



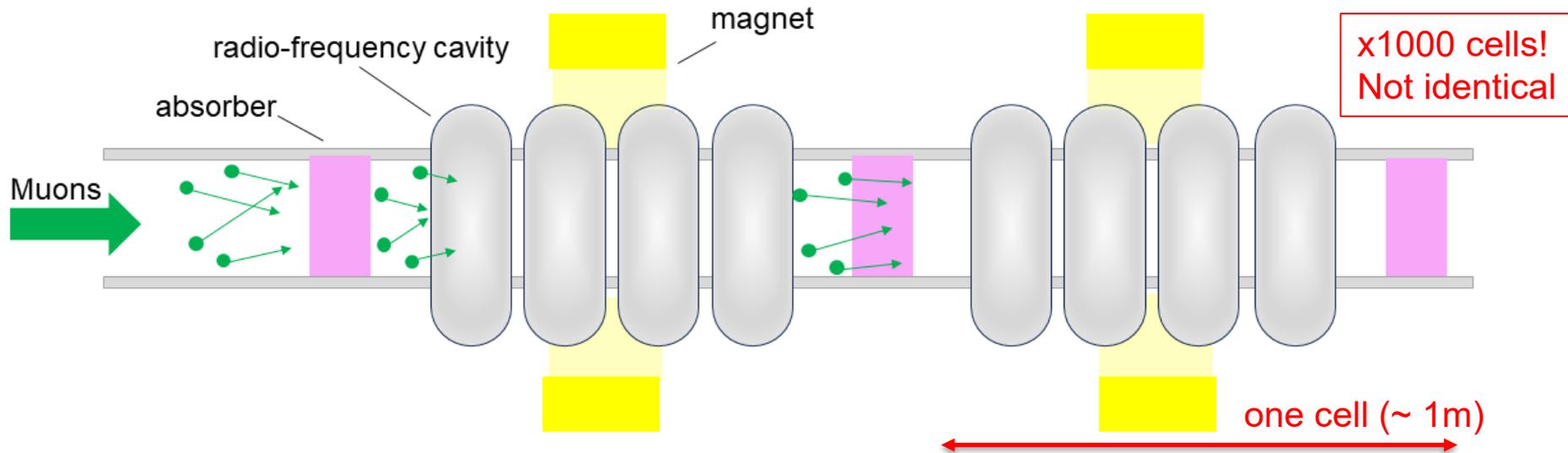
# Muon Cooling Demonstrator Program for the Muon Collider

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Wednesday Meeting

March 3, 2026

# Concept of ionization cooling



- Considerations for MuC cooling:
  - Beam size must be small at the absorber to reduce scattering
  - Absorbers with low  $Z$  and large energy loss must be selected
  - Magnetic field has to increase in strength over distance to keep cooling
  - The magnetic field, makes normal conducting (NC) cavities the only option

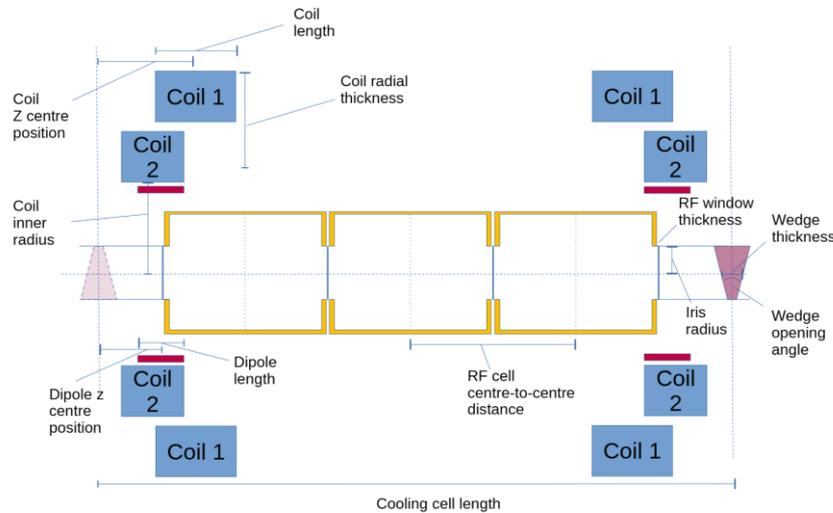


# Cooling cell for demo (IMCC)

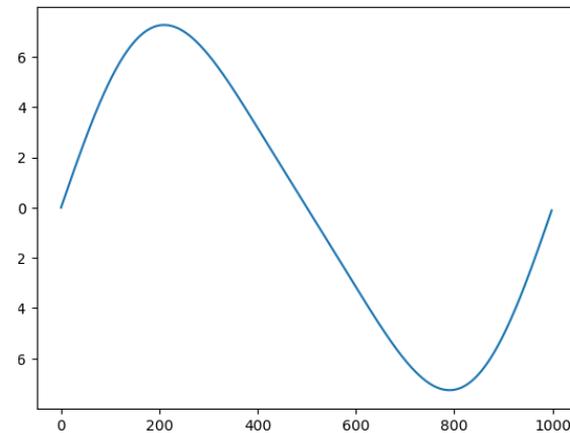
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Stage	Cell length (m)	Stage length (m)	Pipe radius (cm)	Max. on-axis $B_z$ (T)	Integrated $B_y$ (T·m)	Transverse beta (cm)	Dispersion (mm)	On-axis wedge length (cm)	Wedge apex angle (deg)	RF frequency (MHz)	Number of RF cells	RF cell length (cm)	Max. RF gradient (MV/m)	RF phase (deg)
A1	1.8	104.4	28	2.5	0.102	70	-60	14.5	45	352	6	19	27.4	18.5
A2	1.2	106.8	16	3.7	0.147	45	-57	10.5	60	352	4	19	26.4	23.2
A3	0.8	64.8	10	5.7	0.154	30	-40	15	100	704	5	9.5	31.5	23.7
A4	0.7	86.8	8	7.2	0.186	23	-30	6.5	70	704	4	9.5	31.7	25.7
B1	2.3	50.6	23	3.1	0.106	35	-51.8	37	110	352	6	25	21.2	29.9
B2	1.8	66.6	19	3.9	0.138	30	-52.4	28	120	352	5	22	21.7	27.2
B3	1.4	84	12.5	5.1	0.144	20	-40.6	24	115	352	4	19	24.9	29.8
B4	1.2	66	9.5	6.6	0.163	15	-35.1	20	110	352	3	22	24.3	31.3
B5	0.8	44	6	9.1	0.116	10	-17.7	12.5	120	704	5	9.5	22.5	24.3
B6	0.7	38.5	4.5	11.5	0.0868	6	-10.6	11	130	704	4	9.5	28	22.1
B7	0.7	28	3.75	13	0.0882	5	-9.8	10	130	704	4	9.5	28.5	18.4
B8	0.65	46.15	2.85	15.8	0.0726	3.8	-7.0	7	140	704	4	9.5	27.1	14.5
B9	0.65	33.8	2.3	16.6	0.0694	3	-6.1	7.5	140	704	4	9.5	29.7	11.9
B10	0.63	29.61	2	17.2	0.0691	2.7	-5.7	6.8	140	704	4	9.5	24.9	12.2

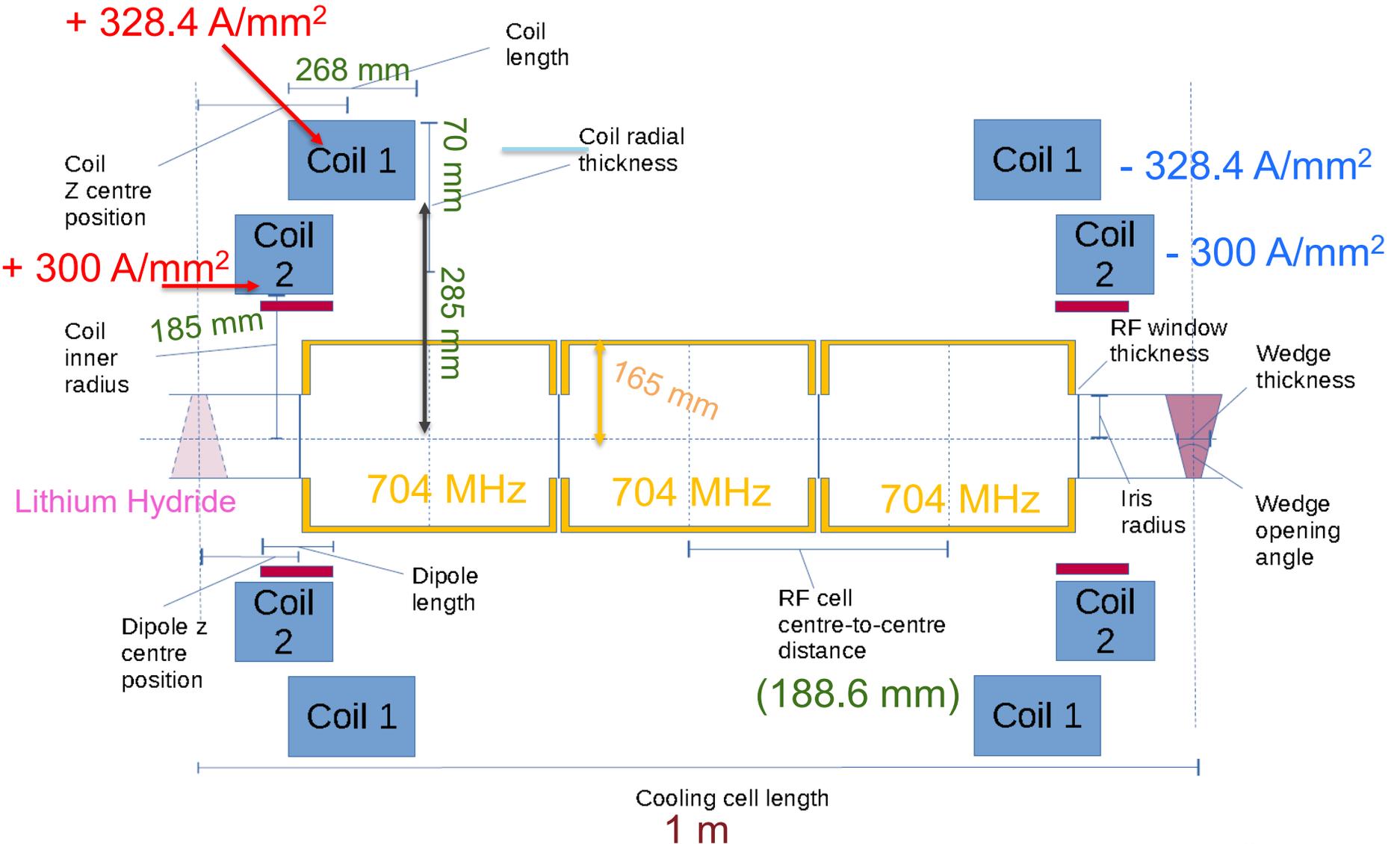
Stage 5



Target field on axis for a 1 m cell

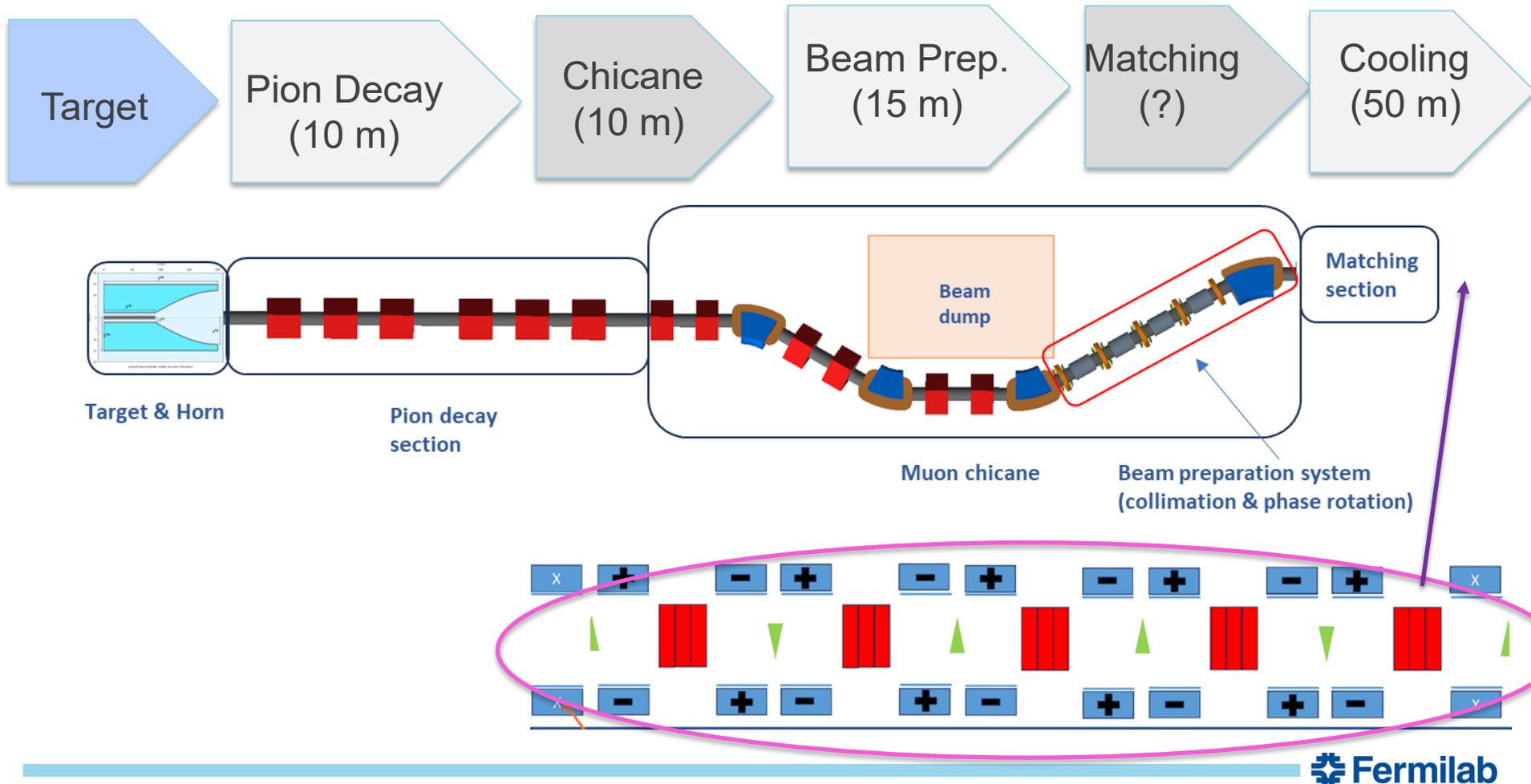


# Cooling cell for demo (1 cell)

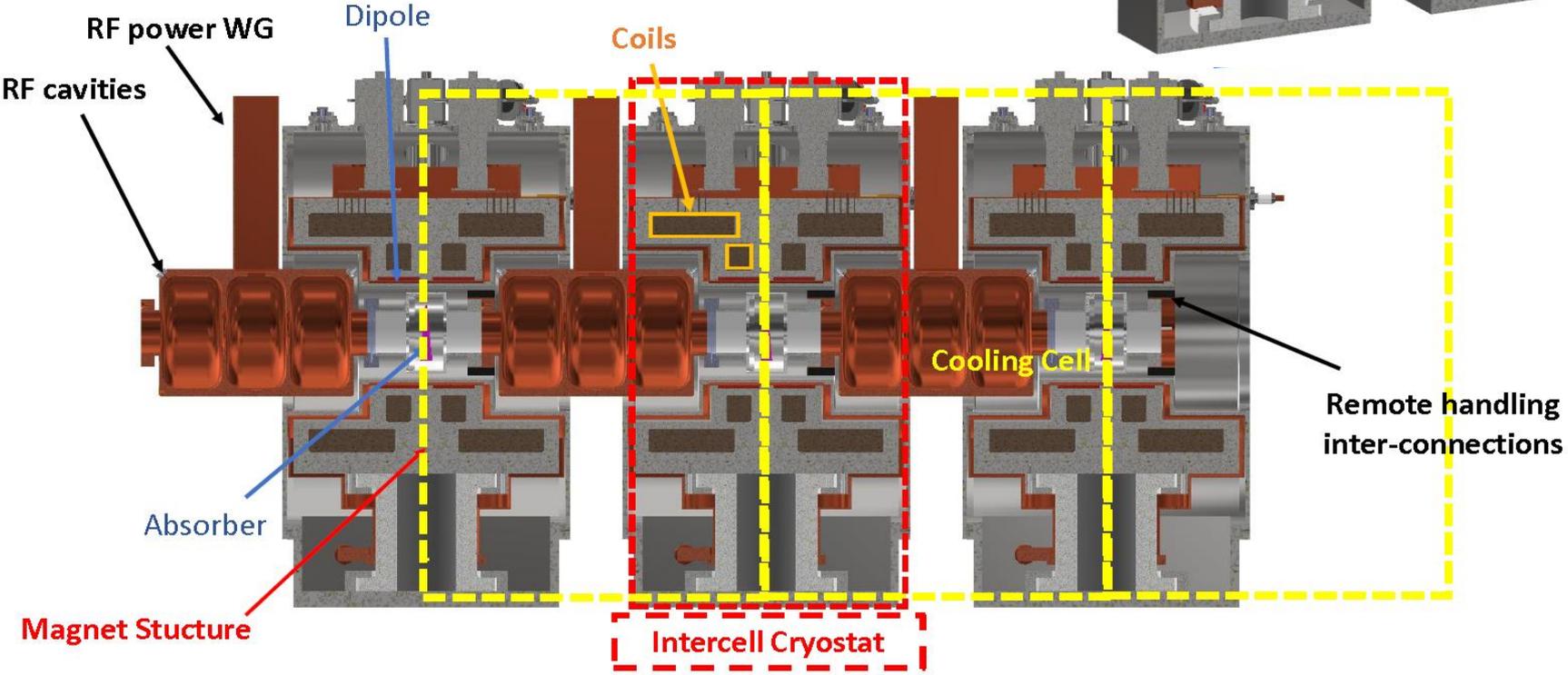
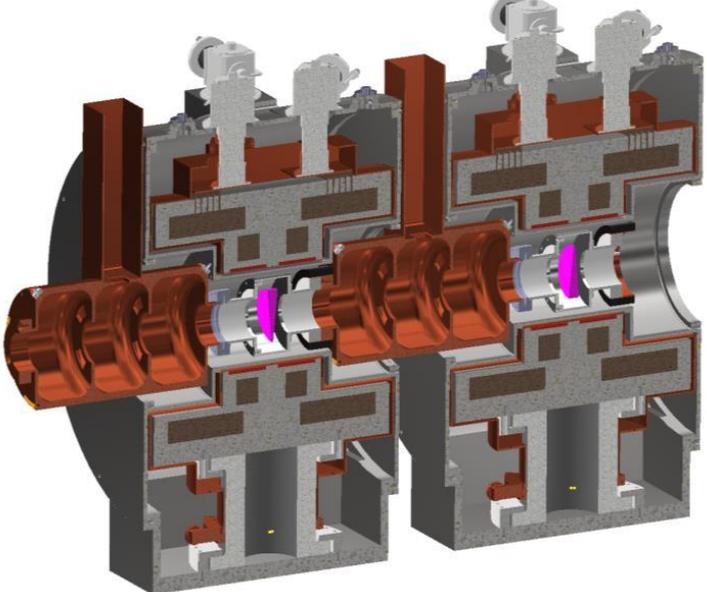


# Cooling demo facility (baseline)

- Key components



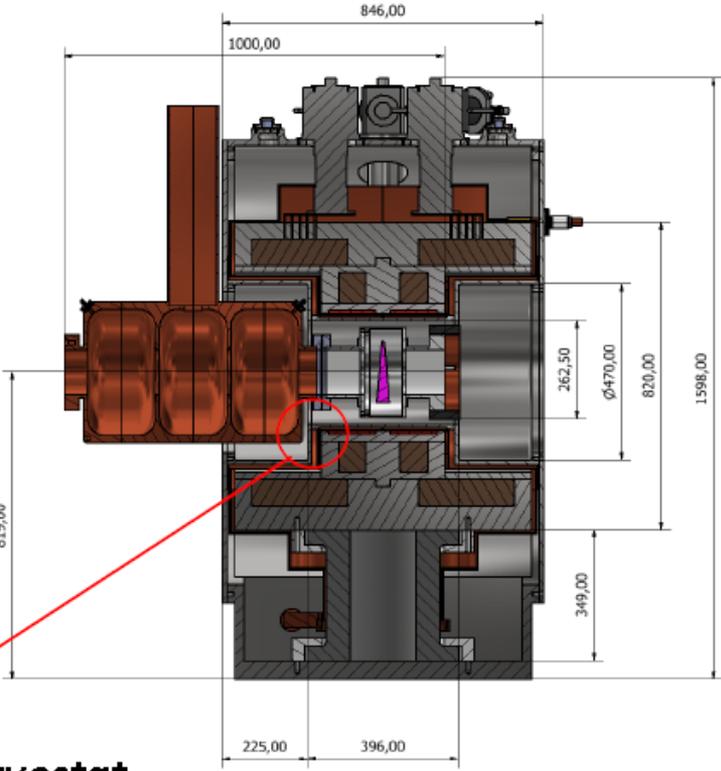
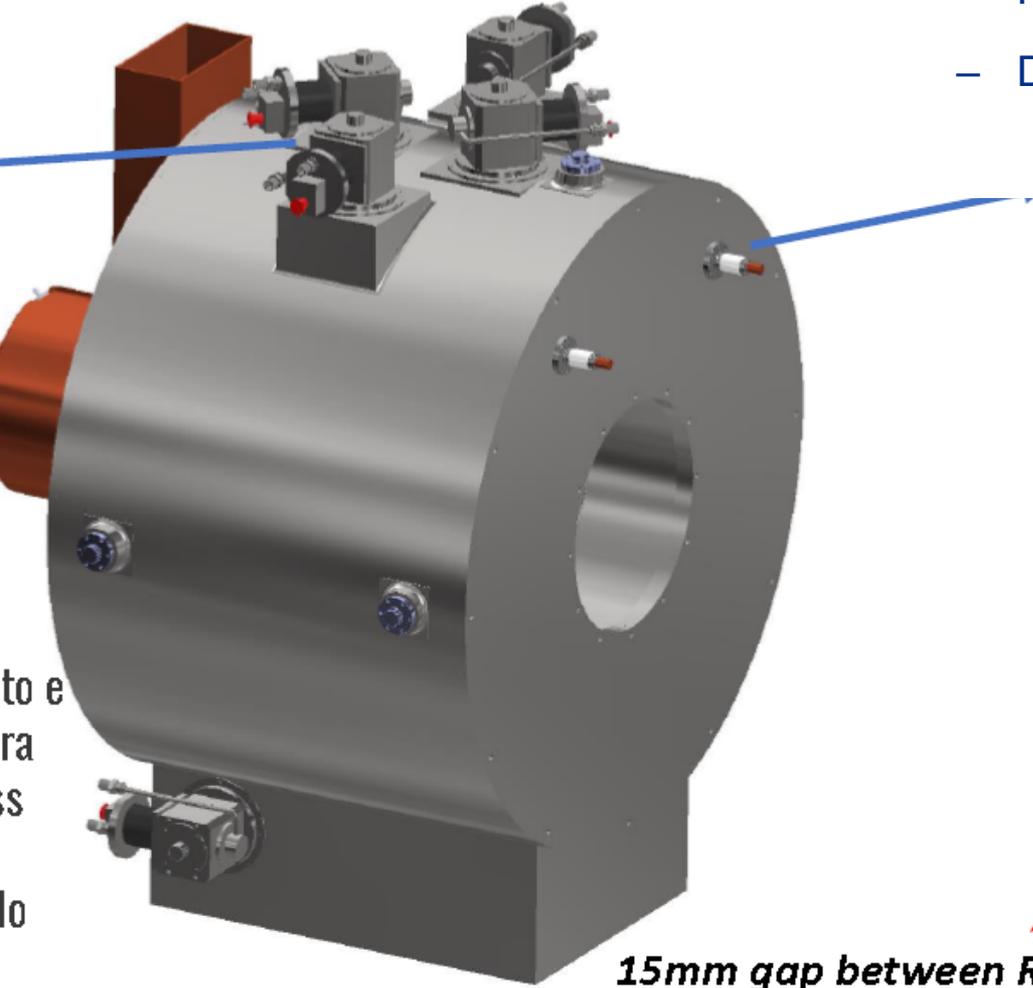
# Cooling cell (engineering)



# Cooling cell (engineering)

Magnets:

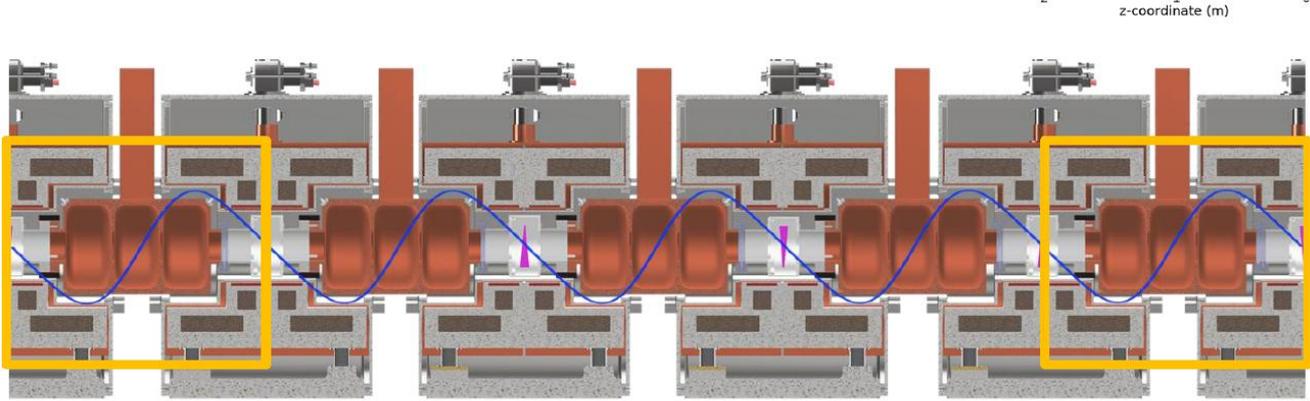
- HTS technology, non insulation coils at 20 K
- Details [here](#)



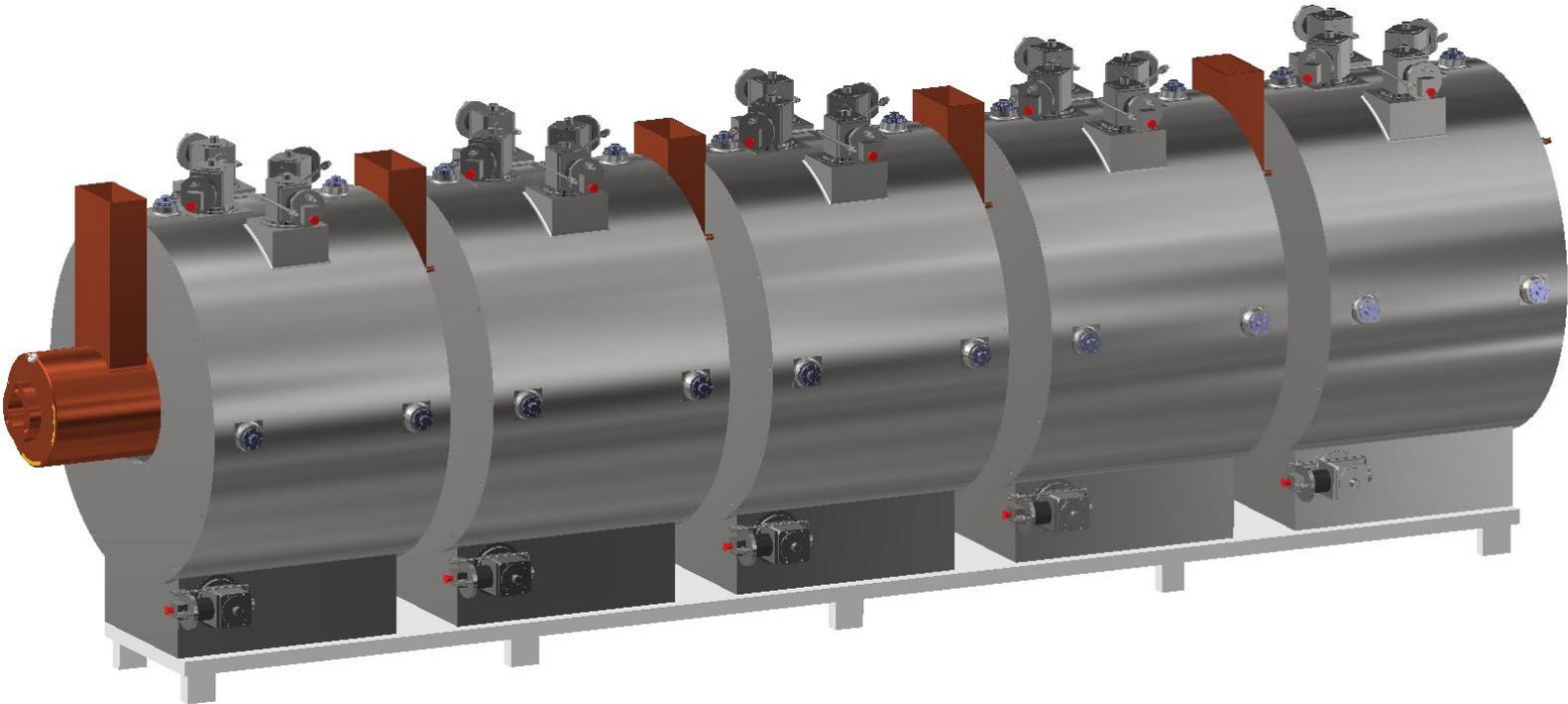
*15mm gap between RF an cryostat*

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# Cooling cell (engineering)

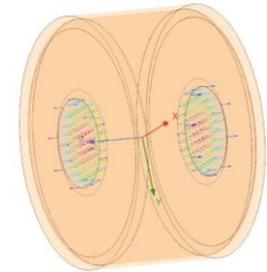
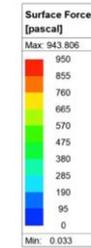
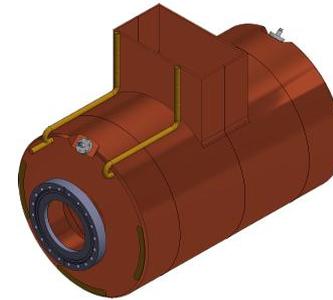
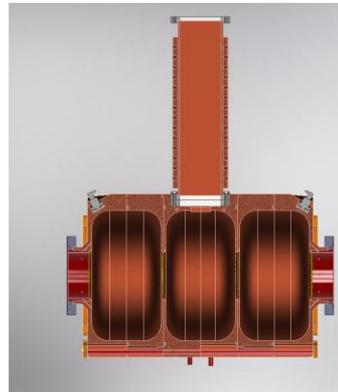


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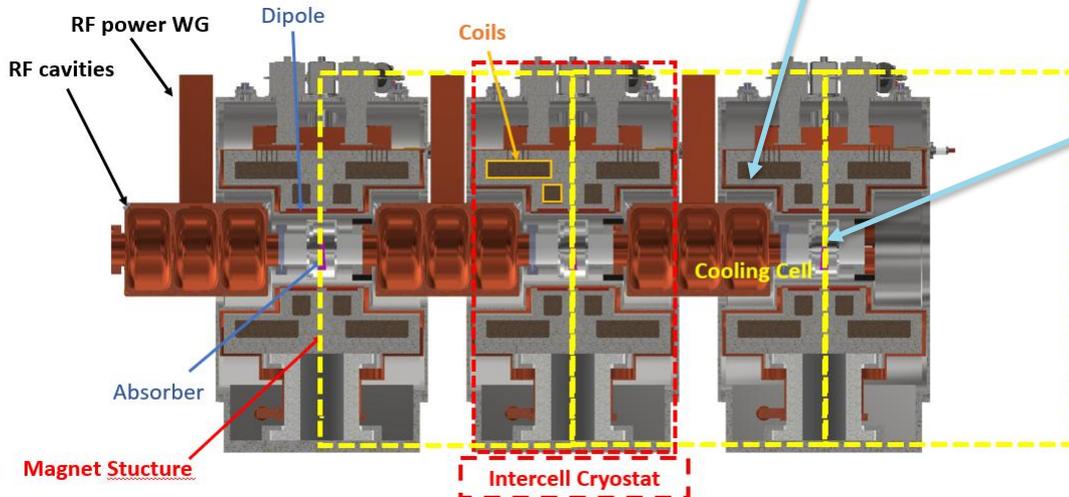


# R&D for cooling cell: rf cavities & absorbers

- RF cavities
  - Baseline design developed
  - Al foils seem ok
  - Details [here](#)



Copper weight: 180 kg  
8 water channels  
Max. external diameter: less than 500

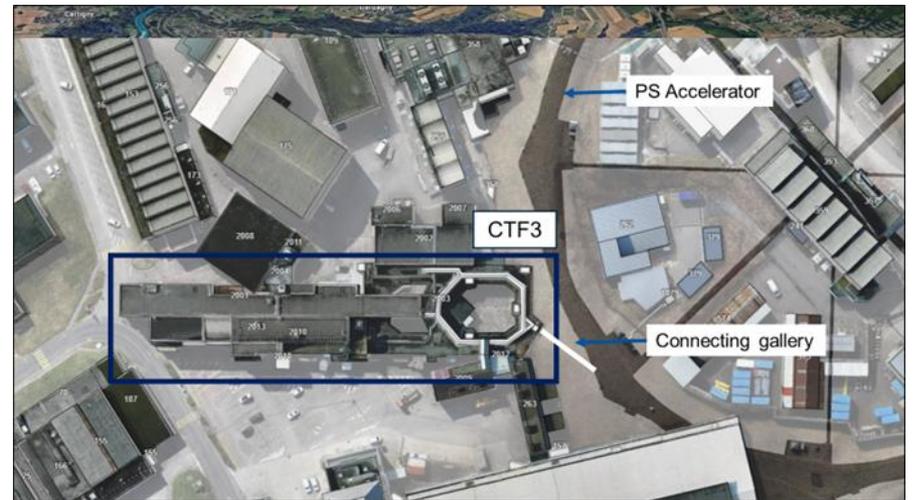
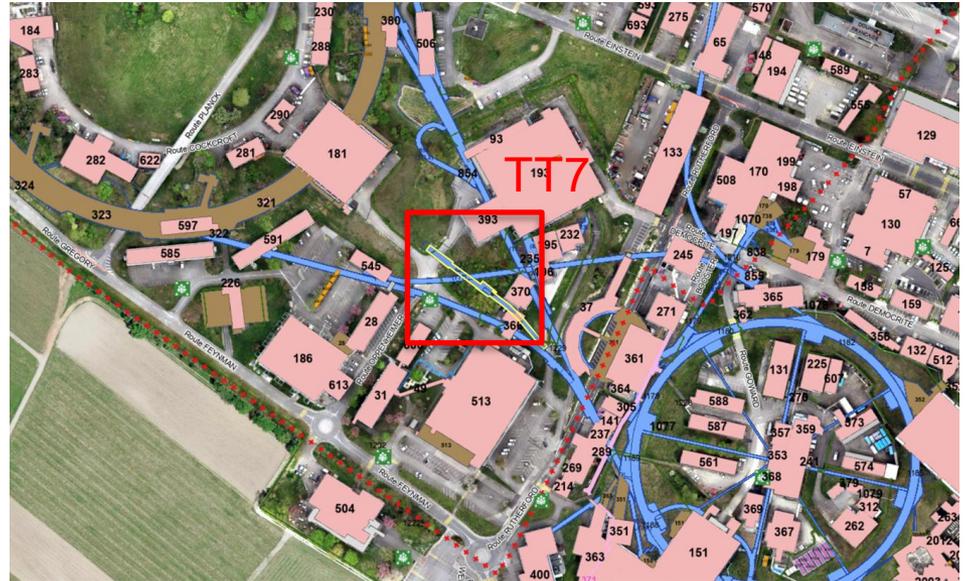


- LiH absorber
  - Uncommon material & reactive
  - Experience from MICE; R&D is needed for manufacturing, operation and integration
  - Details [here](#)



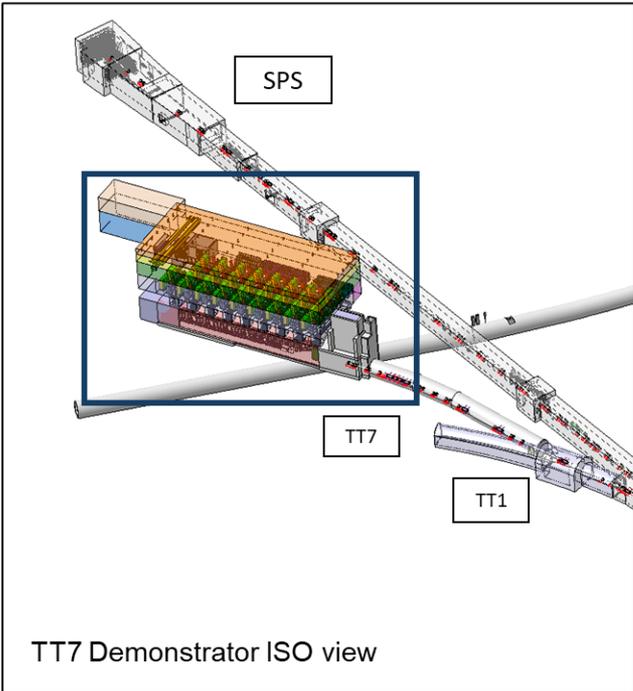
# Facilities at CERN

- TT7
  - Does not require a new beam extraction in the PS
  - Limited beam power
  - Existing tunnel (~50 m)
- CTF3
  - Operation at >10 kW possible
  - ~100 m tunnel)
  - But no connection to PS



# CTF3 Facility at CERN (1)

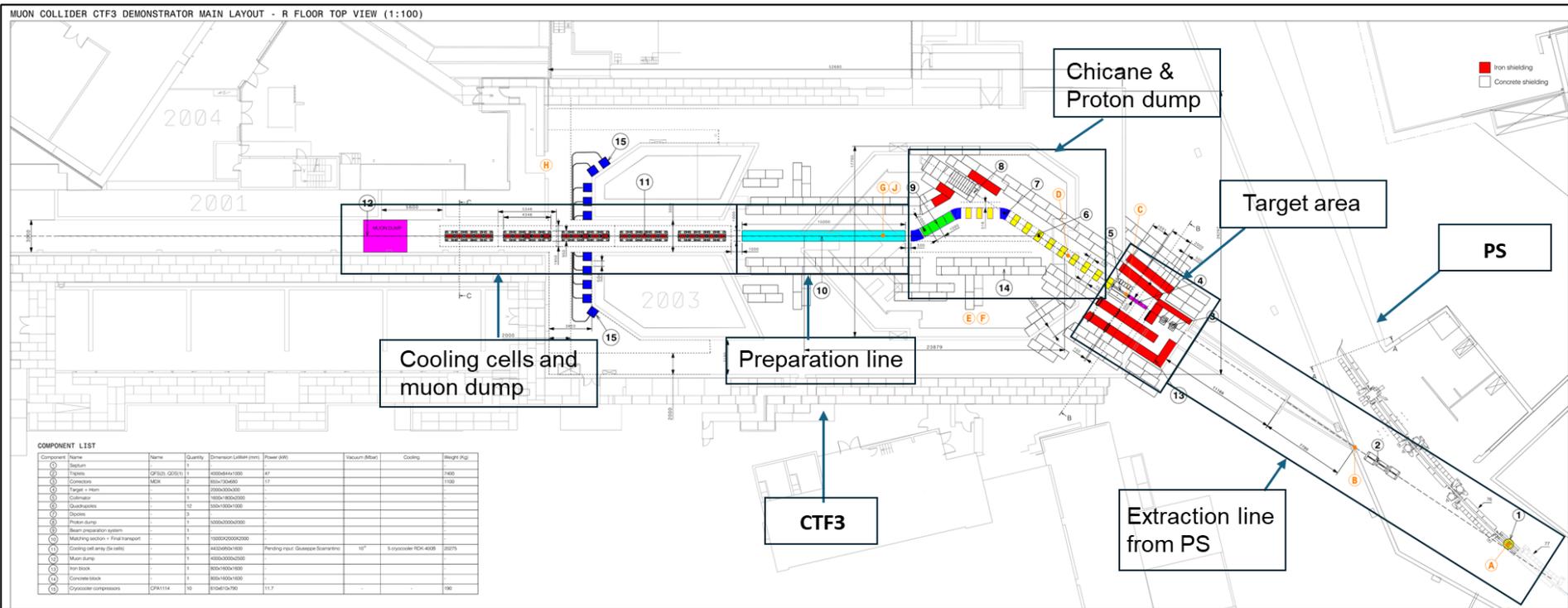
## Why are we studying CTF3 area?



Criteria	CTF3	TT7
Infrastructure	Existing tunnel and surface building (no major works)	Existing tunnel, new surface building required
Beam Power Capability	Compatible with high-power PS beam	Similar potential, but subject to beam transfer integration
Cooling Length	~80 m available in straight tunnel	~50.8 m length + space for chicane, shielding, etc.
Integration Readiness	No 3D Integration model (Study K/O 1 month ago). 2D layout existing.	Full integration study done (EDMS 3200071), civil works identified
Civil Engineering	No major excavation needed	Requires tunnel enlargement and shaft, building construction -> <b>COST DRIVER</b>
Surface Needs	Existing gallery reused for klystrons	New building (15 x 44 m) with crane, RF integration, access
Access & Transport	Proven logistics access (legacy of CTF3 campaigns)	Detailed logistics planning required due to tunnel slope, access
Technical Maturity	Actively under integration study, minimal blockers	Study done, civil & safety constraints remain to be resolved

CTF3 enables a cost-efficient reuse of existing infrastructure, while TT7 demands new construction and major civil works, driving up project costs.

# CTF3 Facility at CERN (2)

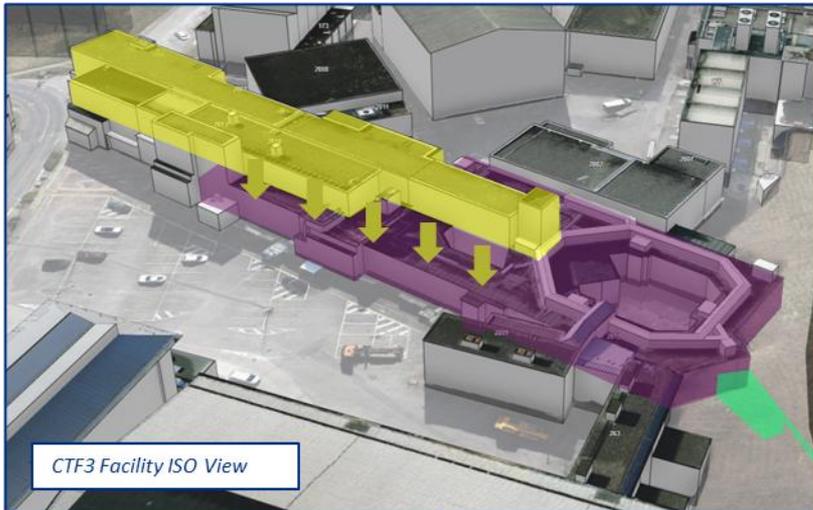


CTF3 Demonstrator integration study / Javier Fernandez Roncal / CERN

- CERN feasibility study ([link](#))

# CTF3 Facility at CERN (3)

## 3.2 CTF3 Concept layout



R-Floor
- Transfer line
- Target area
- Decay channel
- Chicane and proton dump
- Preparation line
- Cooling cells
- Muon dump

1st - Floor
- Klystron gallery
- Power converters

R-Floor
- Connecting gallery with PS

CTF3 Facilities benefits summary
CTF3 Facility not in use* – No need to construct new building.
Existing gallery to PS for beam extraction
Potential space in 1st Floor for klystron gallery and power converters
Potential space in R-Floor for beam line and cooling cells



\* Pending crosscheck with other projects roadmaps on CTF3

### CHALLENGES IDENTIFIED DURING PRELIMINARY STUDY

R-Floor	1st Floor
1. PS Beam extraction still under evaluation (optics tbc)	1. Klystron gallery lacks space without optimization
2. Target and colling cell areas are tight to fit	2. B2001 ceiling too low for klystron service and installation.
3. Assembly and servicing are difficult in the current layout.	

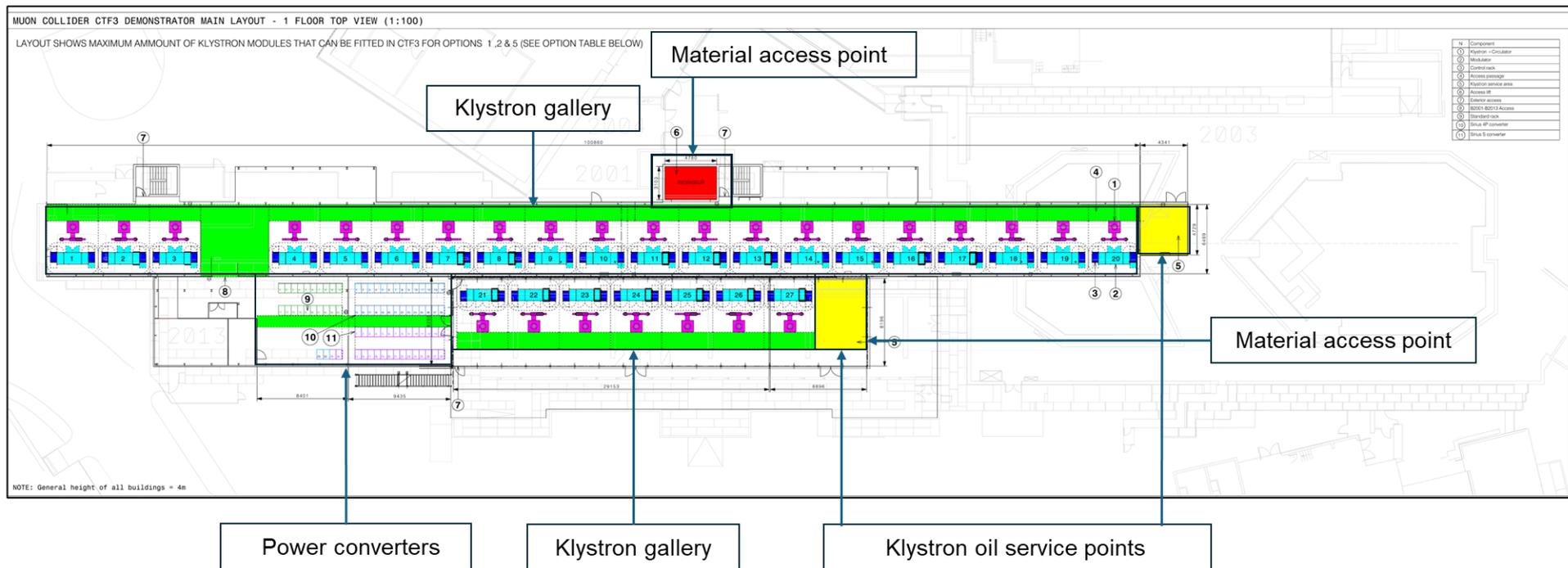
THERE ARE CHALLENGES, BUT NO BLOCKING POINTS



- CERN feasibility study ([link](#))

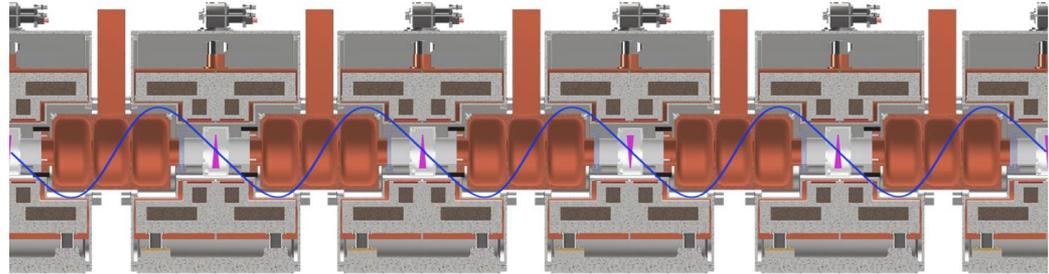
# CTF3 Facility at CERN (4)

## Study: 1<sup>st</sup> – Floor : Klystron gallery



- CERN feasibility study ([link](#))

# R&D towards a cooling demonstrator



- RF cavities R&D
  - Design muon cooling pillbox cavities (including associated foils)
  - Develop power sources for these cavities
  - Test rf cavities in high-magnetic fields (test-stands)
- Magnet R&D
  - Develop magnet concepts for the rf test stand and the cooling demonstrator
  - Cryostat concept, protection for quench and force unbalance, structure support
- Absorbers R&D
  - Manufacturing procedure, prototype, and handling of LiH absorbers
- Assembly process, accessibility issues, upgrade concepts