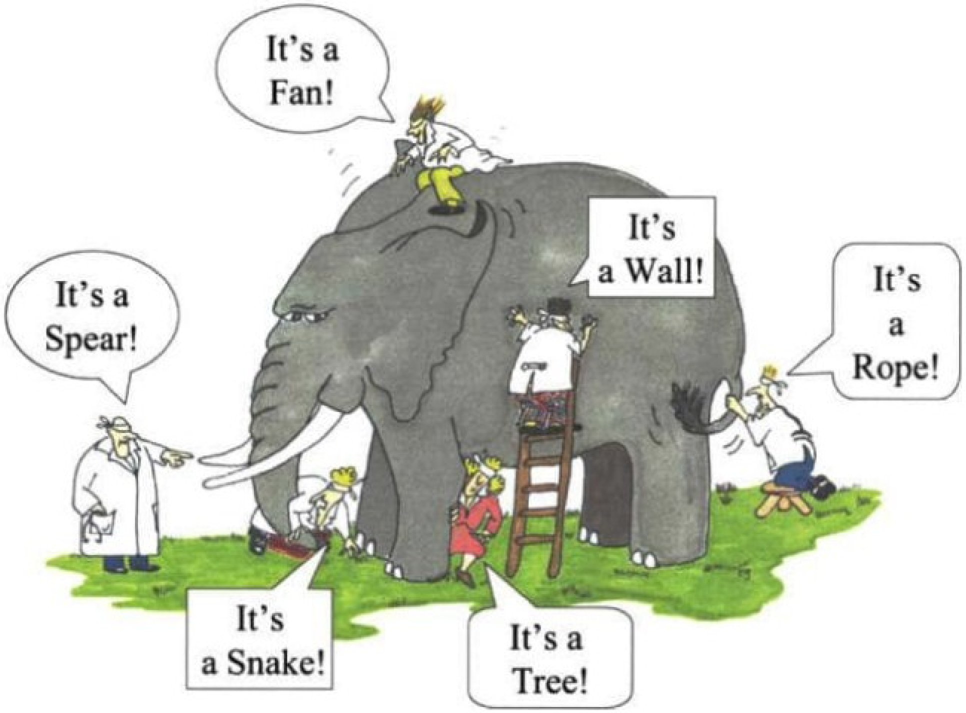
Discussion: Programme & Siting

International MUON Collider Collaboration

Chris Rogers

Science & Technology Facilities Council ISIS

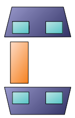
Discussion



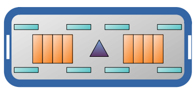
Picture from this source

- General discussion of Demonstrator "programme"
- Specificities on 6D Cooling Demonstrator
- A little on siting
- Closeout

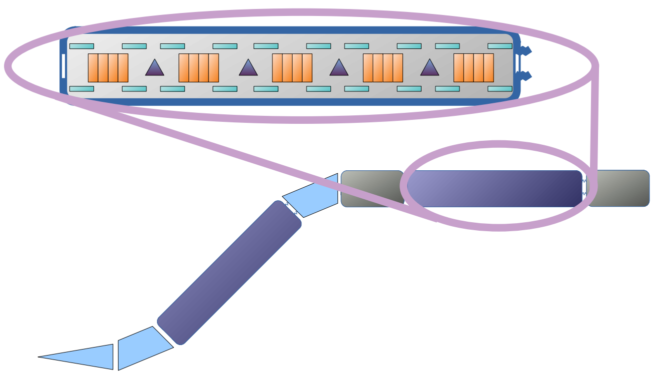
Scope – rectilinear cooling



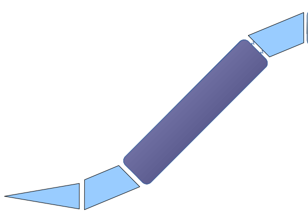
RF Test programme, with upgradeable magnet configuration, to develop novel RF



Prototype cooling vacuum vessel to explore magnet, absorber and RF system integration



Rectilinear cooling vacuum vessel with beam

Rectilinear cooling lattice with beam

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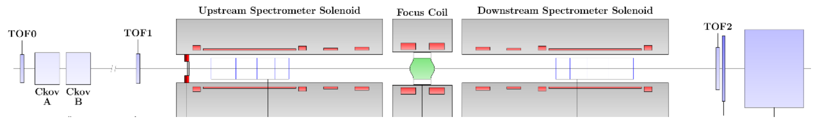
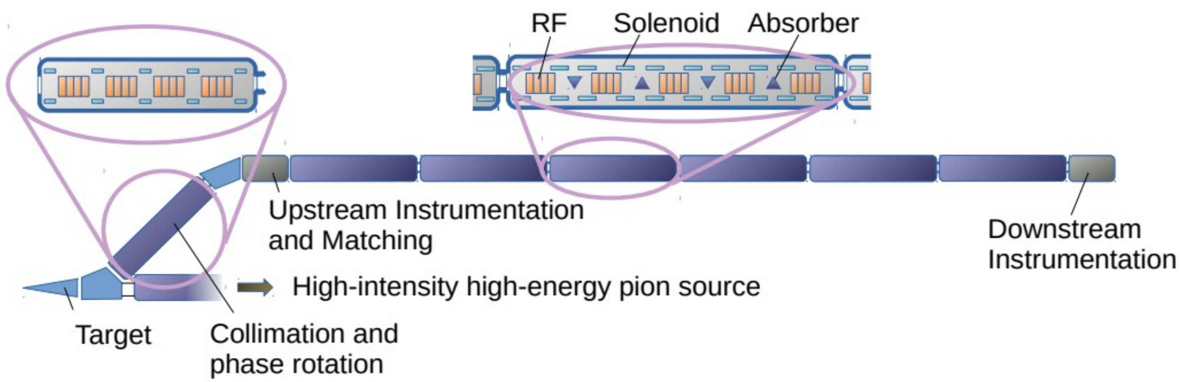
Aims





	MICE	Demonstrator
Cooling type	4D cooling	6D cooling
Absorber #	Single absorber	Many absorbers
Cooling cell	Cooling cell section	Many cooling cells
Acceleration	No reacceleration	Reacceleration
Beam	Single particle	Bunched beam
Instrumentation	HEP-style	Multiparticle-style

- Has anything been forgotten?

Scope – engineering demonstrators

	Cell Length m	Stage Length m	Pipe Radius cm	Max. B_z On-Axis T	Int. B_y Tm	$\beta_\perp$ cm	D_x mm	On-Axis Wedge Len. cm	Wedge Angle deg
A-Stage 1	1.8	104.4	28	2.5	0.102	70	-60	14.5	45
A-Stage 2	1.2	106.8	16	3.7	0.147	45	-57	10.5	60
A-Stage 3	0.8	64.8	10	5.7	0.154	30	-40	15	100
A-Stage 4	0.7	86.8	8	7.2	0.186	23	-30	6.5	70
B-Stage 1	2.3	50.6	23	3.1	0.106	35	-51.8	37	110
B-Stage 2	1.8	66.6	19	3.9	0.138	30	-52.4	28	120
B-Stage 3	1.4	84.0	12.5	5.1	0.144	20	-40.6	24	115
B-Stage 4	1.2	66.0	9.5	6.6	0.163	15	-35.1	20	110
? → B-Stage 5	0.8	44.0	6	9.1	0.116	10	-17.7	12.5	120
B-Stage 6	0.7	38.5	4.5	11.5	0.087	6	-10.6	11	130
B-Stage 7	0.7	28.0	3.75	13	0.088	5	-9.8	10	130
B-Stage 8	0.65	46.15	2.85	15.8	0.073	3.8	-7	7	140
B-Stage 9	0.65	33.8	2.3	16.6	0.069	3	-6.1	7.5	140
? → B-Stage 10	0.63	29.61	2.0	17.2	0.069	2.7	-5.7	6.8	140

Scope – final cooling

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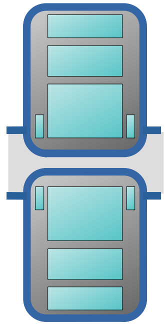
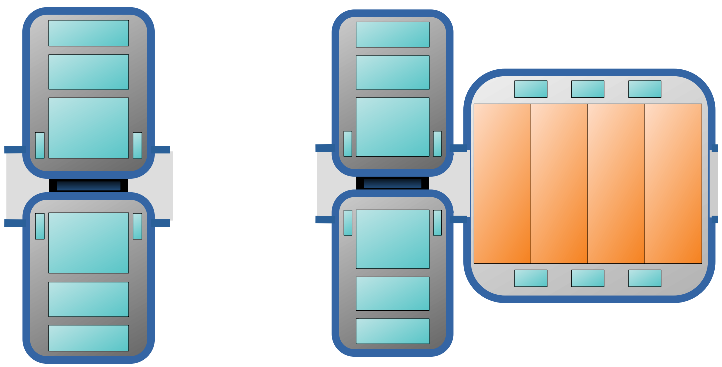
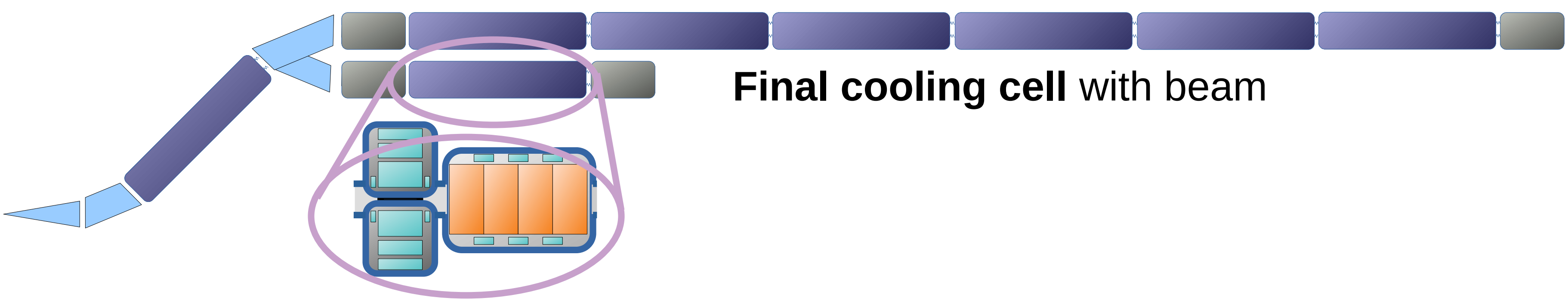


Prototype final cooling magnet



Final cooling test including integration of cooling equipment

Rectilinear cooling lattice with beam



Final cooling cell with beam

- What does it bring?
-

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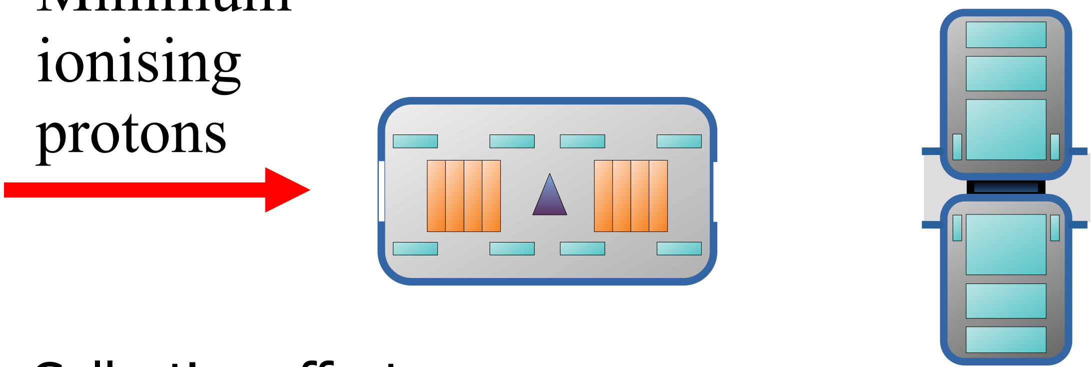
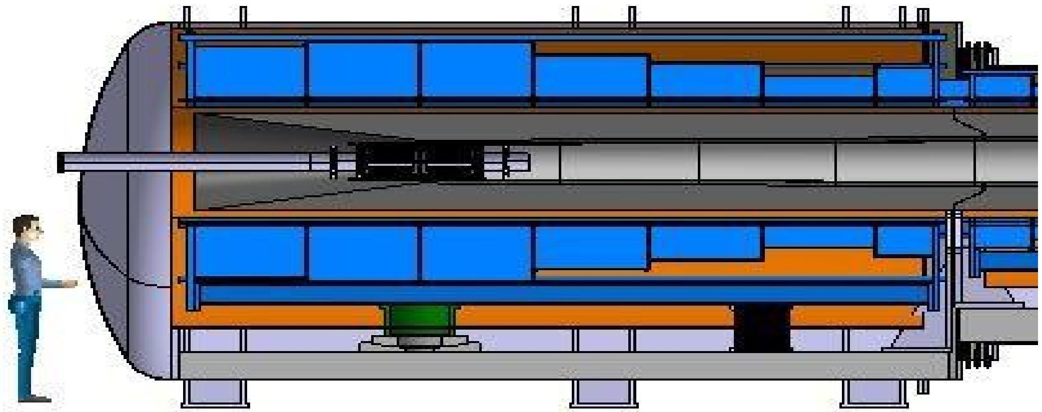
Scope – intensity

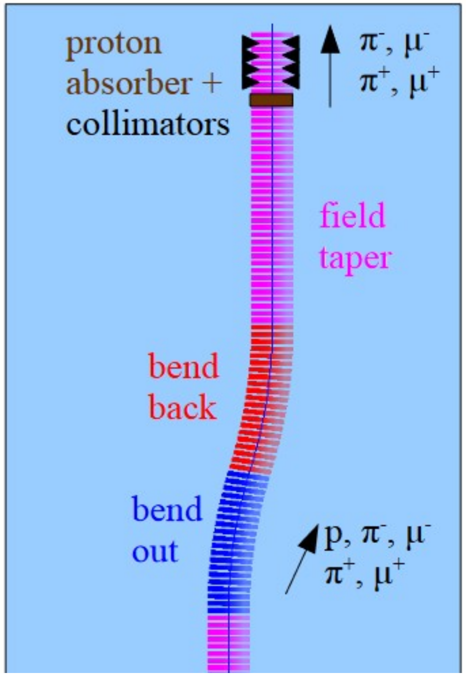
Minimum ionising protons



- Collective effects
  - Space charge and beam loading/wakefield are well-known
  - What about wakefield in presence of absorber?
  - What about surprises?
- Absorber & heat load
  - Easy to calculate
  - Effect unknown (boiling, cavitation, …)
  - Does it need a magnet for checks?

Scope – production efficiency





- Do we need to demonstrate targetry/production efficiency?

6D Cooling Demonstrator

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Rectilinear lattice

Configuration	B2/B1 (%)	Focusing Strength per cell length (T^2 m)	Max Hoop Stress (MPa)	Max Tensile Radial Stress (MPa)	Axial Force on Coil#1/Coil#2 (MN)	Net Axial Force (MN)	Total Torque (MN m)	Total Magnetic Energy Density in cell (MJ m^3)	Coil Volume (half cell) (dm^3)	Conductor length (half cell) (km)	Coil Current Coil#1/Coil#2
Op 1- Min Net Axial Force	14.4	24.42	387	15.3	+7 +10	+17	0.14	152.4	39.7	11.9	1035 575
Op 2- Minimum Axial Force on Coil#2	14.2	24.39	288	11.9	+20.5 +6.5	+27	0.51	135.6	63.8	19.1	768 334
Op 3- Min hoop stress on Coil#2	13.6	26.39	342	7.65	-12.3 +33.1	+20.8	1.25	138.0	63.4	19.0	686 720
Op 4- Min Coil Volume	13.5	26.37	417	6.08	-10.6 +25.1	14.5	1.29	125.0	58	17.4	674 847
WP8 - 2-coil 25% current reduction configuration	5.03	38.88	672 (422 with prestress)	0.14	-27 +67	50	--	292.1	43.31	12.2	1253

- What aspects of the lattice force HTS?
- Should we back off to a lattice that can be LTS?
- **Cooling performance much less important than timely implementation**

Rectilinear lattice

	Cell Length m	Stage Length m	Pipe Radius cm	Max. B_z On-Axis T	Int. B_y Tm	$\beta_\perp$ cm	D_x mm	On-Axis Wedge Len. cm	Wedge Angle deg
A-Stage 1	1.8	104.4	28	2.5	0.102	70	-60	14.5	45
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A-Stage 4	0.7	86.8	8	7.2	0.186	23	-30	6.5	70
B-Stage 1	2.3	50.6	23	3.1	0.106	35	-51.8	37	110
B-Stage 2	1.8	66.6	19	3.9	0.138	30	-52.4	28	120
B-Stage 3	1.4	84.0	12.5	5.1	0.144	20	-40.6	24	115
B-Stage 4	1.2	66.0	9.5	6.6	0.163	15	-35.1	20	110
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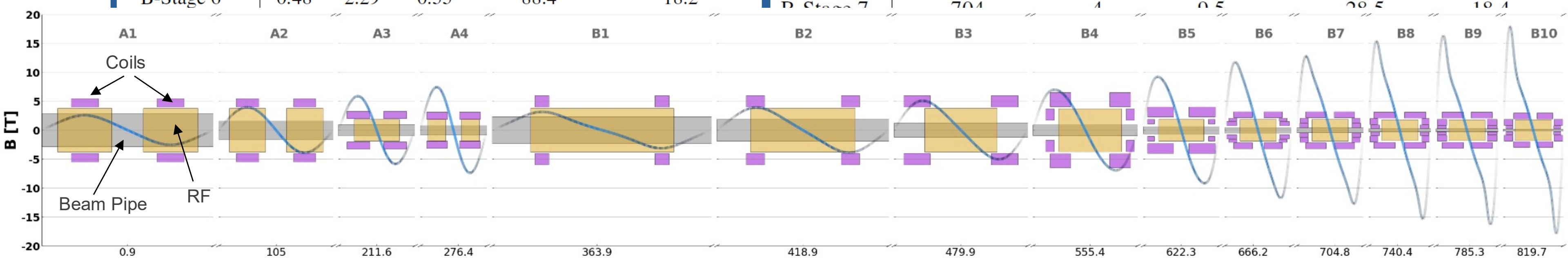
B-Stage 6	0.7	38.5	4.5	11.5	0.087	6	-10.6	11	130

	ε_T mm	ε_L mm	ε_{6D} mm^3	Stage Transmission	Cumulative Transmission %
Start	16.96	45.53	13500		100
A-Stage 1	5.17	18.31	492.60	75.2	75.2
A-Stage 2	2.47	7.11	44.03	84.4	63.5
A-Stage 3	1.56	3.88	9.59	85.6	54.3
A-Stage 4	1.24	1.74	2.86	91.3	49.6
Bunch merge	5.13	9.99	262.5	78.0	38.7
B-Stage 1	2.89	9.09	76.07	85.2	33.0
B-Stage 2	1.99	6.58	26.68	89.4	29.4
B-Stage 3	1.27	4.05	6.73	87.5	25.8
B-Stage 4	0.93	3.16	2.83	89.8	23.2
B-Stage 5	0.70	2.51	1.32	89.4	20.7
B-Stage 6	0.48	2.29	0.55	88.4	18.2

	RF Frequency MHz	Num. RF	RF Length cm	Max. RF Gradient MV/m	RF phase deg
A-Stage 1	352	6	19	27.4	18.5
A-Stage 2	352	4	19	26.4	23.2
A-Stage 3	704	5	9.5	31.5	23.7
A-Stage 4	704	4	9.5	31.7	25.7
B-Stage 1	352	6	25	21.2	29.9
B-Stage 2	352	5	22	21.7	27.2
B-Stage 3	352	4	19	24.9	29.8
B-Stage 4	352	3	22	24.3	31.3
B-Stage 5	704	5	9.5	22.5	24.3
B-Stage 6	704	4	9.5	28.2	22.1
B-Stage 7	704	4	9.5	28.5	18.4

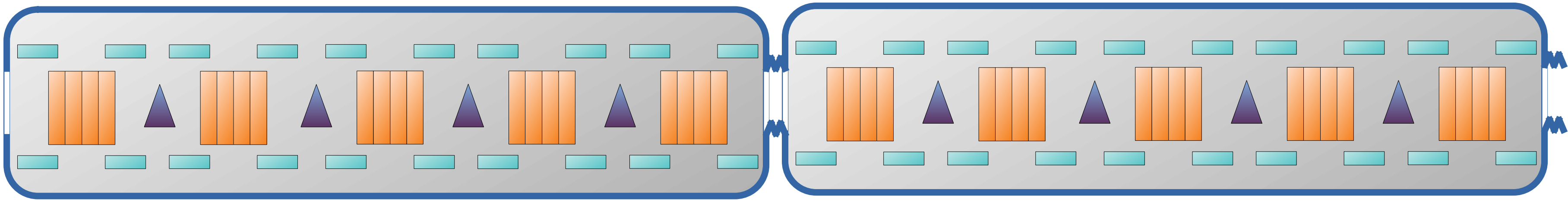


RF - windows

- Pros:
  - More voltage on beam (factor 2?)
- Cons:
  - More prone to wakefields
  - Limits aperture → transmission issues
  - Introduces scattering
  - Demands more RF power (?)

Integration

- Cell macro structure
  - Sharing cryomodule between cells beneficial
  - What is the correct number of cells to use?
    - Alignment/tolerances/correction
    - RF average gradient
    - Space for beam instrumentation/feedthroughs
- Missing “RF” space or missing “absorber” space
- Nb: simulation of “empty” cells has not been done
  - What is the impact on e.g. RF bucket



RF Testing Sites

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- RF Test stand (3 GHz)
  - INFN LASA
  - SLAC
  - DL
- RF Test stand (<~ 1 GHz)
  - CERN
  - ESS (needs more RF power)
- More than one site will likely be needed
  - (Think of ILC cavity R&D programme)

Cooling test beams

- CERN – existing capability
- FNAL – existing capability
- ISIS – presently restricted to < 100 MeV/c
- SNS – following upgrade
- ESS – following upgrade
- HIAF – following upgrade
- CiADS – following upgrade
- JPARC/COMET – existing capability ~ 50 MeV

Anything Else?

Cooling test beams

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International Muon Collider Collaboration: Demonstrator Workshop

October 30, 2024 to November 1, 2024
Fermilab - Wilson Hall
US/Central timezone

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Survey

Feedback and Further Thoughts

Please put any feedback or further thoughts here

1. What Demonstrators do we need to convince ourselves that muon collider can be approved?

2. What Demonstrators do we need to convince the community that muon collider can be approved?

3. Of the ideas proposed at the workshop which do you believe are most promising? Are there any further things that should be explored?

Enter

If only I had remembered...

Thanks!

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Thanks!

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Farha Bhimji (A/V Support)

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Thanks!

Speakers

Participants

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And Finally…

- Safe travels!