UK Muon Collider - Status

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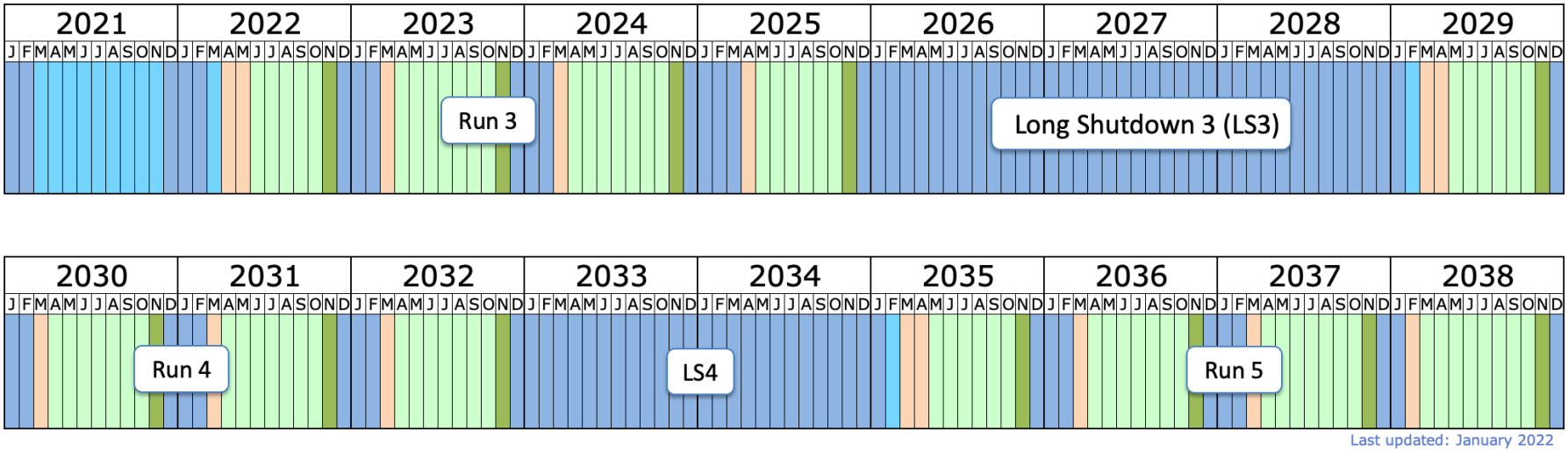
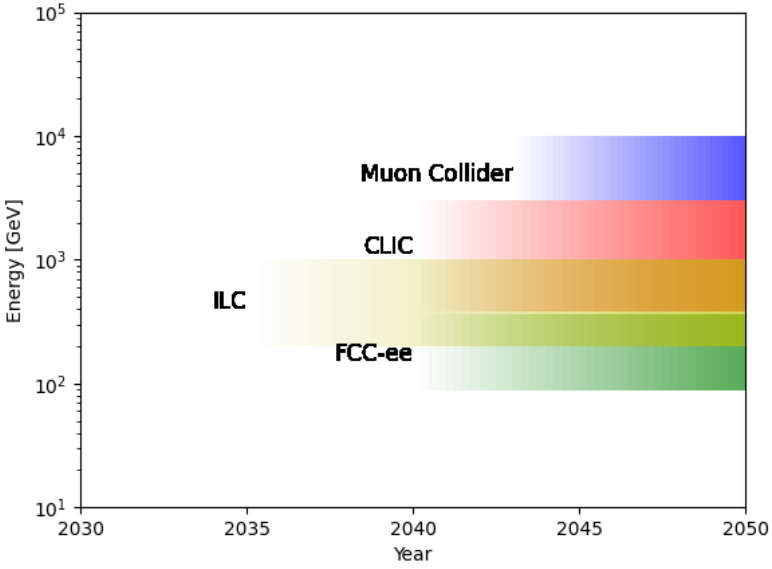
Future Accelerator Facilities



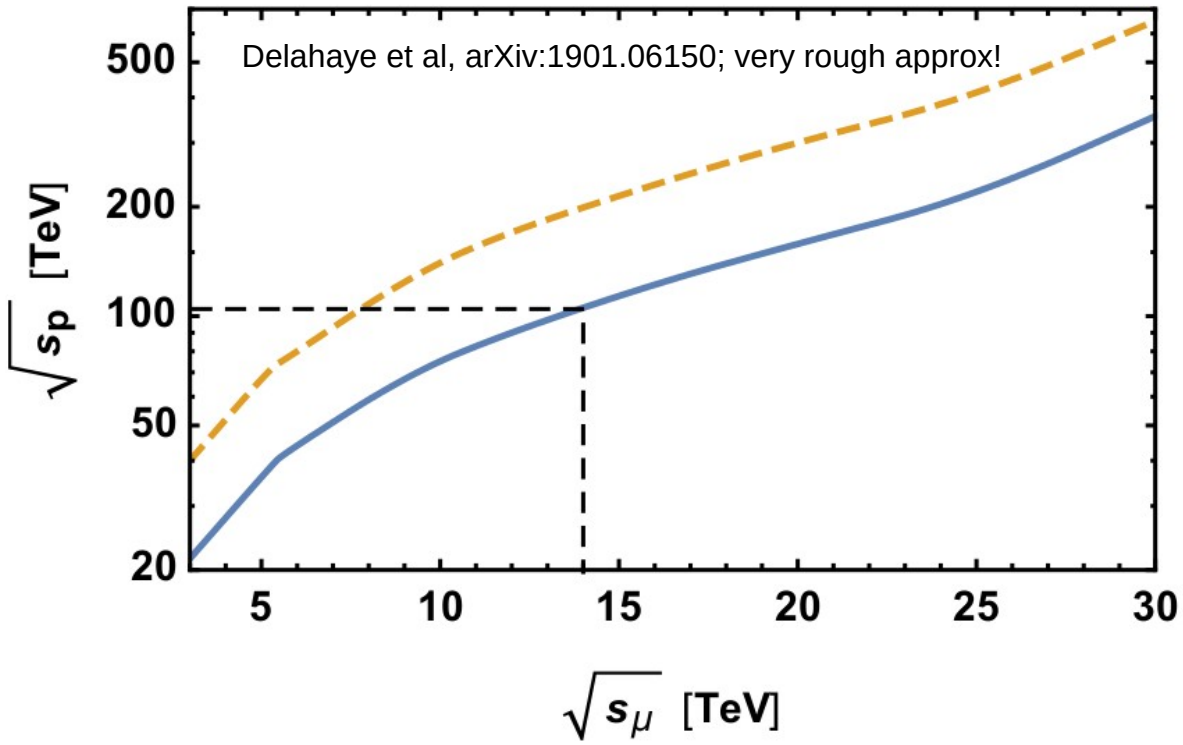
- HL-LHC will become operational ~late 2020s
  - Run for ~10 years
  - No further upgrades possible
- Lead time for a new facility about 25 years
  - Now need to determine the next collider
  - Decisions in next ~ 5-10 years determine future of high energy physics for 50-100 years

Future Collider Options

- No future collider
- CLIC/ILC
  - 200 – 3000 GeV electron-positron linear collider
  - 3 TeV is maximum forseeable energy
    - Limited by RF voltage
    - Limited by luminosity
- FCC-ee/hh
  - Up to 360 GeV electron ring collider
    - Limited by synchrotron radiation
  - 100 TeV proton ring collider
    - Limited by dipole magnets
    - Limited by wall-plug power
- Muon collider
  - 3-14 TeV muon collider
    - Limited by?



Muons Physics Reach



Energy at which cross-section is equal

Assuming equal Feynman amplitude (EW)

Assuming factor 10 enhancement in pp (EW+QCD)

- Seek a particle which
  - Is not so low mass as an electron
  - Is a fundamental particle
- **Muons!**

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European strategy

- UESPP (2020) identified high priority R&D areas
  - Magnets
  - RF
  - LPWFA
  - ERLs
  - **Muon beams**
- CERN charged Lab Director's Group to define roadmap
  - https://arxiv.org/pdf/2201.07895.pdf
  - Identified development of muon collider as a high priority
  - Identified synergy with HEP and non-HEP facility R&D
- Muon beam R&D excellent fit for UK R&D profile
  - History with Neutrino Factory
  - Interest in nuSTORM
  - Synergy with ISIS (upgrades)

International Muon Collider - Goals

- Goals for the next 5 years
  - Define baseline for a muon collider (e.g. at CERN)
  - Identify areas of significant technical risk - “showstoppers”
    - Work through mitigations
  - Develop an R&D plan to deliver muon collider
    - Demonstrator for muon ionisation cooling - “big ticket” R&D item
    - RF test stand(s)
    - Solenoid R&D
    - Targetry
    - etc
- Funding model is CERN + institutes
  - Core team comes from CERN
  - Institutes (labs and universities) contribute extras
  - Room for US, Asia to join
  - EU grant to help institutes to contribute
    - Enables us to ask STFC/etc for matching funds
    - Enables us to support R&D

International Muon Collider - Facility

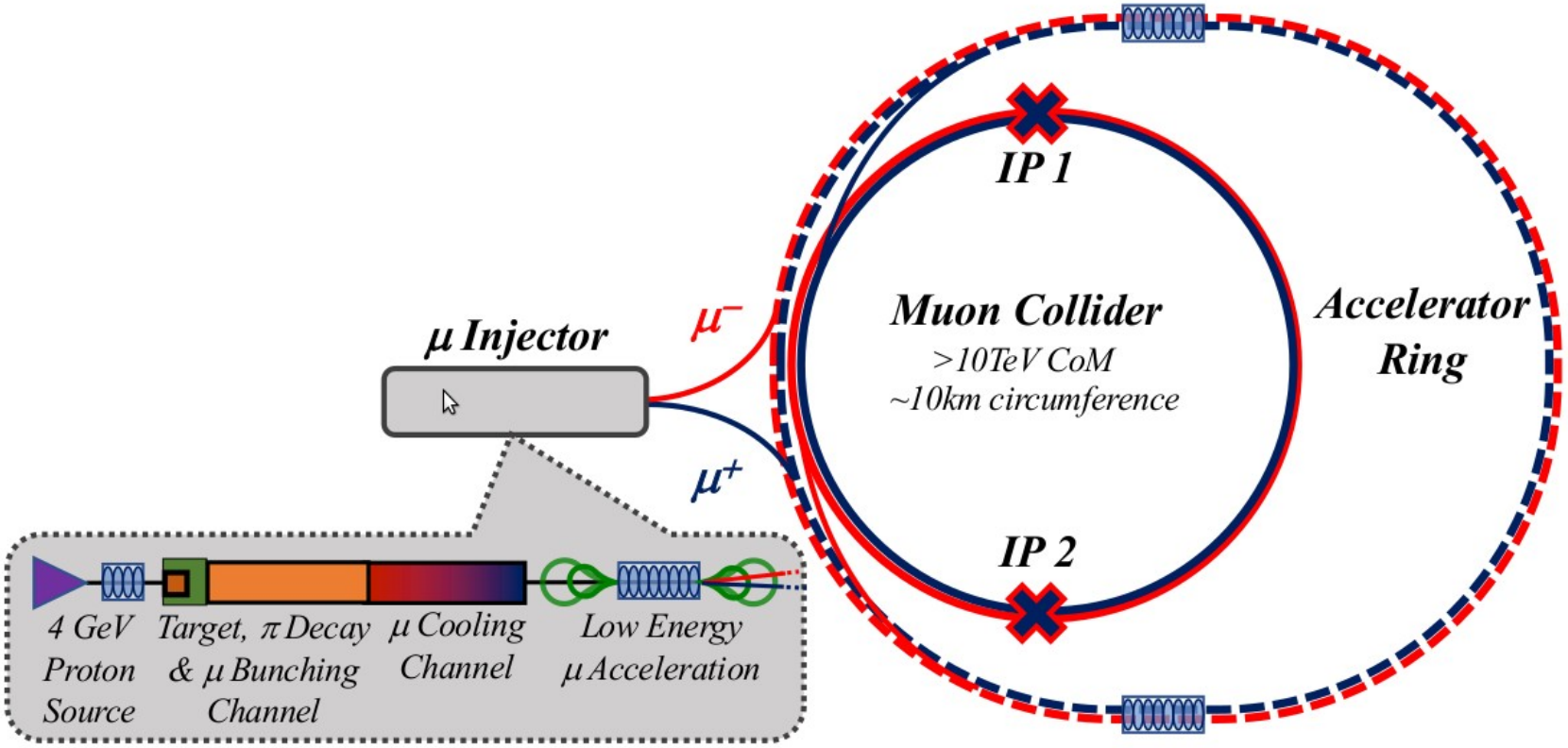


Fig. 5.1: A conceptual scheme for the muon collider.

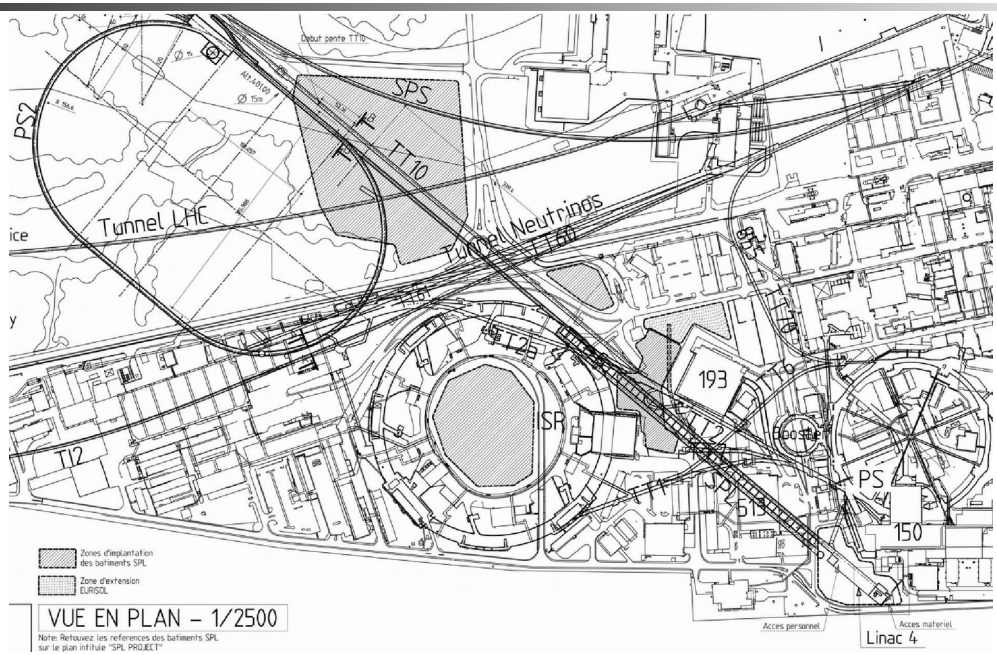
Muon Collider – Muon Source Issues

- Protons
  - “Conventional” issues – ion source, H- stripping
  - Bunch compression
- Target
  - “Fusion” style magnet
  - Beam dump
- Cooling
  - RF cavities in high magnetic field
  - High-field solenoids
  - Absorber heating
  - Lattice integration

Muon Collider – HEC Issues

- Acceleration
  - Very rapid acceleration
  - Neutrinos from decay
- Collider
  - High fields
  - Neutrinos from decay
  - Detector backgrounds
- Detector
  - Shielding from muon decay products
  - Timing/resolution to deal with remaining backgrounds
  - Track/event reconstruction, in the presence of backgrounds

How can UK help MuC - Protons



- Proton source requirements have big overlap with ISIS
- Technical limitations/challenges are well understood
  - Except bunch compression
- Will become an R&D item later in MuC project life cycle
- Possible opportunity with EU INFRA-TECH grant in 2024
  - (subject to UK vs Horizon Europe)
- Watching brief

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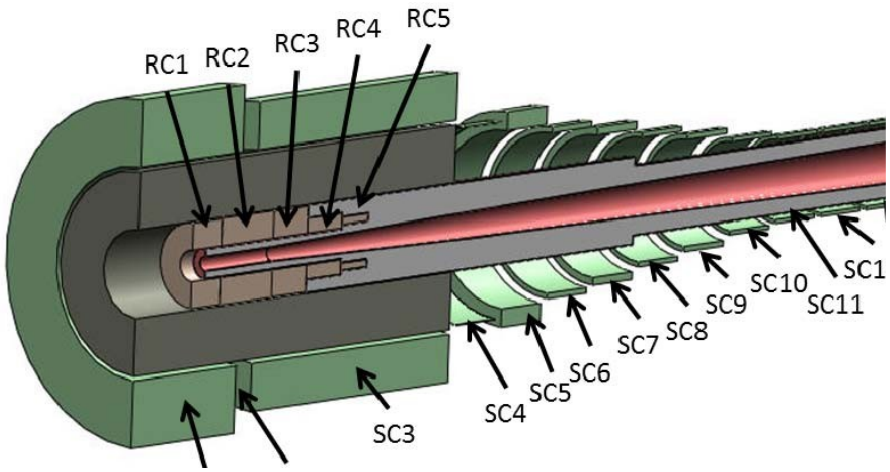
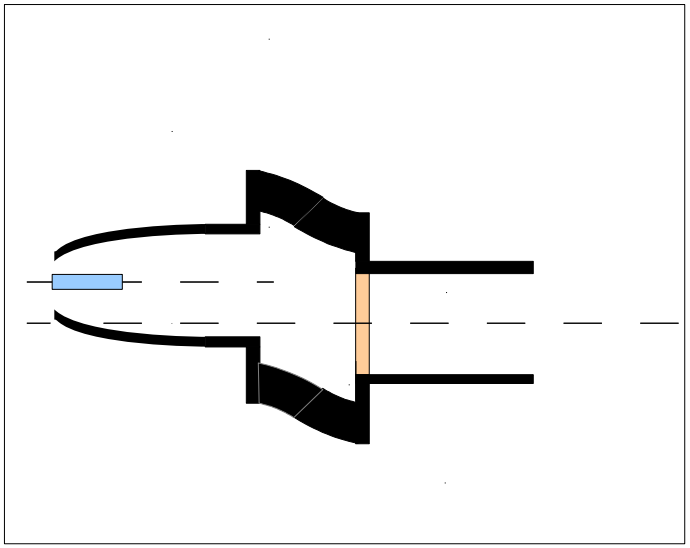
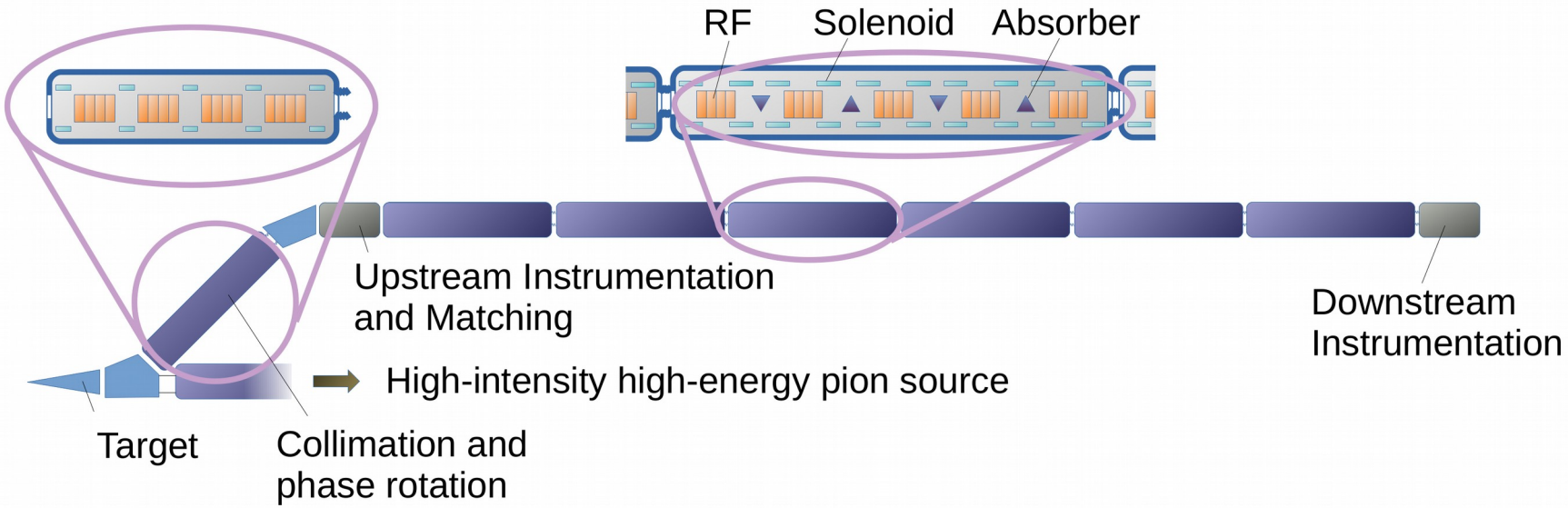
How can UK help MuC - Target





- UK has world expertise in pion production targets
- Typically low-Z targets with horn focusing
- MuC target plans to use solenoid focusing
  - Fusion-type solenoid
- Beam dump/chicane
  - Need some sort of septum for proton extraction

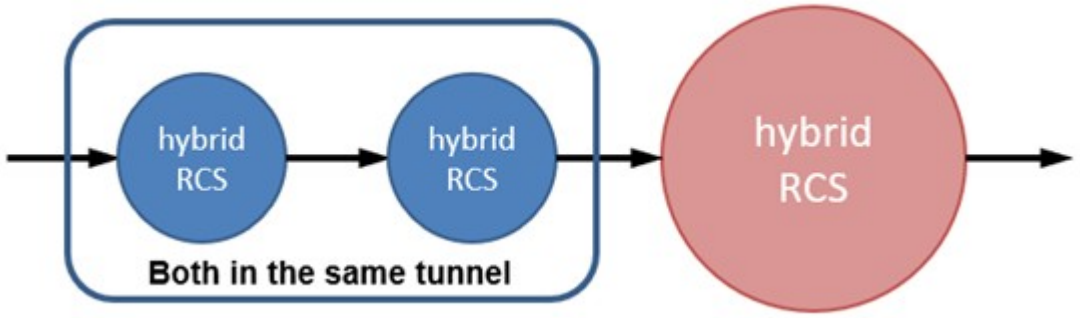
How can UK help MuC - Cooling



- UK holds European/world expertise on muon cooling
- Medium-scale facility ~ 2030s “Cooling Demonstrator”
- UK has leadership role esp in physics
- Opportunity - Needs target (horn type?)
- Opportunity - Needs RF
- Can be compatible with high-intensity high-energy pion source e.g. nuSTORM

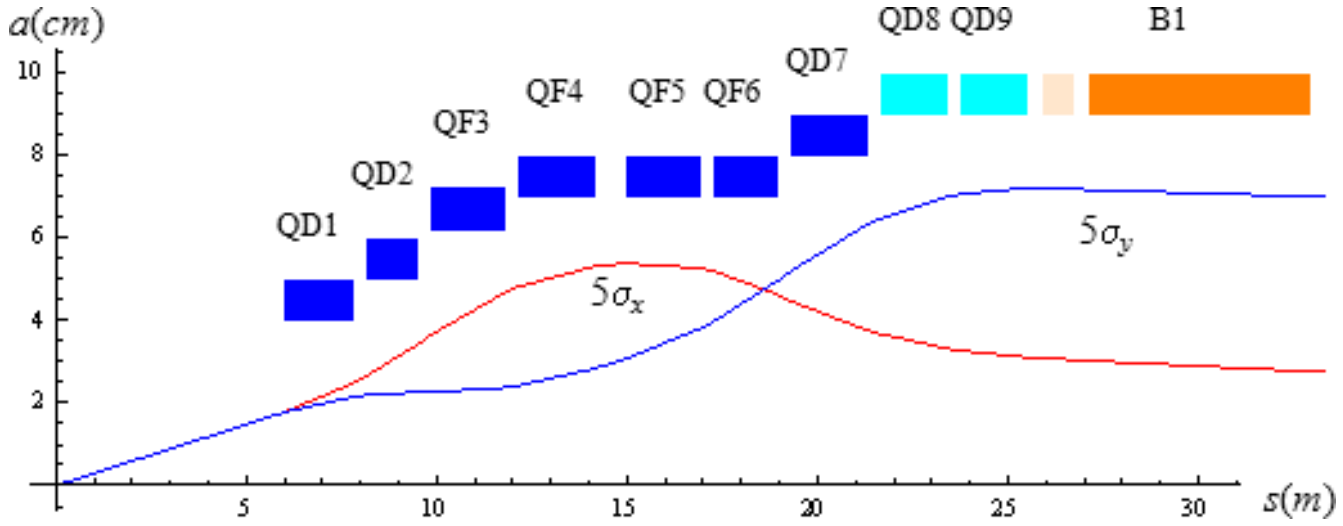
How can UK help MuC - Acceleration

Max. instantaneous power (linear ramping)
RCS1 → 89.3 GW
RCS2 → 89.1 GW
RCS3 → 44.4 GW



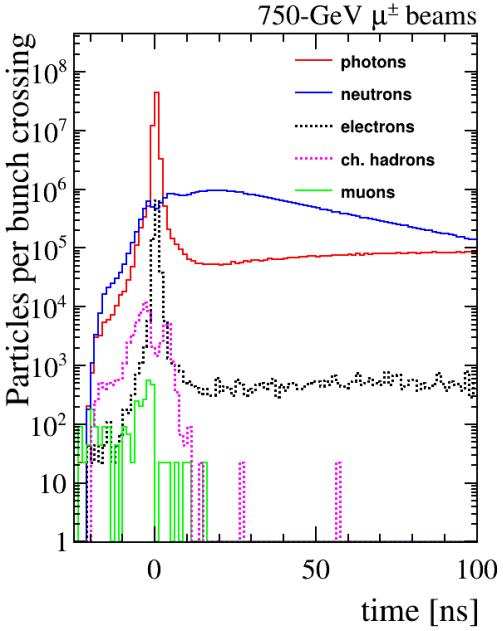
- MuC requires rapid acceleration to fight muon decay
- Baseline is a Very Rapid Cycling Synchrotron
  - Magnet and power supplies technologically limit performance
- Opportunity – UK has the fastest RCS in Europe (ISIS)
- Opportunity – UK leads Europe in Fixed (magnetic) Field Accelerators (FFA)

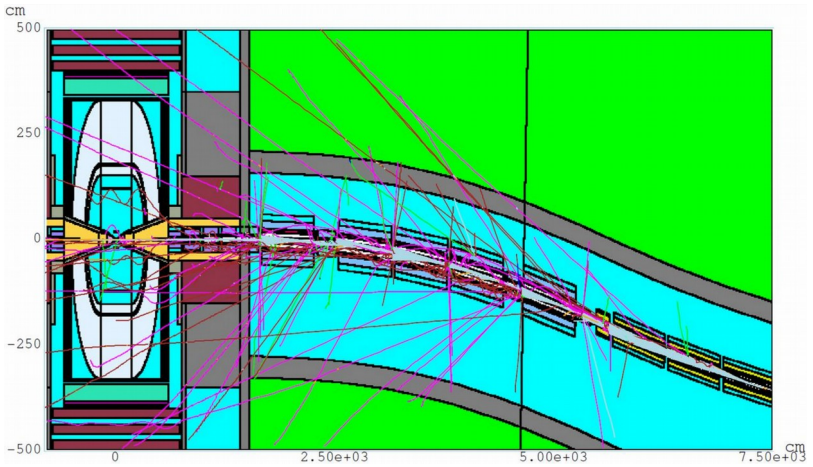
How can UK help MuC - Collider



- Collider should be as compact as possible
  - Maximise the number of muon circulations i.e. collisions before decay
  - → High field dipoles
- Machine-Detector Interface polluted by muon decay products (electrons and positrons)
  - Luminosity dependent on final focus quadrupoles/etc
  - Opportunity – UK has expertise in linear collider beam delivery

How can UK help MuC - Detector





- Detector must reject backgrounds arising from muon decay products
  - Shielding of detectors using high-Z nose cones
  - Timing cut to remove backgrounds
  - Detector reconstruction/track finding to reject further backgrounds

How can MuC help UK

- Support ongoing R&D that is in synergy with Muon Collider
  - nuSTORM
  - ISIS upgrades
  - High power RF source
- Position UK to deliver crucial components for Muon Beams
  - Leverage UK investment back from CERN
  - “Return on Investment”
    - RF test stand (~early 2020s)
    - RF for Muon cooling demonstrator (~late 2020s)
    - NuSTORM (~late 2020s)

UK – Muon Collider Funding Outlook

	Task	Deliverable	UK Staff FTEy	Name	Postdoc FTEy	Name	Student FTEy	Institute/Name	EU DEV Staff FTEy	Postdoc FTEy	Name	Student FTEy
WP1 – Management												
	?	?	0.6	Cerri								
	?	?					1	Buriyokov				
WP2 – Physics and Detector	**?**	?										2.25
WP3 – Proton Driver												
	Coordination	Coordination and Communication	0.4	Rogers								
	Ionisation Cooling	6D cooling + demo layout	1.6	Rogers							STFC/ISIS	
		6D cooling + demo layout	0.4	Pasternak								
		6D cooling + demo layout					3.5	RAL PPD/JAI ICL				
											2	STFC/ICL PD 1
		Maintenance of codes	0.4	Boogert								
		Maintenance of codes									1	STFC/ICL PD 1
	Target	Heat load on target and magnet										
		Preliminary target complex design									1.2	STFC/TD PD 2
		Target shock load and pion yield	0.4	Back								
			0.4	Boyd								
							1.75	RAL PPD				1.75
WP4 – Cooling		Tungsten Powder Jet									1.2	STFC/TD PD 2
	FFA Acceleration											
WP5 – High Energy Complex	**MDI studies**		0.4	Burrows			3.5	RAL PPD/JAI Oxf				
	0.704 GHz RF Power Systems		0.4	Burt								3.5
	3 GHz RF Breakdown Studies		0.4	Cross								
WP6 – RF							3.5	RAL PPD/Strathclyde				
WP7 – Magnets	?	?	0.4	Yang								3.5
WP8 – Cooling Complex												
Sum			**5.8**				**13.25**			**5.4**		**11**

Aims of the Meeting

- In the light of existing and proposed funding
  - How does UK support the muon collider?
  - How does UK leverage muon collider to support other UK projects?
  - How does UK leverage other UK projects to support muon collider?
  - Where do we have gaps? What is not covered but should be?

UK muon beams - update

UK Muon Beams - Update

Friday 27 May 2022, 10:00 → 13:00 Europe/London

Description We will be in Conference Room 16 - this is in the Target Station 2 building. Would be great if folks could make it to RAL, in which case please do let Chris Rogers know so he can inform the front gate.

For those unable to travel, we can use the following zoom setting:

Direct link:
https://ukri.zoom.us/j/94165841196?pwd=TG9DblFDL1FLVTVULzhlYXdhaFhlZz09

Meeting ID: 941 6584 1196
Pass code: 105658

There is a map of the RAL site here. CR16 is in R80 towards the South West corner of the site. If you need advice, reception will be happy to help.

RALCampusA3.pdf

10:00 → 10:30	**UK Muon Collider - Status** Speaker: Chris Rogers (STFC)	30m
10:30 → 10:45	**Proton source and FFAs** Speaker: Jean-Baptiste Lagrange (STFC)	15m
10:45 → 11:00	**Target conceptual design** Speaker: Chris Densham (STFC)	15m
11:00 → 11:15	**Target yield calculations** Speaker: Dr John Back (Warwick) jbackMuCTgt_27Ma...	15m
11:15 → 11:30	**Cooling** Speaker: Ken Long (Imperial Coll.)	15m
11:30 → 11:45	**MDI** Speaker: Philip Burrows (Oxford University)	15m
11:45 → 12:00	**Magnets** Speaker: Dr Yifeng Yang (Southampton University)	15m
12:00 → 12:15	**RF** Speaker: Graeme Burt (Cockcroft Inst)	15m
12:15 → 12:30	**Muons at ISIS** Speakers: Adrian Hillier (STFC), Koji Yokoyama (Science and Technology Facilities Council) ISIS Update muon-a...	15m
12:30 → 12:50	**NuStorm** Speaker: Paul Kyberd (Brunel University)	20m
12:50 → 13:00	**Discussion**	10m

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