operation,

DAW CCL



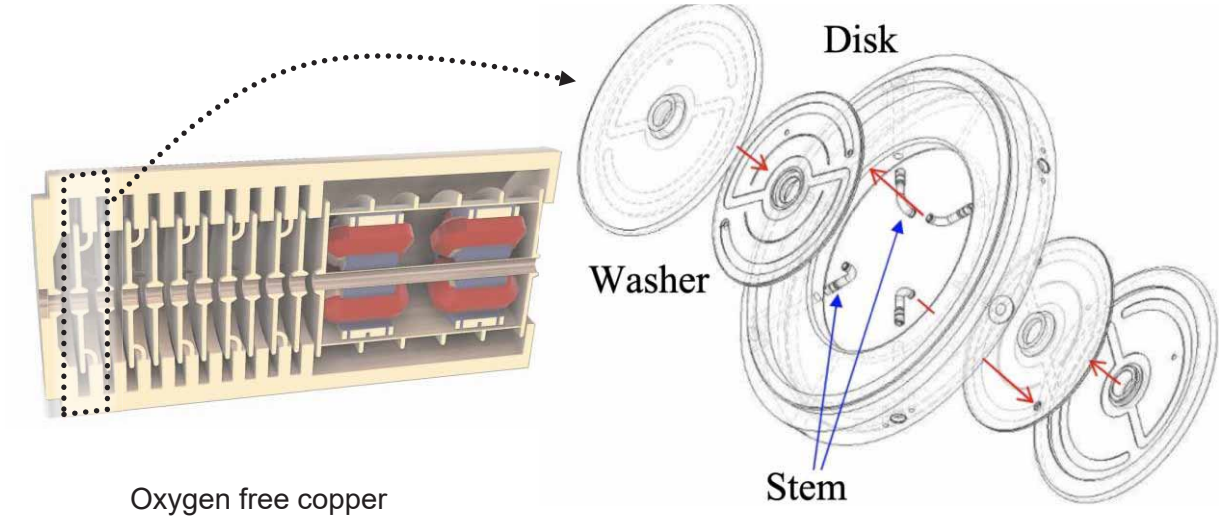
DAW 1st tank and bridge coupler model

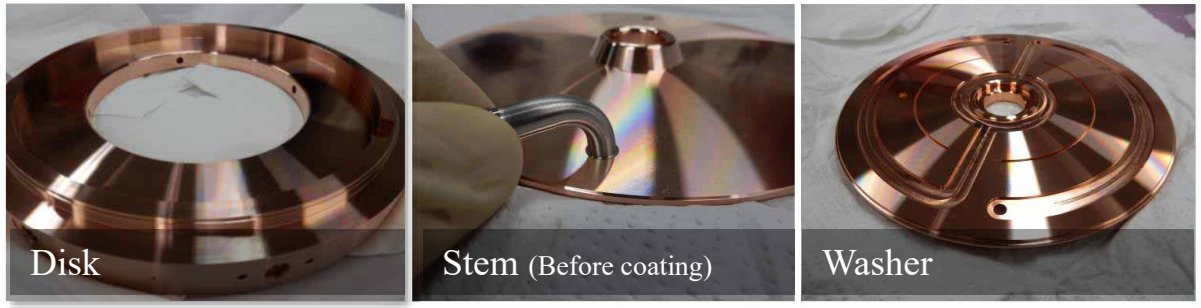


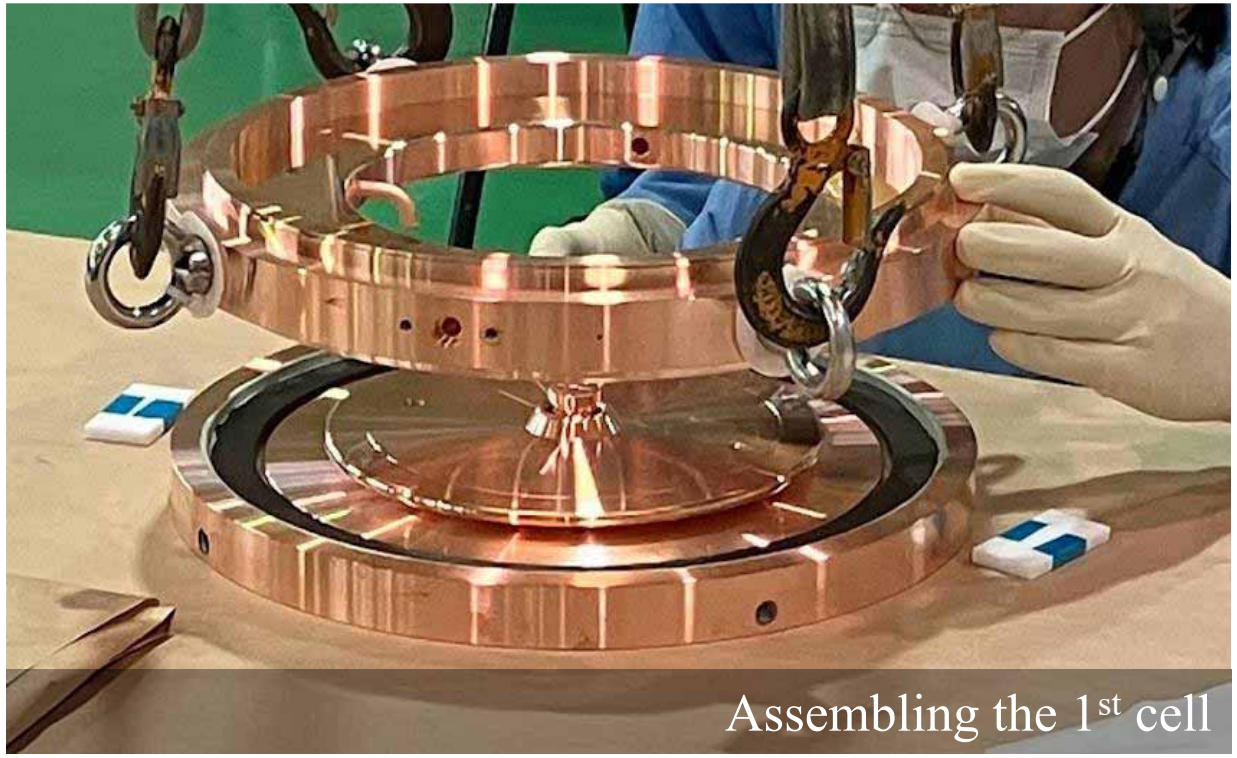
Structure	DAW CCL
f_0	1296 MHz
Operation mode	π/2
W_{in}	4.26 MeV
W_{out}	**41.4 MeV**
Section length	16.15 m
# of tanks	14
# of modules	3
# of tanks / module	4, 5, 5
# of cells / tank	11
Bore radius	12 mm
ϕ_s	-30 deg
E_0	**5.6 MV/m**
ZTT	18.6 ~ 62.7 MΩ/m
Max. surface field	28.9 MV/m (0.9 E_k)
Max. power / tank	420 kW

Fabrication of DAW 1st tank

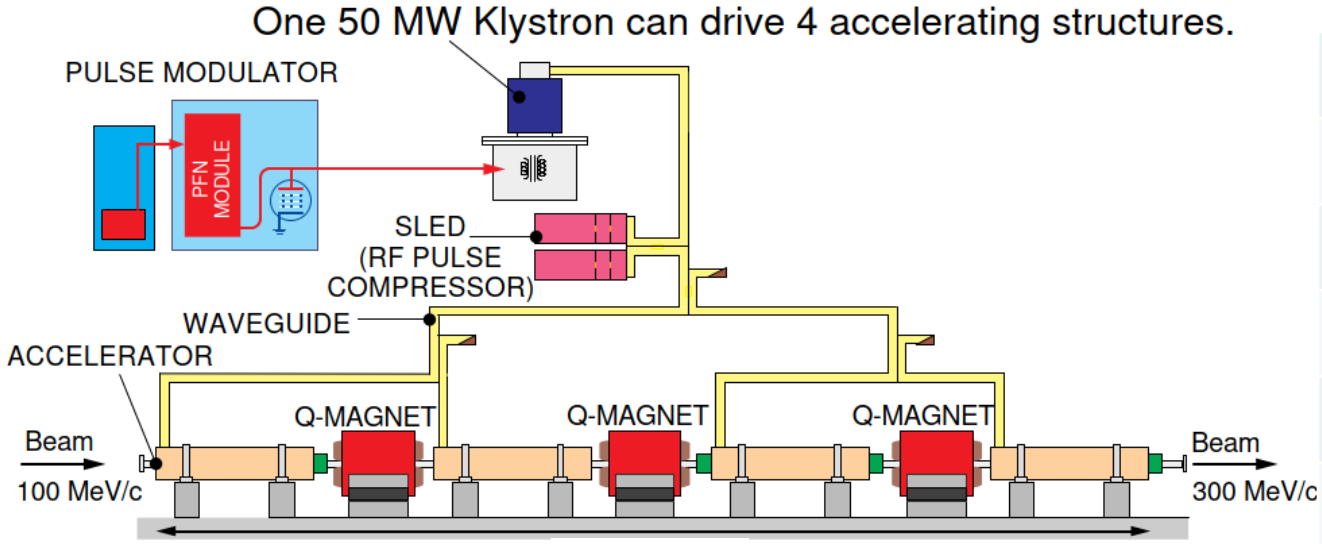
- Fabrication of DAW 1st tank is now underway.

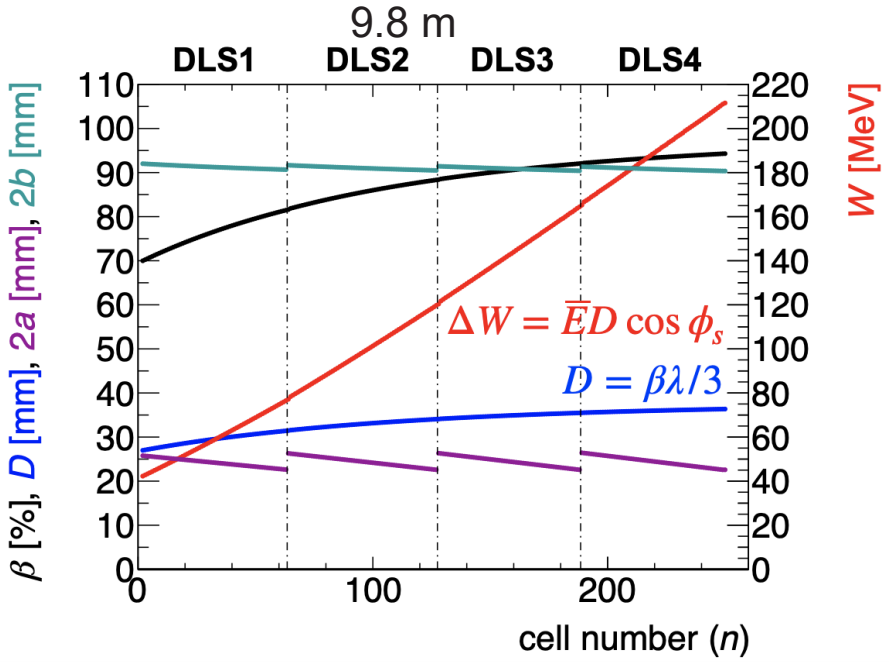






Disk Loaded travelling wave Structure

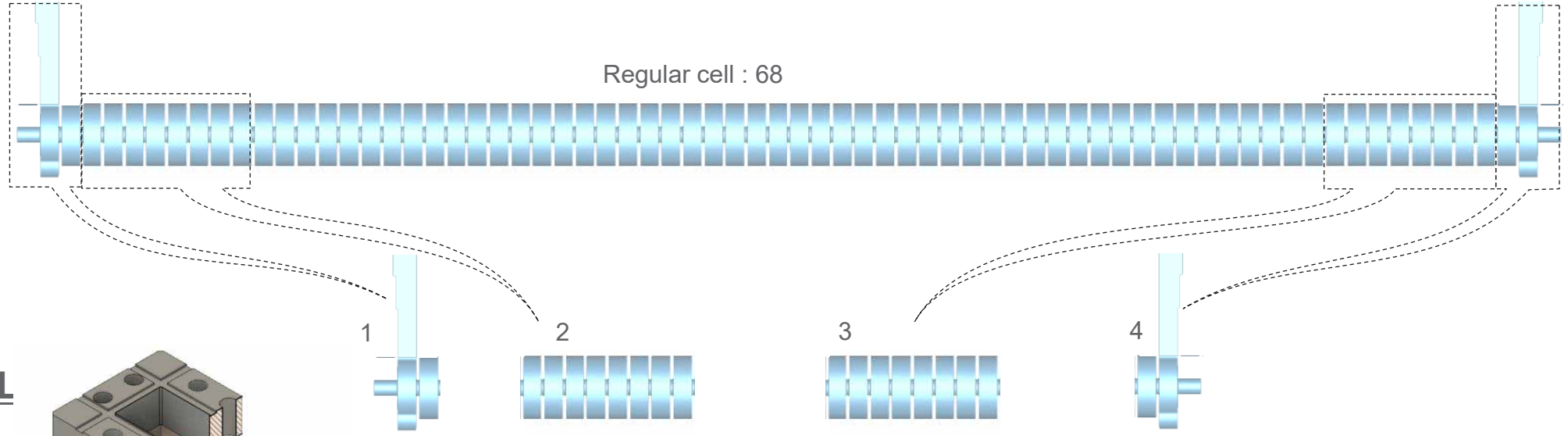




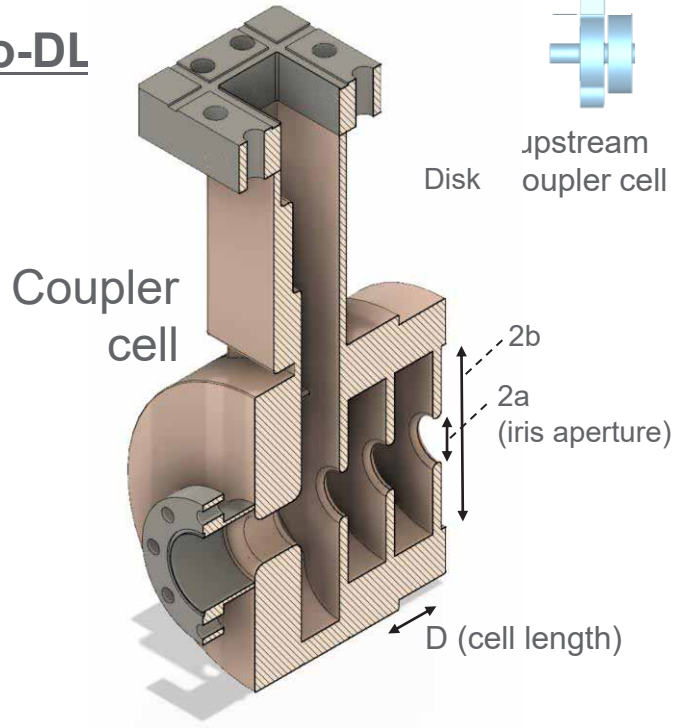
Structure	Disk loaded TW
f_0	2592 MHz
Operation mode	$2\pi/3$
W_{in}	41.4 MeV
W_{out}	212.4 MeV
Section length	9.8 m
# of acc. tunes	4
# of cells / tube	63, 63, 60, 60
Iris aperture diameter $2a$	22.6 ~ 26.4 mm
ϕ_s	-13 deg
Max. E_0	21 MV/m
Z	32.2 ~ 57.0 MΩ/m
Max. power / tube	40 MW

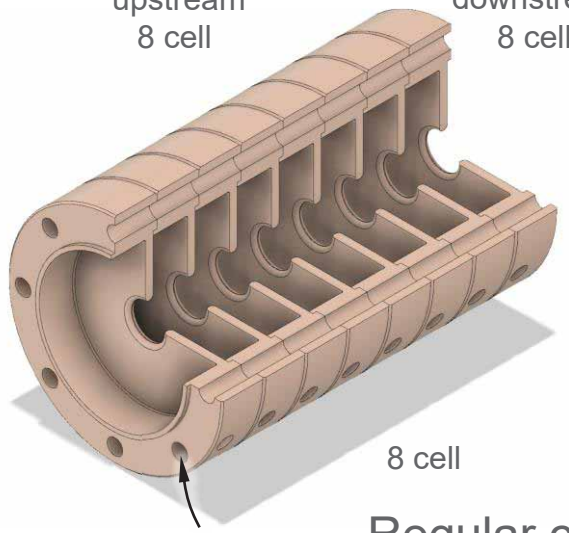
DLS prototyping

DLS1 :



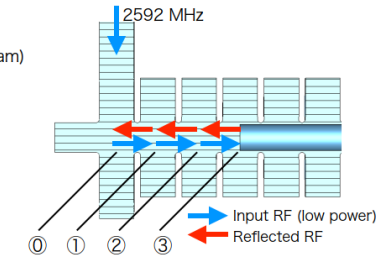
Proto-DL

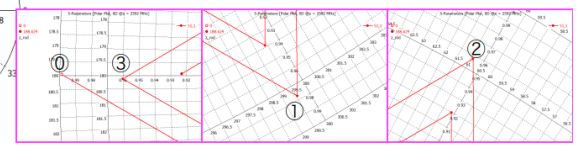




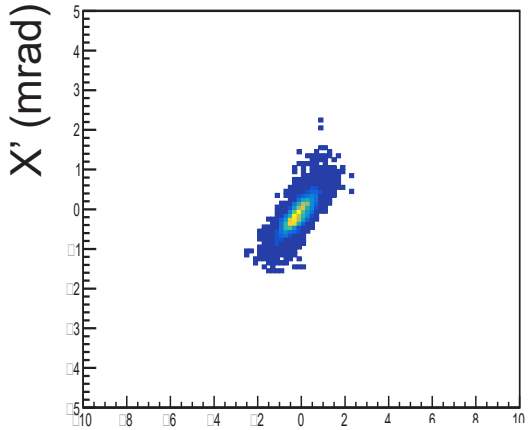
- Fine tuning with detune rod

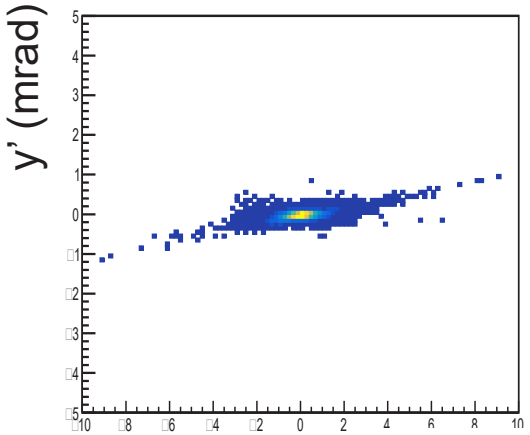
Note: distances are different (DLS1 downstream)
①–⓪: 31.449 mm
Others: 31.436 mm

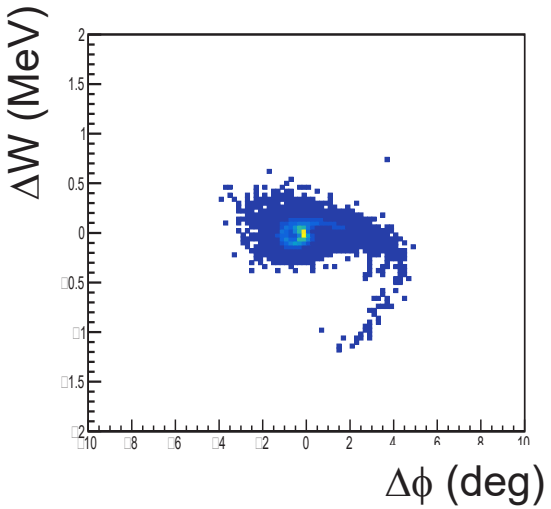


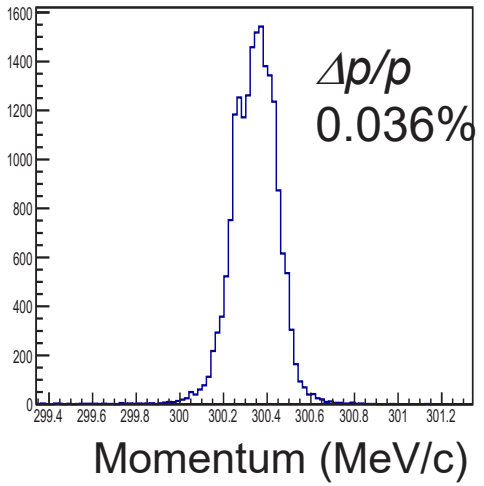


E2E simulation



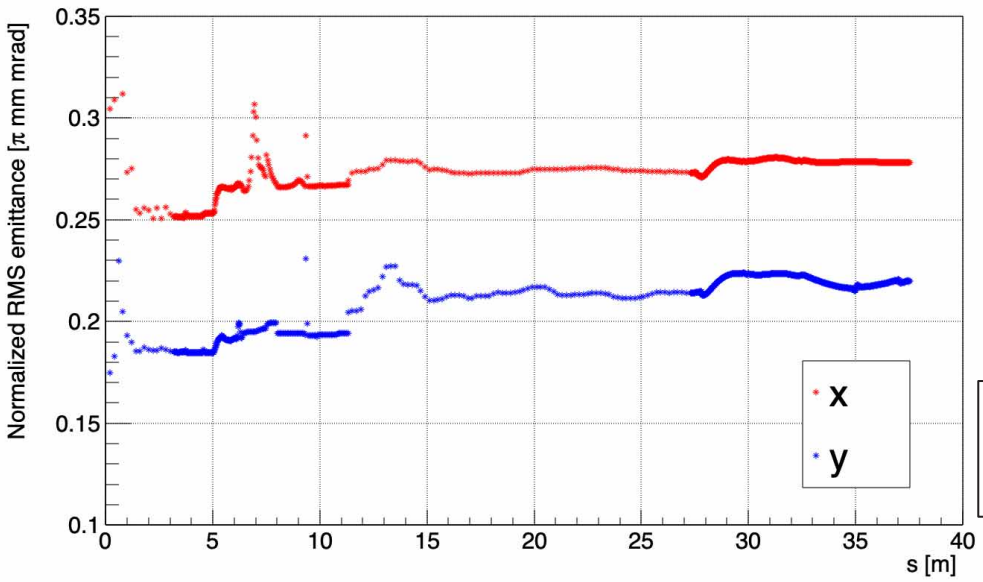






	Initial	RFQ	IH	DAW	DLS
transmission (%)	99	95	100	100	100
Decay loss (%)	22	19	1	4	1
$\varepsilon_{n,\,rms,\,x}$ (π mm mrad)	0.51	0.25	0.27	0.27	0.28
$\varepsilon_{n,\,rms,\,y}$ (π mm mrad)	0.12	0.18	0.19	0.21	0.22

Emittance evolution from the RFQ



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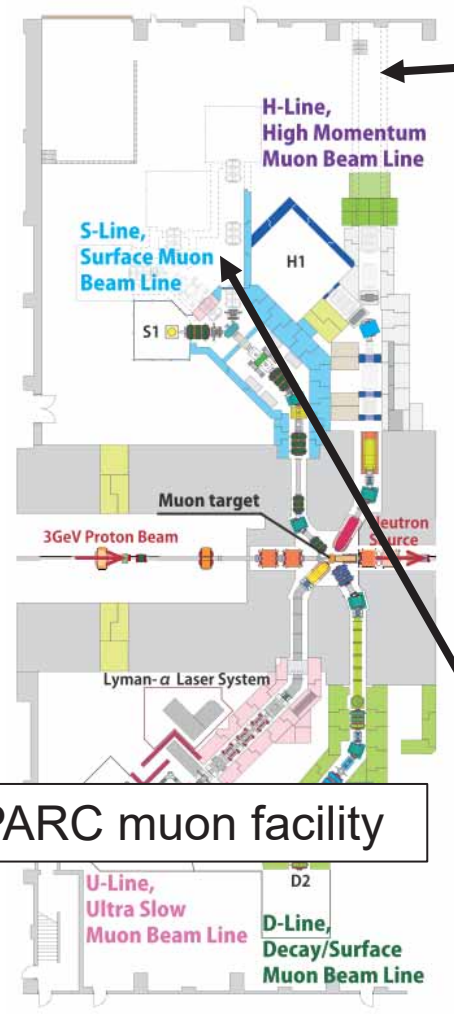
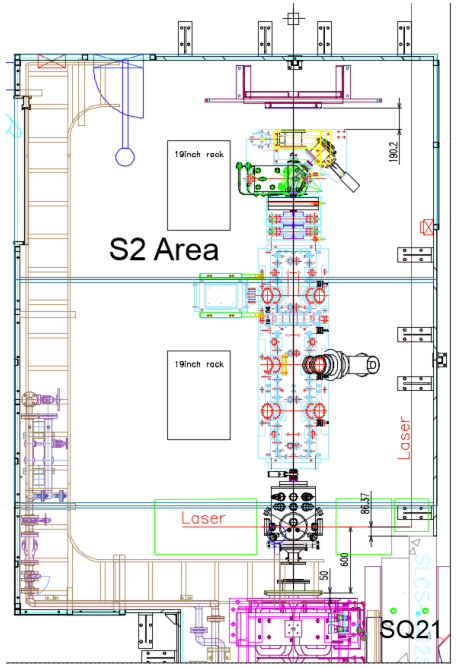
Upcoming beam test plan

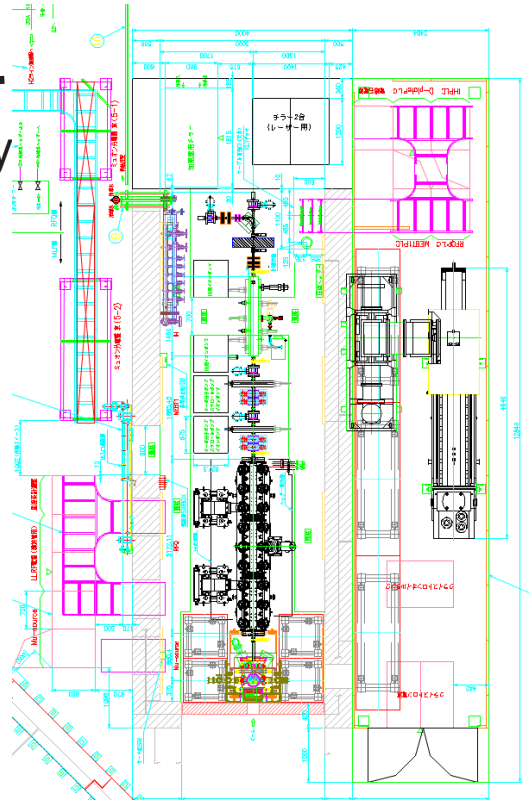


J-PARC muon facility

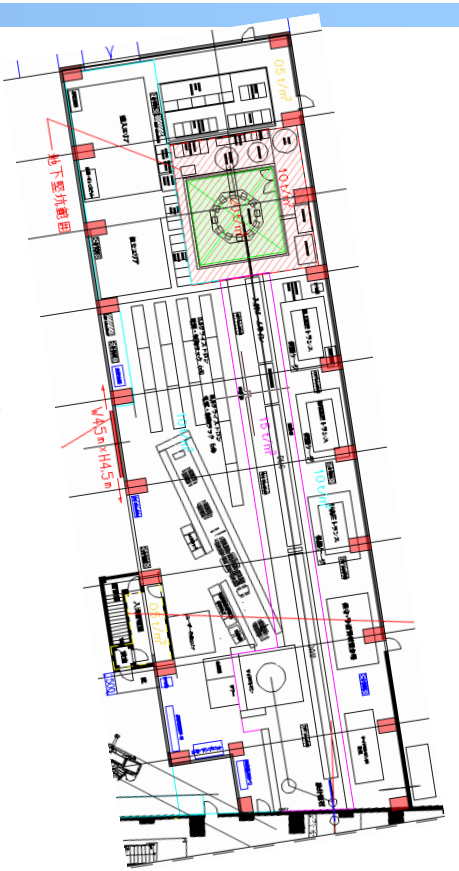
Scale is arbitrary



2022
USM acceleration
using test RFQ



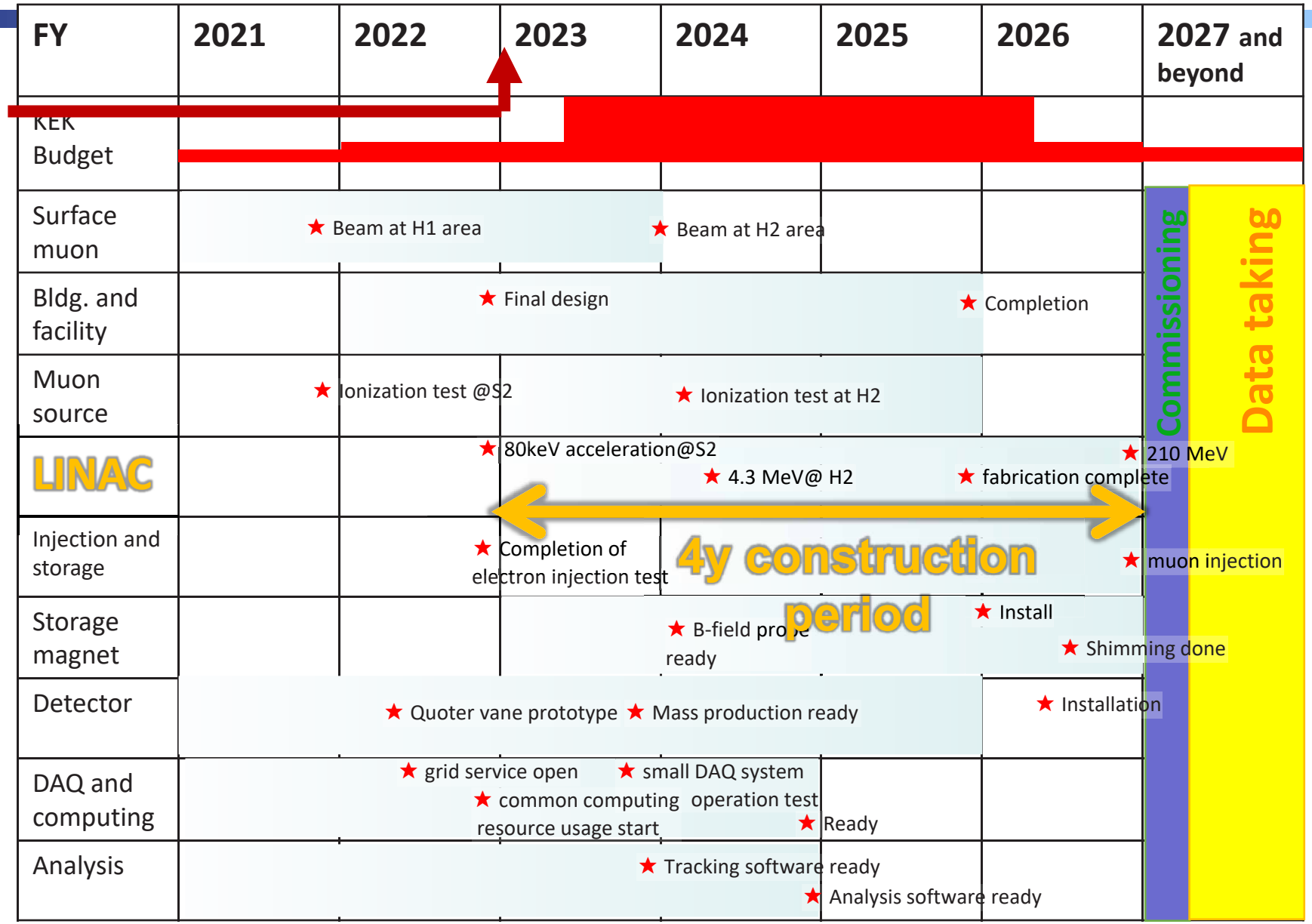
2024
Upto IH within
existing building



And finally, extend
the building

Overall schedule of E34

Construction budget assumed to be authorized



Summary

- We are now developing the world's first muon linac.
- Design work is almost finished.
- Among 4 accelerating structures, RFQ and IH-DTL are ready.
- Fabrication of DAW is started, and prototyping the DLS.
- Construction budget is expected to be authorized soon. We are moving from design phase to construction phase.

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