Proton, Target and Cooling: Summary

International
MUON Collider
Collaboration

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On behalf of the **proton, target and cooling WPs**
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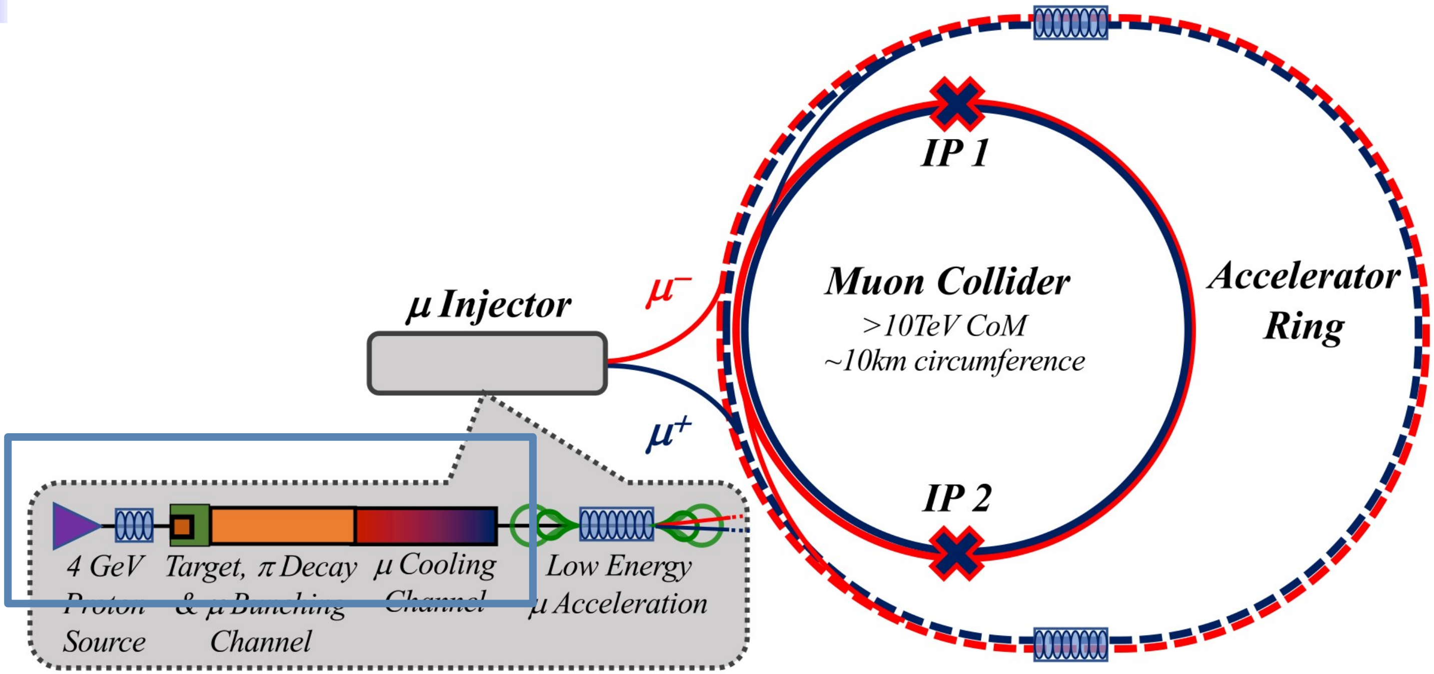
Low energy complex



- Produce a multi-MW and extremely short - O(ns) - proton pulse
- Fire protons onto a target to make pions
- Capture the pions and decay to muons
- (Bunch the muons)
- Reduce the beam size – cool – the resultant muon beams

Luminosity

$$\mathfrak{L} \approx \underbrace{\frac{e\tau_\mu}{(4\pi m_\mu c)^2}}_{K_L} \frac{f_{hg}\sigma_\delta \bar{B}}{\varepsilon_\perp \varepsilon_L n_b f_r} \underbrace{\eta_+\eta_-(\eta_\tau P_p \gamma m_\mu c^2)^2}_{P_+P_-}$$

- P_p – proton beam power
- n_b - number of bunches
- f_r – rep rate (number of acceleration cycles/second)
- ε_{perp} – transverse emittance
- ε_L – longitudinal emittance
- $\eta_{+/-}$ - proton to muon conversion ratio

Novel muon source concepts

Muon Catalysed Fusion-based source (Y. Mori)

- Produce negative muons on a target
- Negative muons travel into D-T mix → Muonic He^+
- Reaccelerate He^+ and strip → low emittance negative muon source
- Need to challenges considering some of the RF gradients required

Novel positron production target for LEMMA (M. Eldred)

- Fire electrons onto a crystal
- Produce ~GeV photons
- Photons strike secondary target to produce positrons
- Need to understand if we sufficiently mitigate the challenges in LEMMA positron production

Proton Driver Siting

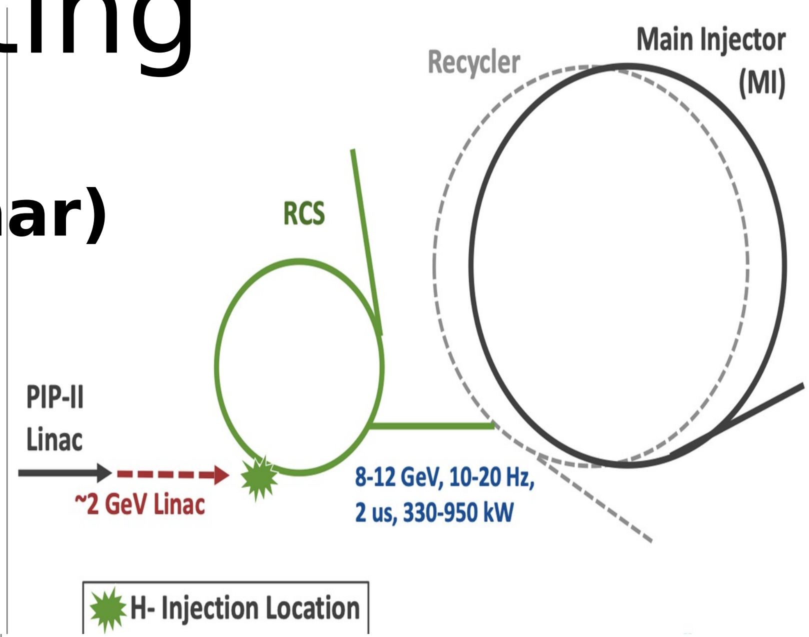
Fermilab's Possible layouts

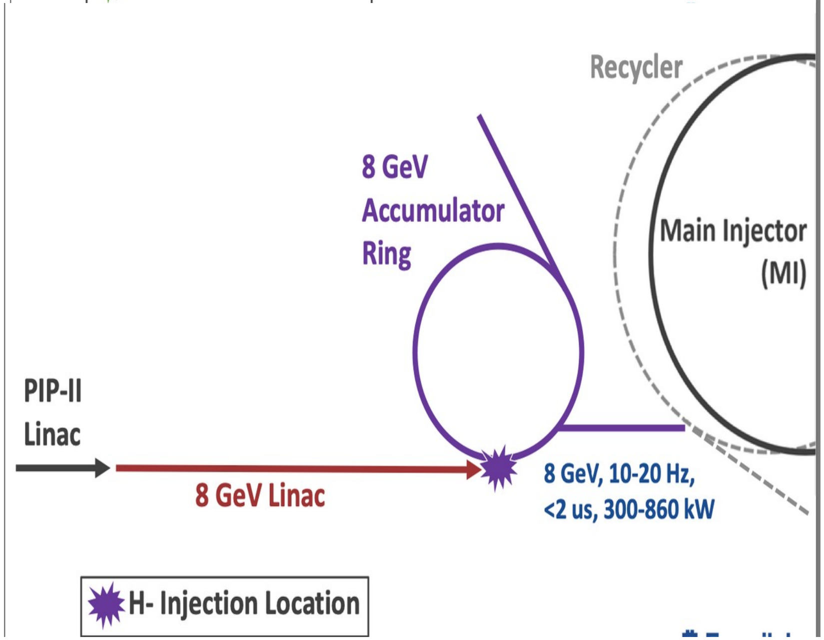
European Siting (C. Plostinar)

- Multi MW machine demonstrated
- Pulse compression is the challenge
- Considerations on project set-up
  - Green Field vs Established Lab
  - In-kind setup

US Siting (J. Eldred)

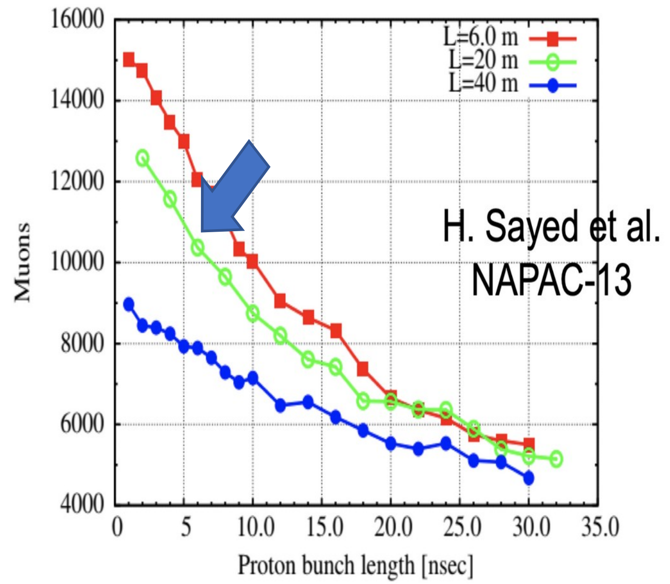
- Synergies with other Neutrino Facilities
- Muon collider is compatible with PIP III
- R&D topics to consider
  - H- laser stripping
  - Pulse Compression Beam Dynamics
  - Extreme Space Charge

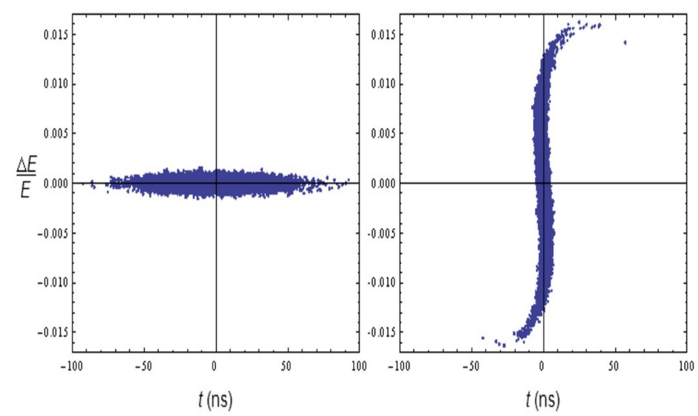




Pulse Compression (D. Neuffer)

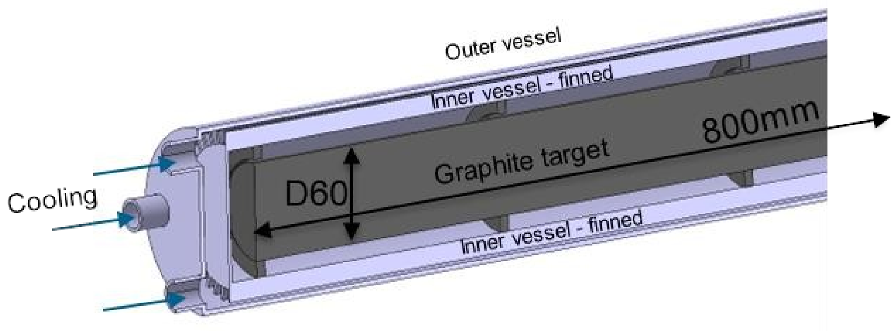
- Baseline MAP design: Full energy Linac at 8 GeV + Accumulator and Compressor rings (could be design as a single ring?)
- Keep the final pulse length between 1-3 ns rms.
- Accumulator with h=4 (4 bunches), ¼ rotator and combination of bunches onto the target
  - 2 x 10^{14} p/bunch (15 Hz and 4 MW) -> (2 MW, 5 Hz similar intensities for MuCol for the same energy)
- A more complete study and transport to target of such smalls pulse is still needed but the whole compression looks feasible. Still more work on Space Charge effects is needed.
- J-PARC MR reaches a bunch intensity needed for the MC (200 kJ/bunch) → Look at other machines already established



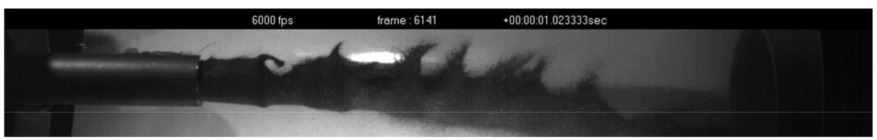


Target

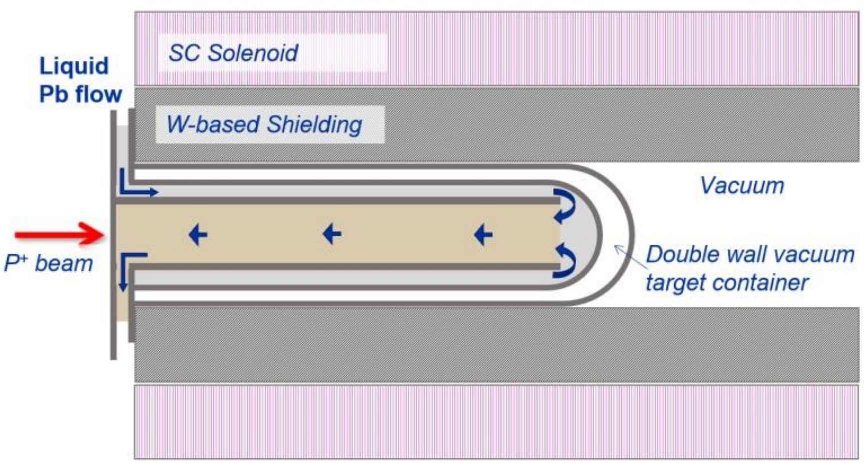
- Three targets under consideration



Graphite (R. Franquiera)
Well-known…. T2K/CNGS
Lifetime vs radius
Pion yield



Fluidised tungsten powder
(C. Densham)
Novel
Tungsten handling?



Liquid lead (C. Carelli)
Pressure waves/cavitation
Prior experience with Hg

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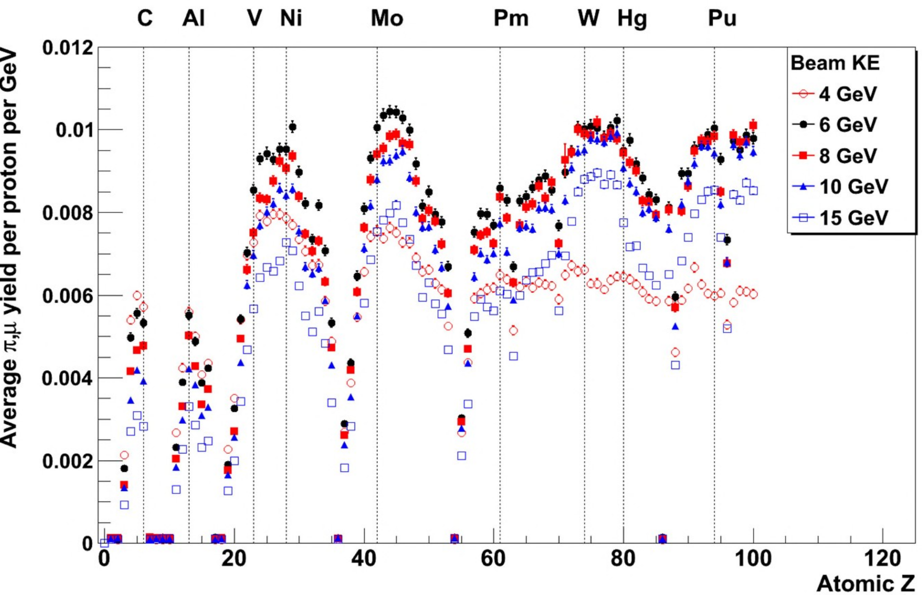
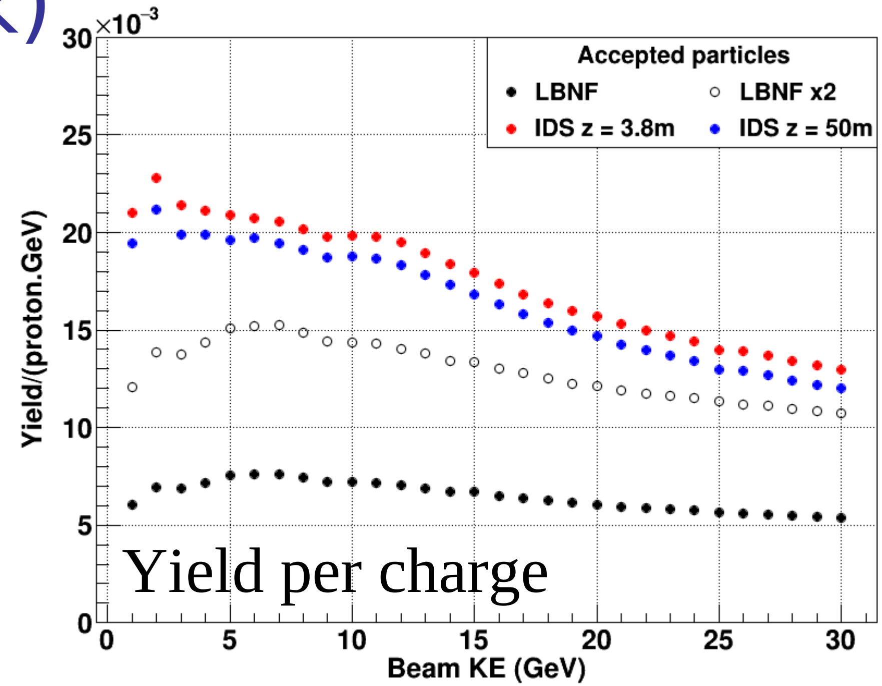
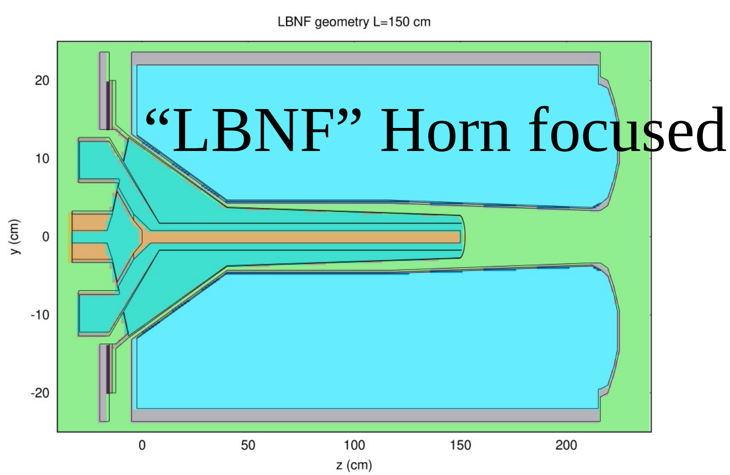
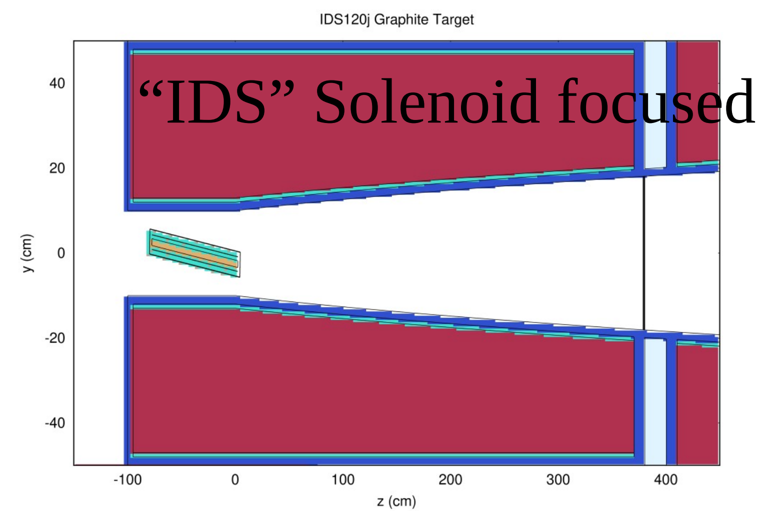
Pion yield (J. Back)









Factor ~ 6 improvement using solenoid focus target over LBNF horn

Rectlinear Cooling (Rogers)

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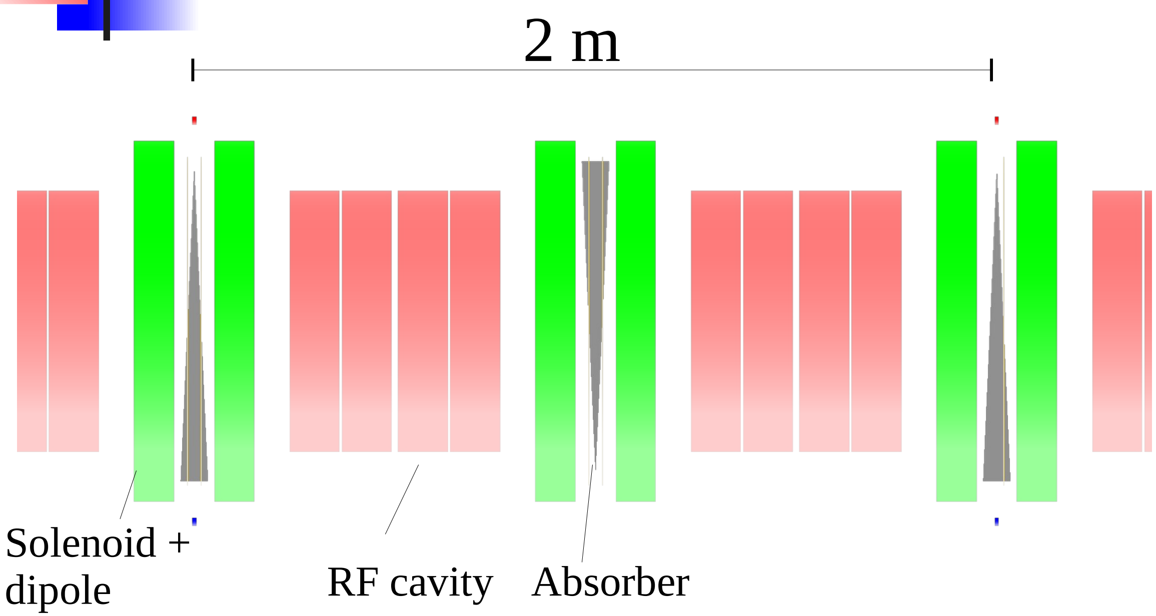
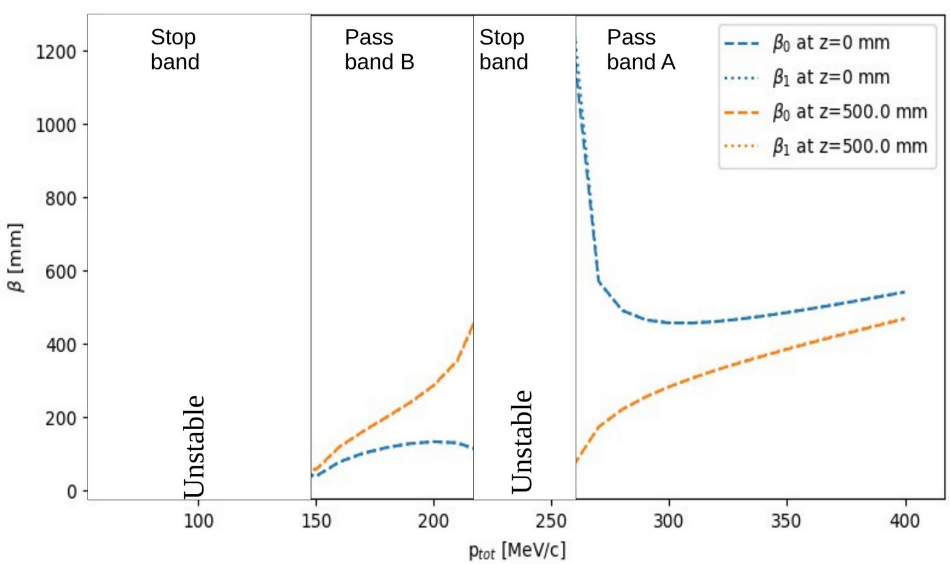
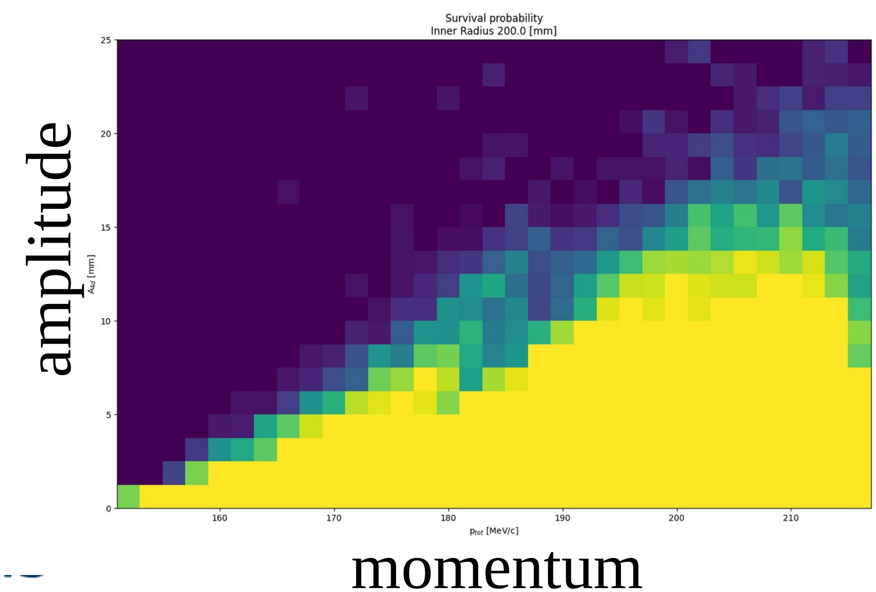


Cooling System	
Cell length	2 m
Peak solenoid field on-axis	7.2 T
Dipole field	0.2 T
Dipole length	0.1 m
RF real estate gradient	22 MV/m
RF nominal phase	20°
RF frequency	704 MHz
Wedge thickness on-axis	0.0342 m
Wedge apex angle	5°
Wedge material	LiH





Final Cooling (B. Stechauner)

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PRELIMINARY

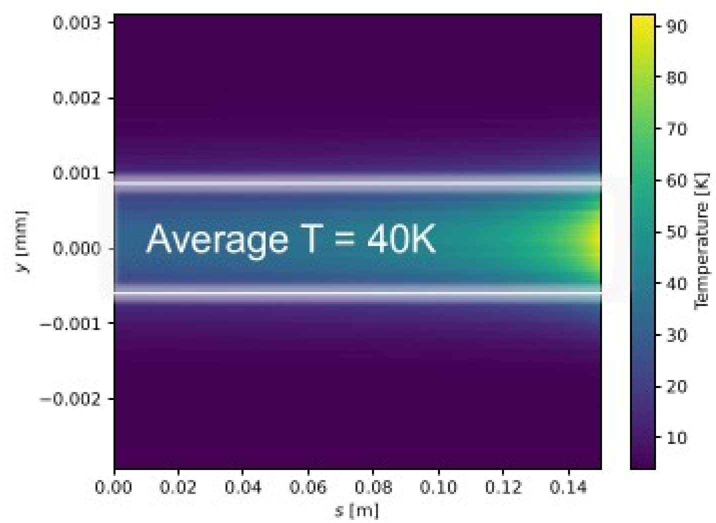
	Cell configuration						Beam parameters (end of the cell)				
	Length [m]	LH thickness [m]	Drift [m]	1. Freq [MHz]	1. Vmax [MV]	2. Phase	Emittance Tr. [mm mrad]	Emittance Long. [mm]	Bunch length [mm]	Pz [MeV/c]	Pz spread
							300,0	1,56	49,9	135	3,5
1	7,4	0,21	0,9	321	17,9	57	278	2,18	73,5	121,3	3,85
2	5,56	0,17	0,56	266	10,4	46,1	256	2,27	69,3	105,78	3,5
3	5,45	0,11	0,7	249	10,8	81,3	243	3,7	134,5	102,2	5,4
4	4,6	0,11	0,85	201	10,48	76,3	**229**	**6,4**	**400**	**95,6**	**6,7**

Concern about liquid hydrogen "blow out"

Final cooling stages:- hydrogen vapour & limited energy loss to maintain a feasible magnet length

Exotic alternative absorbers may be considered

20MeV to 5Mev



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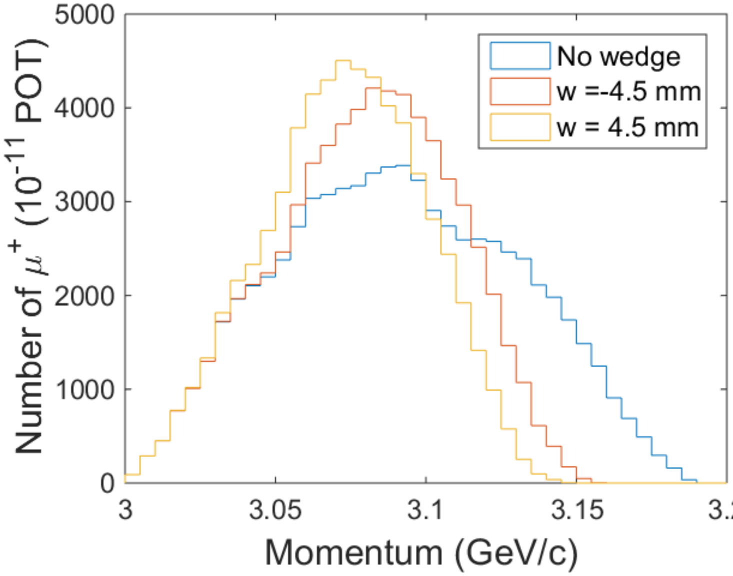
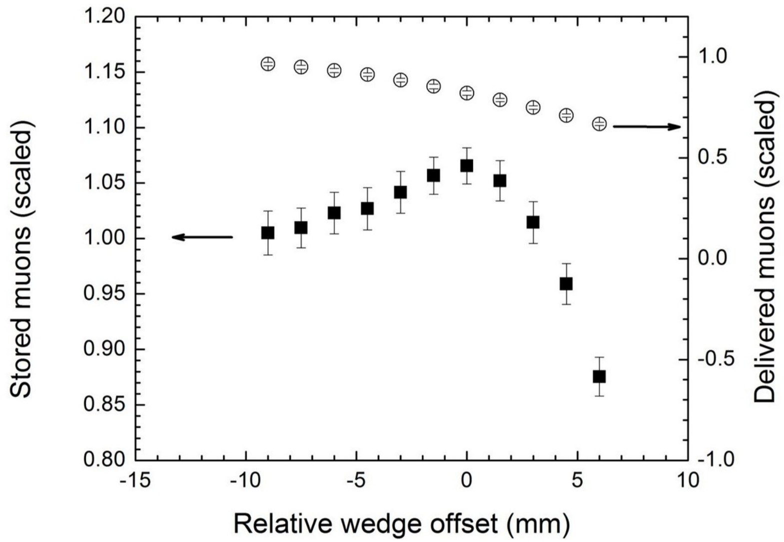
US Studies (D. Stratakis)

Use of wedge absorber to reduce momentum spread in g-2 beamline

Example of emittance exchange?

Successfully enhanced the muon rate in g-2





Further Thoughts

- Low energy complex requires tricky, multi-parameter optimisation
  - Need to ensure that we are careful to work to a common baseline
  - Suitably updated; releases and versioning of geometries/etc
- Develop a list of technical issues
  - Capture all the problems, make sure nothing gets forgotten
  - Reduce bus factor
- Develop a job list
  - "WBS"
  - Make sure it's clear who is doing what
  - Capture any gaps (there are many)
  - Ensure clear understanding of what we can/cannot do with current resource levels

Conclusions

- **Great** start to the design process
  - Concepts and progress in every area
  - Mode is establishing a baseline
  - Uncovered some technical issues
  - Nothing yet that can prevent a facility being constructed
- **Looking forwards to the year ahead**
- **Many thanks to all those who contributed**