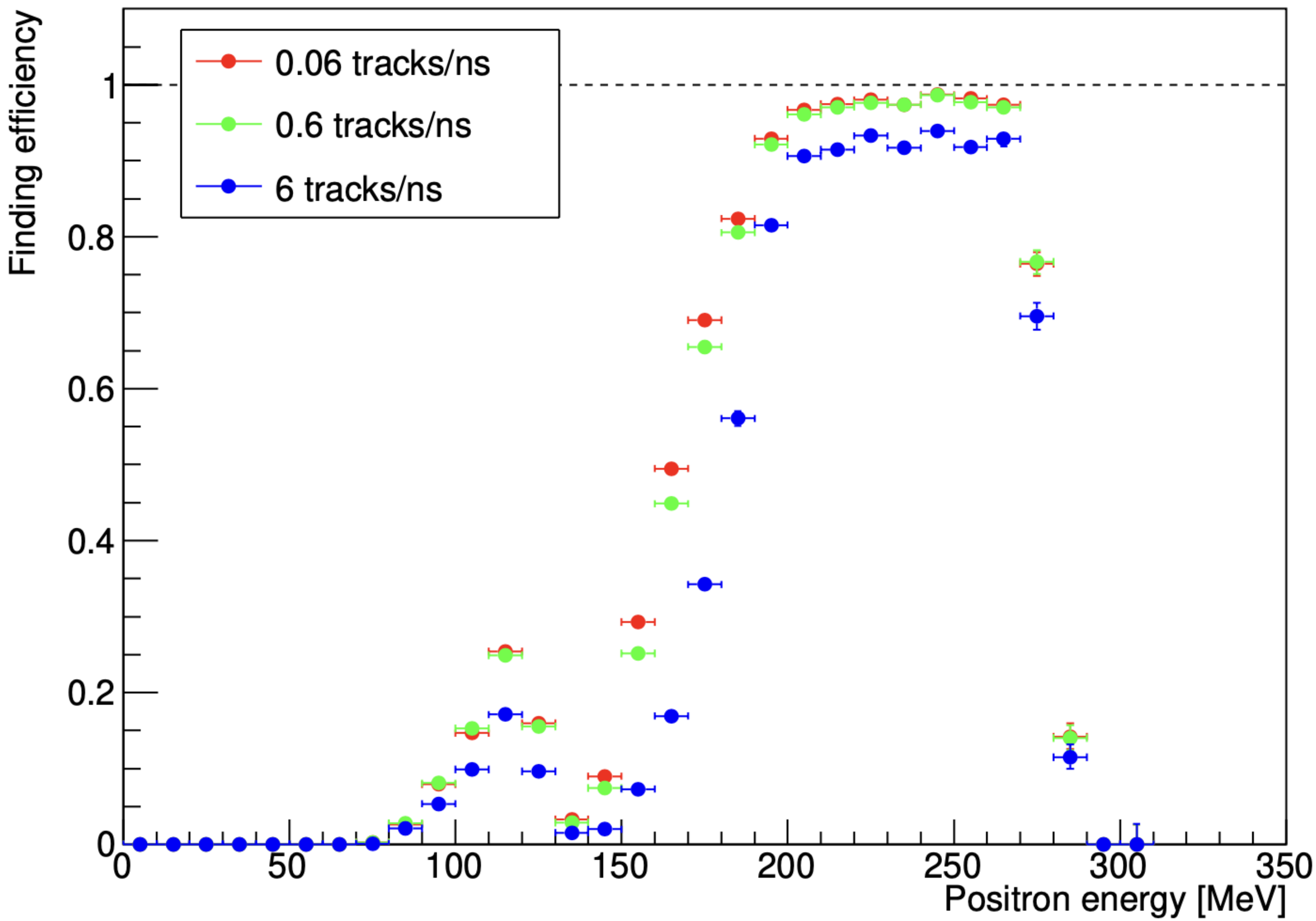
2023 April

Track reconstruction efficiency



Higher Energy, Stronger B-field

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(IPNS/KEK)

based on the discussion with

Graziano Venanzoni and his colleagues


October 2024

Experimental sensitivities

$$\frac{\Delta\omega_a}{\omega_a} = \frac{1}{\omega_a \gamma \tau P}\sqrt{\frac{2}{NA^2}}$$

$$\omega_a = a_\mu \frac{eB}{m}$$

450 ppb

valuable	definition	value
ω_a	anomalous spin precession frequency, $a_\mu \cdot (eB/m)$	$2\pi/2\ \mu$s
B	magnetic field strength	3 T
γ	Lorentz gamma factor, E/m	3
p	momentum of muon	300 MeV/c
τ	muon lifetime at rest	2.2 μs
P	muon polarization	50%
N	number of detected decay positron	6×10^{11}
A	average analyzing power of positron	0.42

Towards higher sensitivities

$$\frac{\delta\omega_a}{\omega_a} = \frac{1}{\omega_a \gamma \tau P}\sqrt{\frac{2}{NA^2}}$$

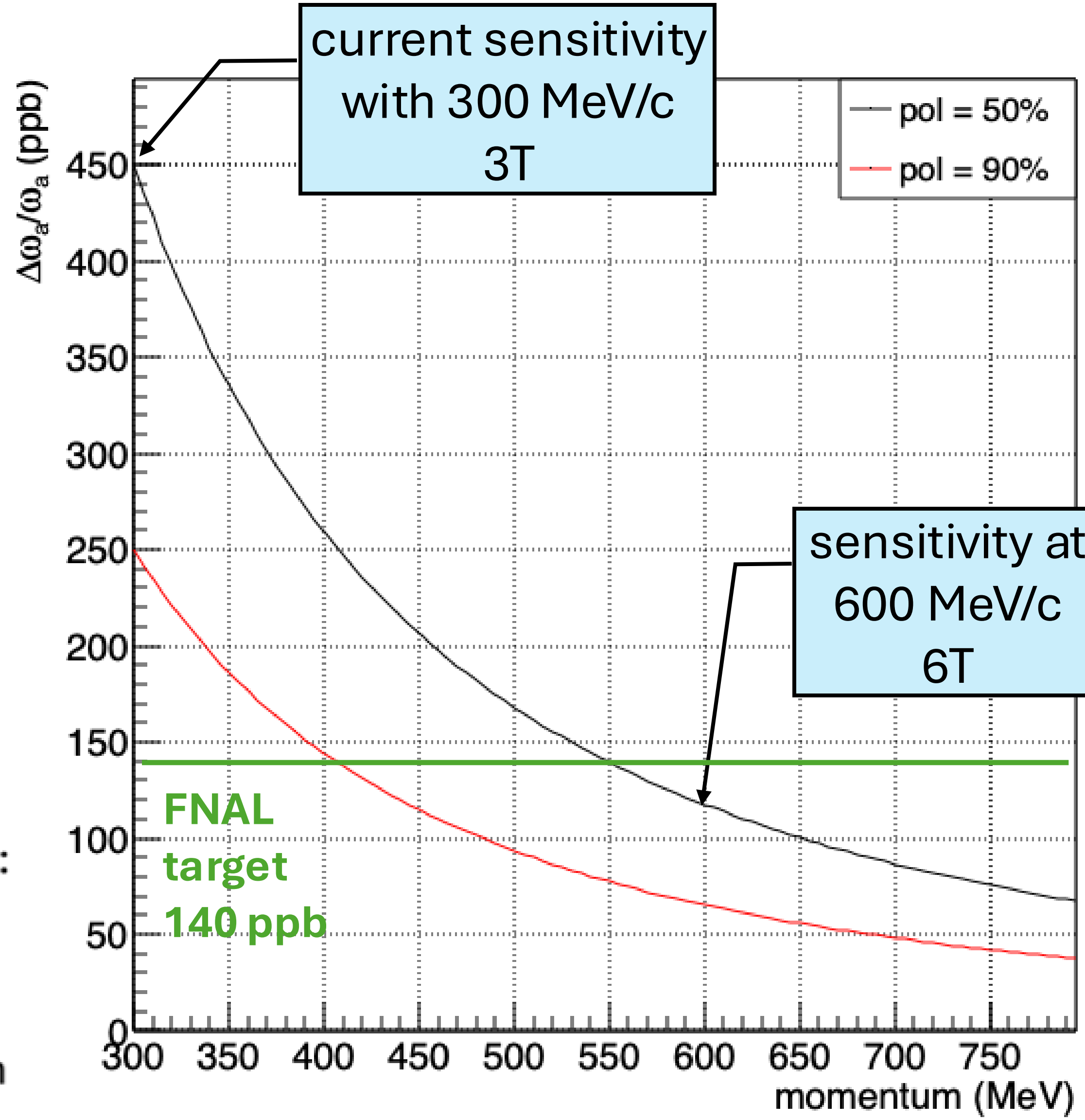
$$\omega_a = a\frac{qB}{m}$$

If p (=300 MeV) → 2 p (=600 MeV):
- B → 2 B → ωa → 2 ωa
- γ→ 1.9 γ

→ A factor 3.8 statistical gain:
450 ppb → **119 ppb** (=450/3.8)

If Polarization (50%) → 2 P (=100%):
- additional factor 2:
- 119 ppb –> **60 ppb** (=230/2)

- TOT: possible factor 7.6 stat gain



Possibilities

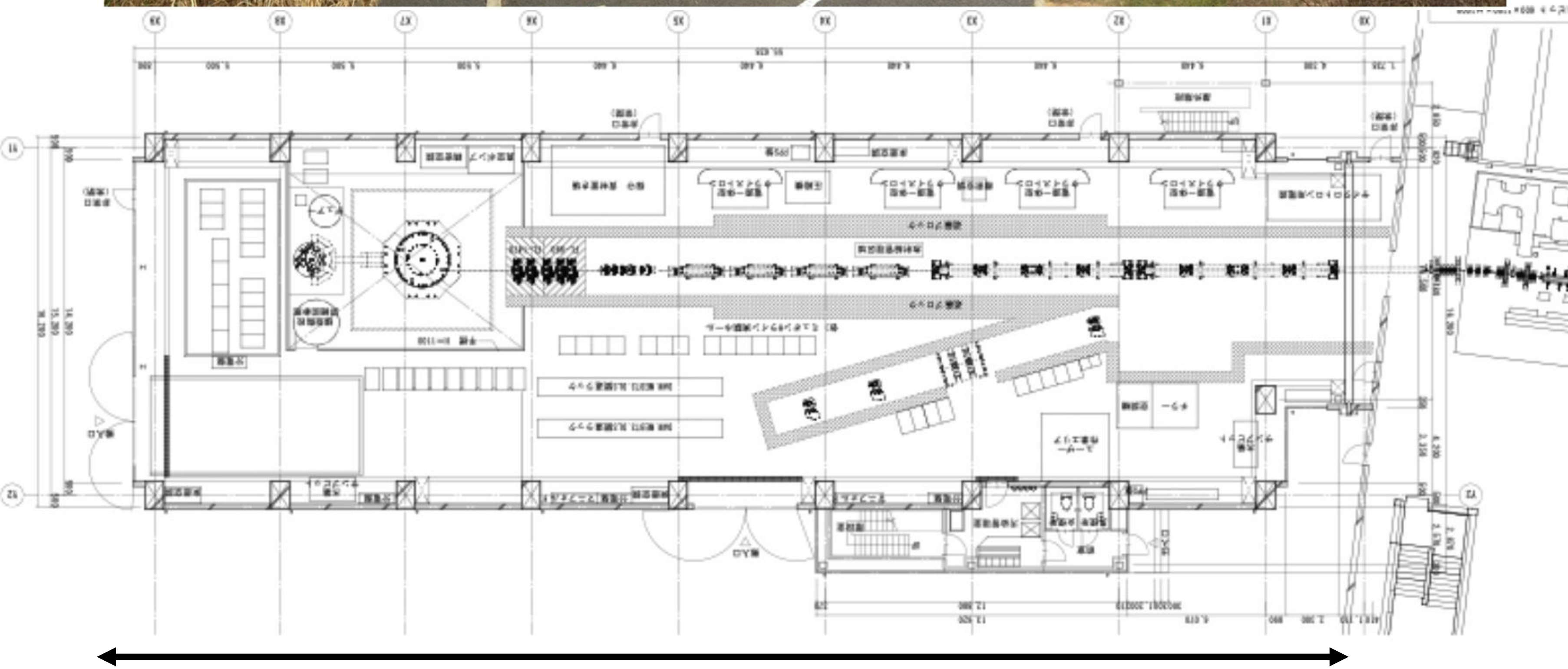
$$\frac{\Delta\omega_a}{\omega_a} = \frac{1}{\omega_a \gamma \tau P}\sqrt{\frac{2}{NA^2}}$$

$$\omega_a = a_\mu \frac{eB}{m}$$

1. Higher polarization (P)
2. Higher energy (γ)
3. Stronger magnetic field (B)

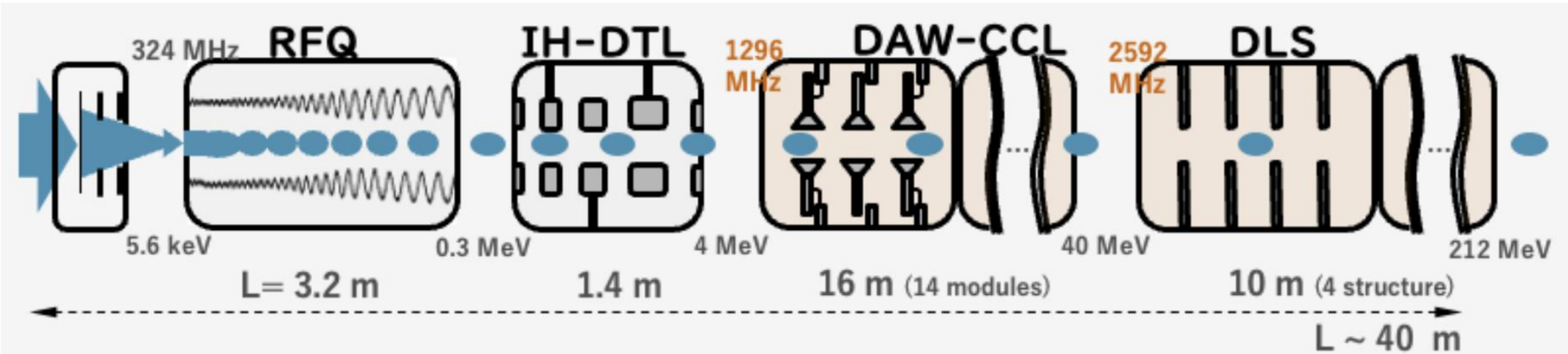
to be discussed by Shusei this evening

Higher energy



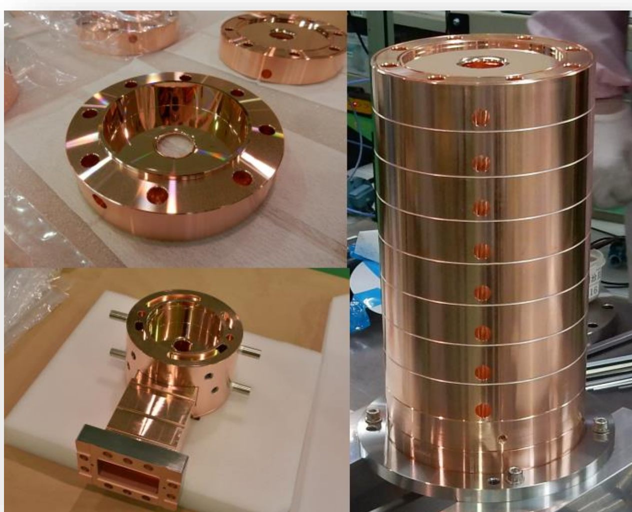
55 m

Higher energy



17 MeV/m

Disk Loaded Structure (DLS)



Options for higher accel. gradient cavities

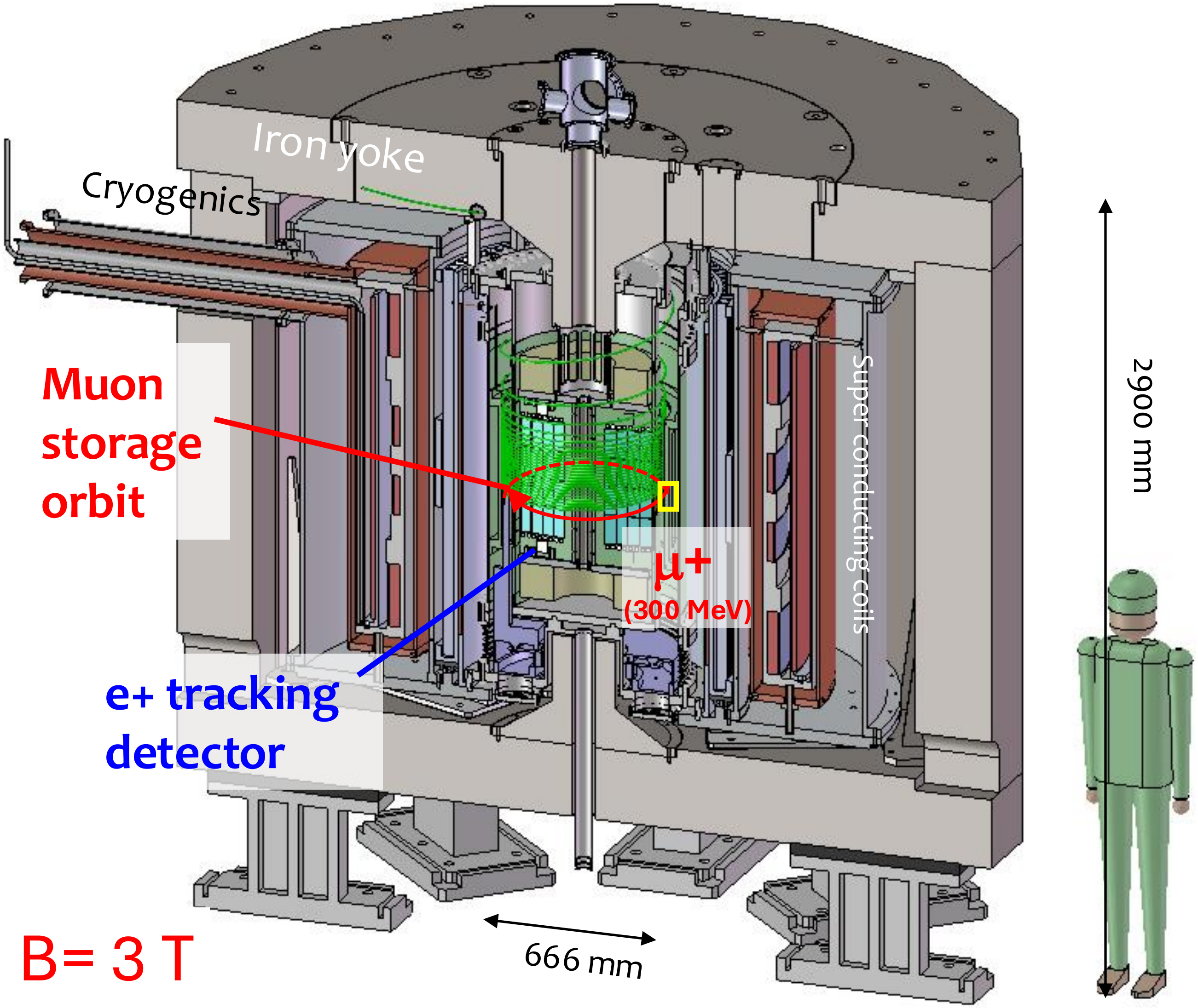
- **Cold Cupper Cavities (70-120 MeV/m)**
- **Plasma wake field cavities (~GeV/m)**

Synergies with higgs factories and/or future colliders

Beam emittance become smaller (1/γ)

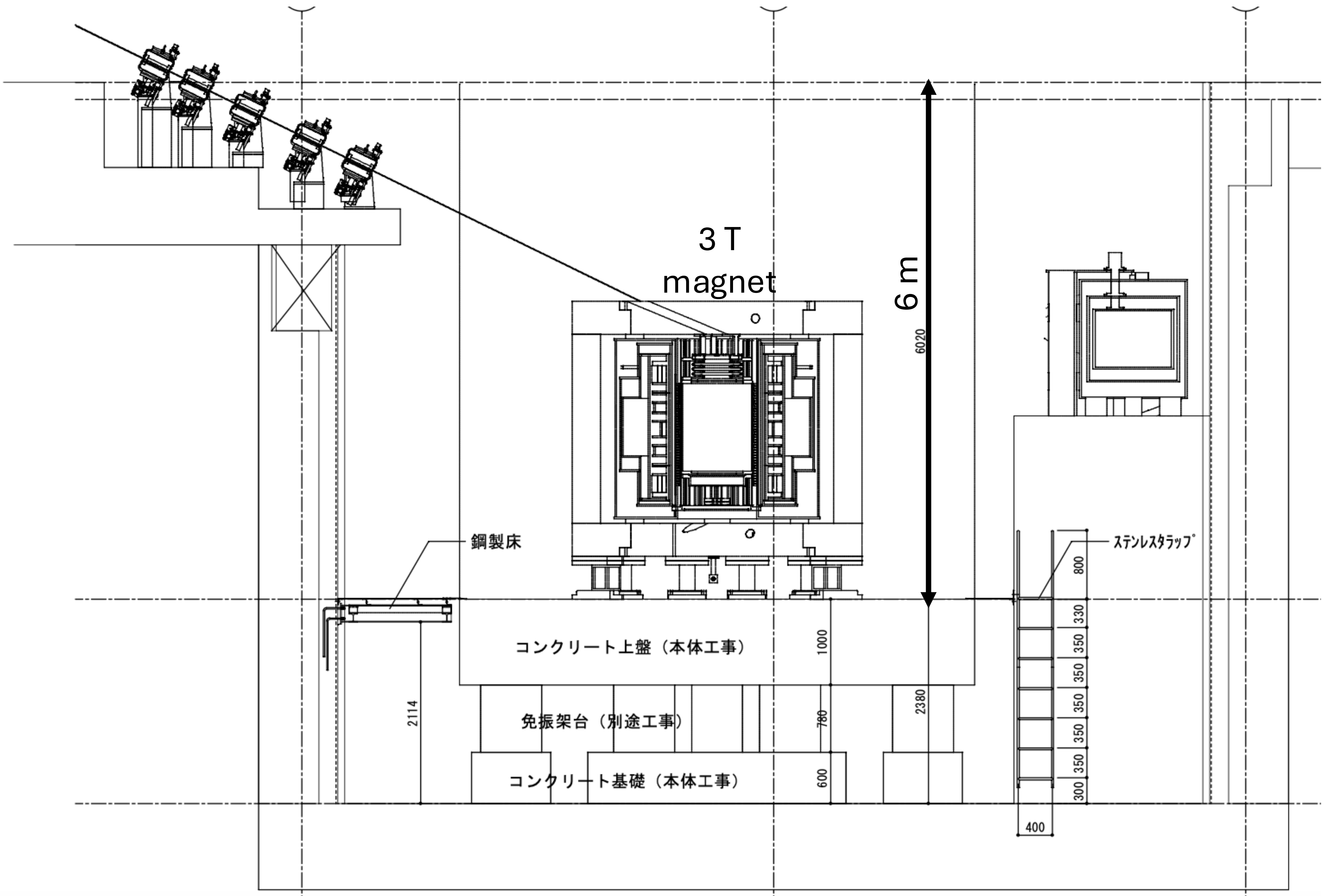
Muon storage magnet

NiTi Superconductor
→ Ni_3Sn or HTS for higher current?

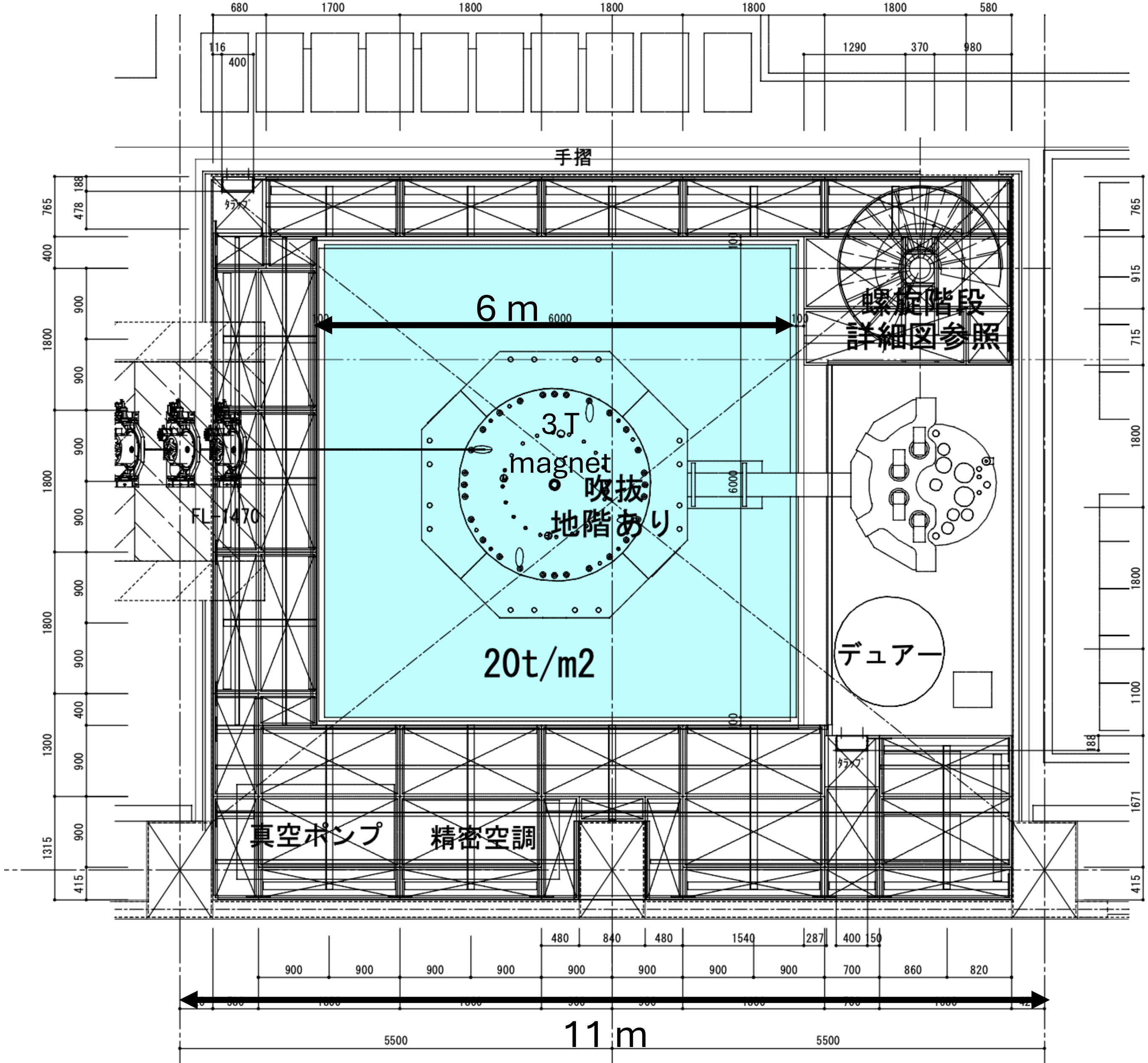


M. Abe et. al., NIM A 890, 51 (2018)

Storage magnet area



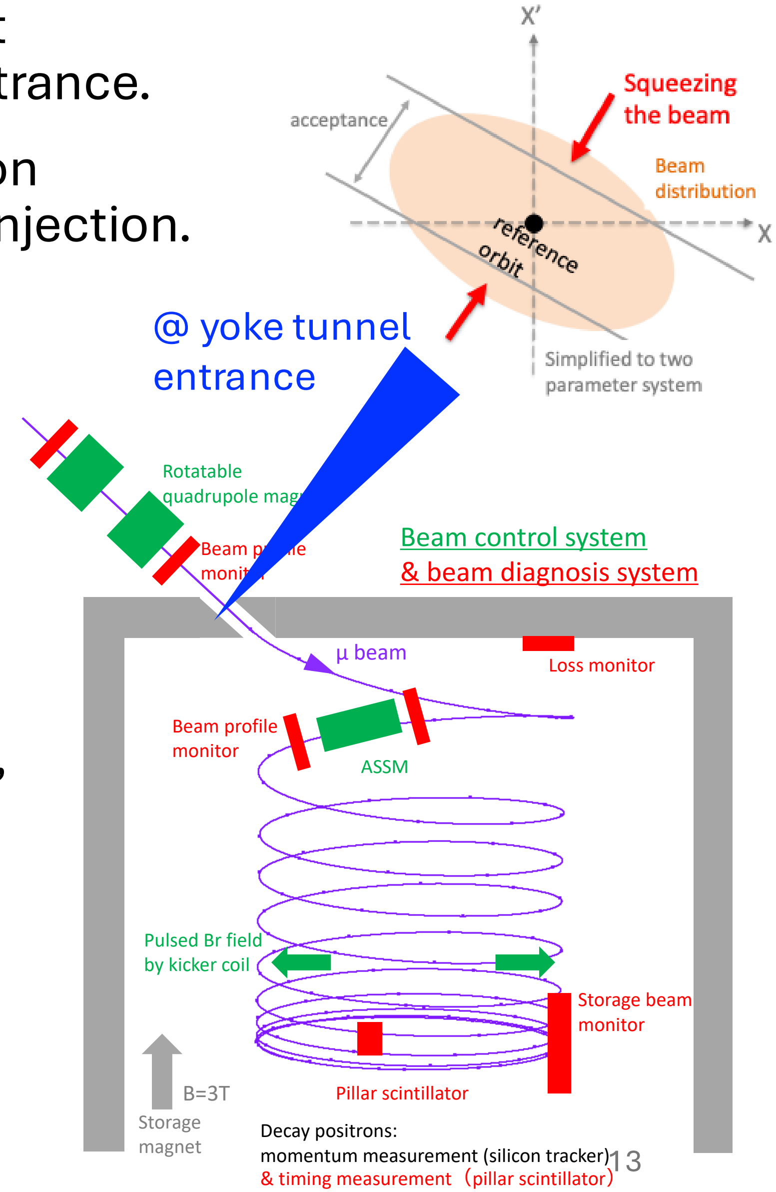
Storage magnet area



Slide by Sinji Ogawa

Beam injection at high P/ high B

- For 3D beam injection, beam distribution must match with narrow acceptance at iron yoke entrance.
- This is because beam passes through the region with a large transverse B-field gradient during injection.
  - A muon shifted at initial point feels different B-field. This leads to a different pitch angle after injection.
  - B-field gradient of $\frac{\partial B_r}{\partial r}$ comes from $\frac{\partial B_z}{\partial z}$, and this seems nearly inevitable during beam injection from Bz=0 T to 3 T.



- Comparing “300MeV/c, 3T” and “600MeV/c,6T”,
  - higher momentum reduces emittance -> Good for beam injection
  - higher B-field increases B-field gradient during injection -> Bad for beam injection.
- Beam injection at “600MeV/c,6T” is not trivial and needs a dedicated study.

Benefits and challenges

Benefits

- **Physics: Better sensitivity**
- **Systematics** : beam emittance becomes smaller. longer life time allows more precessions.
- **Linac** : general interests from accelerator community in demonstration of high-gradient cavities in the operational facility.
- **Injection :** smaller beam emittance might allow us to higher efficiency.

Challenges

- **Linac** :R&D is necessary. Infrastructure for cryogenics in the case of cold Cupper.
- **Injection :** stronger kick for the beam. This might require increase of number of kicker coils which might impact the magnetic field uniformity.
- **Magnet** : stronger weak focusing field. Larger iron yoke to store the magnetic flux. More cooling power, thus more liquid helium. R&D for Ni_3Sn or HTS.

Summary

- Higher energy & stronger B field offer better sensitivities for g-2 beyond the baseline design.

- We identified several challenges / issues to resolve, but no show-stopper.

- We wish to discuss these options in wider communities with fresh eyes to find an appropriate path to go forward.