International
MUON Collider
Collaboration

MuCol

Muon Collider Collaboration

D. Schulte
On behalf of the International Muon Collider Collaboration

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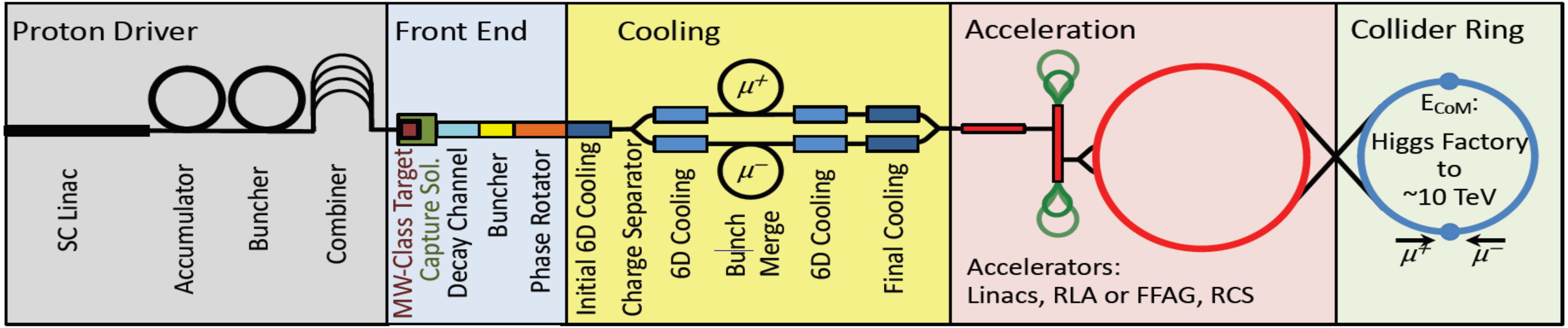
Birmingham, July, 2024

Muon Collider Overview

Would be easy if the muons did not decay
Lifetime is $\tau = \gamma \times 2.2\ \mu s$



Short, intense proton bunch

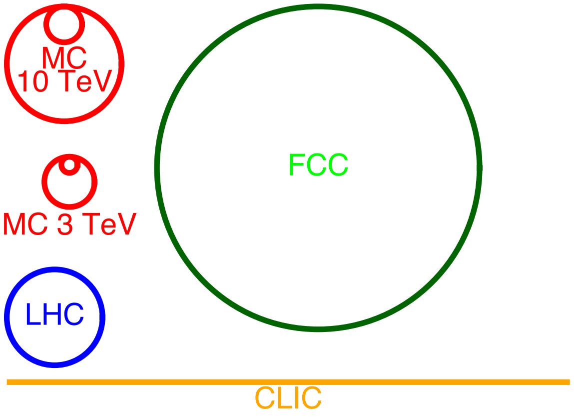
Ionisation cooling of muon in matter

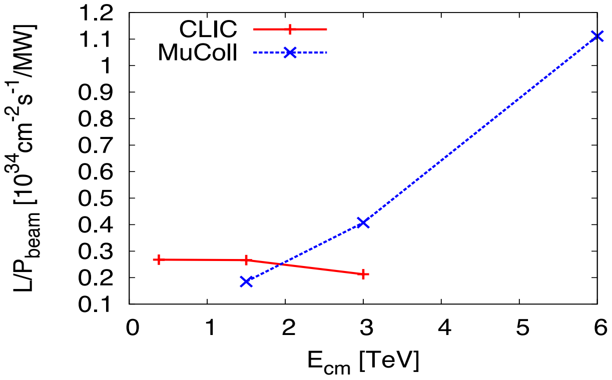
Acceleration to collision energy

Collision

Protons produce pions which decay into muons
muons are captured

Muon Collider Promises





US Snowmass Implementation Task Force: Th. Roser, R. Brinkmann, S. Cousineau, D. Denisov, S. Gessner, S. Gourlay, Ph. Lebrun, M. Narain, K. Oide, T. Raubenheimer, J. Seeman, V. Shiltsev, J. Straight, M. Turner, L. Wang et al.

	CME [TeV]	Lumi per IP [$10^{34}cm^{-2}s^{-1}$]	Cost range [B$]	Power [MW]
FCC-ee	0.24	8.5	12-18	290
ILC	0.25	2.7	7-12	140
CLIC	0.38	2.3	7-12	110
CLIC	3	5.9	18-30	550
MC	**3**	**1.8**	**7-12**	**230**
MC	**10**	**20**	**12-18**	**300**
FCC-hh	100	30	30-50	560

Judgement by ITF, take it *cum grano salis*

IMCC Goals

IMCC: International Muon Collider Collaboration

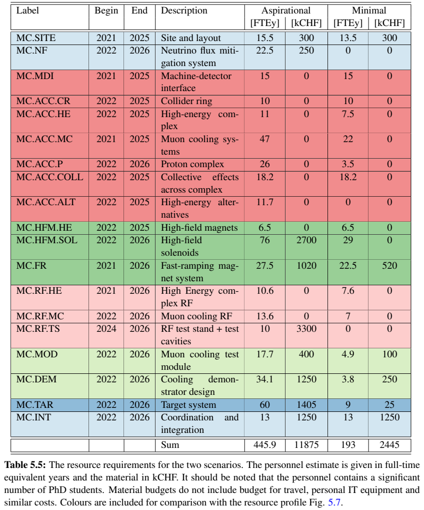
Develop high-energy muon collider as option for particle physics:

- Muon collider promises **sustainable** approach to the **energy frontier**
  - limited power consumption, cost and land use
- **Technology** and **design advances** in past years
- Reviews in Europe and US found **no unsurmountable obstacle**

Accelerator R&D Roadmap identifies the required work

Goals are

- Assess and develop the muon collider concept for a O(10 TeV) facility
- Identify potential sites to implement the collider
- Develop an initial muon collider stage that can start operation around 2050
- Develop an R&D roadmap toward the collider



Label	Begin	End	Description	Aspirational [FTEy]	Aspirational [kCHF]	Minimal [FTEy]	Minimal [kCHF]
MC.SITE	2021	2025	Site and layout	15.5	300	13.5	300
MC.NF	2022	2026	Neutrino flux mitigation system	22.5	250	0	0
MC.MDI	2021	2025	Machine-detector interface	15	0	15	0
MC.ACC.CR	2022	2025	Collider ring	10	0	10	0
MC.ACC.HE	2022	2025	High-energy complex	11	0	7.5	0
MC.ACC.MC	2021	2025	Muon cooling systems	47	0	22	0
MC.ACC.P	2022	2026	Proton complex	26	0	3.5	0
MC.ACC.COLL	2022	2025	Collective effects across complex	18.2	0	18.2	0
MC.ACC.ALT	2022	2025	High-energy alternatives	11.7	0	0	0
MC.HFM.HE	2022	2025	High-field magnets	6.5	0	6.5	0
MC.HFM.SOL	2022	2026	High-field solenoids	76	2700	29	0
MC.FR	2021	2026	Fast-ramping magnet system	27.5	1020	22.5	520
MC.RF.HE	2021	2026	High Energy complex RF	10.6	0	7.6	0
MC.RF.MC	2022	2026	Muon cooling RF	13.6	0	7	0
MC.RF.TS	2024	2026	RF test stand + test cavities	10	3300	0	0
MC.MOD	2022	2026	Muon cooling test module	17.7	400	4.9	100
MC.DEM	2022	2026	Cooling demonstrator design	34.1	1250	3.8	250
MC.TAR	2022	2026	Target system	60	1405	9	25
MC.INT	2022	2026	Coordination and integration	13	1250	13	1250
			Sum	445.9	11875	193	2445

Table 5.5: The resource requirements for the two scenarios. The personnel estimate is given in full-time equivalent years and the material in kCHF. It should be noted that the personnel contains a significant number of PhD students. Material budgets do not include budget for travel, personal IT equipment and similar costs. Colours are included for comparison with the resource profile Fig. 5.7.

http://arxiv.org/abs/2201.07895

IMCC Organisation

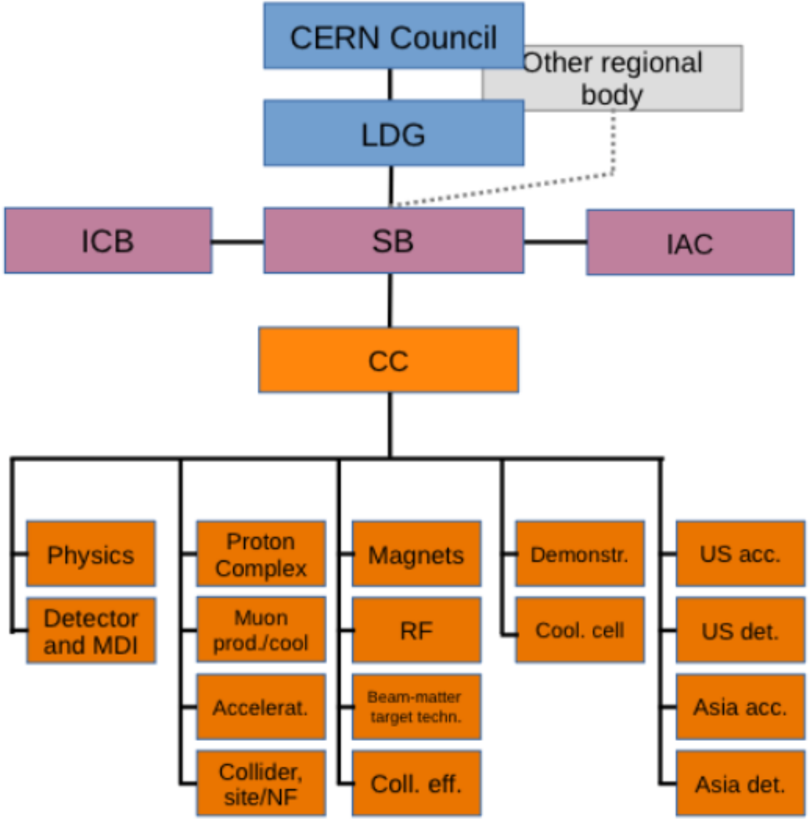
Collaboration Board (ICB)
- Elected chair: **Nadia Pastrone**
- **50 full members, 60+ total**

Steering Board (ISB)
- Chair **Steinar Stapnes**
- CERN members: Mike Lamont, Gianluigi Arduini
- ICB members: **Dave Newbold** (STFC), Mats Lindroos (ESS), Pierre Vedrine (CEA), N. Pastrone (INFN), Beate Heinemann (DESY)
- Study members: SL and deputies

Advisory Committee

Coordination committee (CC)
- Study Leader: Daniel Schulte
- Deputies: Andrea Wulzer, Donatella Lucchesi, **Chris Rogers**

Will integrated the US, also increase in the leadership



CERN Council

Other regional body

LDG

ICB

SB

IAC

CC

Physics

Detector and MDI

Proton Complex

Muon prod./cool

Accelerat.

Collider, site/NF

Magnets

RF

Beam-matter target techn.

Coll. eff.

Demonstr.

Cool. cell

US acc.

US det.

Asia acc.

Asia det.

MuCol

3 MEUR from the EU, the UK and Switzerland, about 4 MEUR from the partners

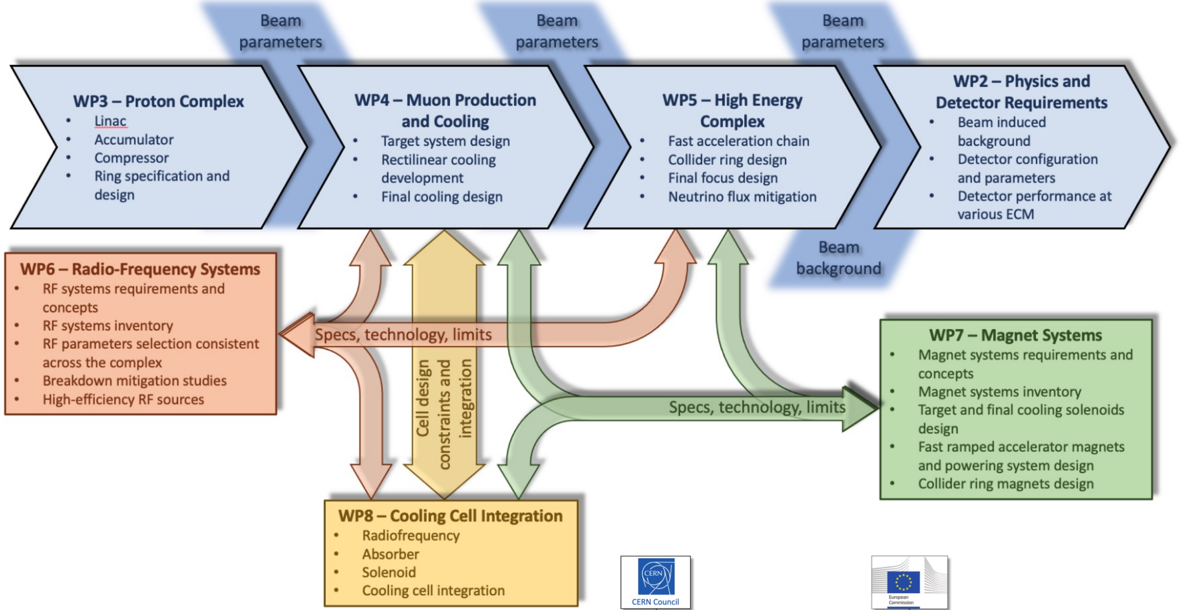
The **backbone** of the study in Europe

- 30 partners
- Strongly interweaved
    - Share most meeting
    - Similar management structure

Instrumental to kick off collaboration

- Motivated partners to commit
- Added resources
- Motivated CERN to commit more

Management similar to IMCC
Deputy: Chris Rogers



Beam parameters

Beam parameters

Beam parameters

WP3 – Proton Complex

- Linac
- Accumulator
- Compressor
- Ring specification and design

WP4 – Muon Production and Cooling

- Target system design
- Rectilinear cooling development
- Final cooling design

WP5 – High Energy Complex

- Fast acceleration chain
- Collider ring design
- Final focus design
- Neutrino flux mitigation

WP2 – Physics and Detector Requirements

- Beam induced background
- Detector configuration and parameters
- Detector performance at various ECM

Beam background

WP6 – Radio-Frequency Systems

- RF systems requirements and concepts
- RF systems inventory
- RF parameters selection consistent across the complex
- Breakdown mitigation studies
- High-efficiency RF sources

Specs, technology, limits

Cell design constraints and integration

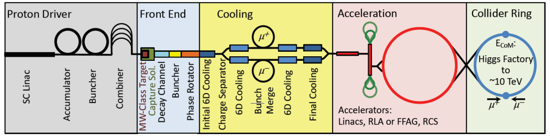
Specs, technology, limits

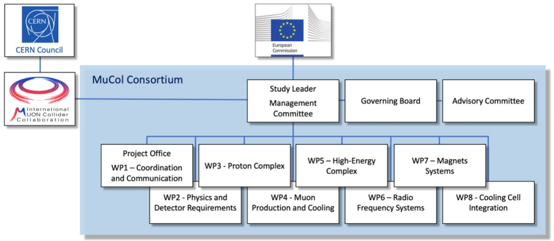
WP7 – Magnet Systems

- Magnet systems requirements and concepts
- Magnet systems inventory
- Target and final cooling solenoids design
- Fast ramped accelerator magnets and powering system design
- Collider ring magnets design

WP8 – Cooling Cell Integration

- Radiofrequency
- Absorber
- Solenoid
- Cooling cell integration





CERN Council

European Commission

MuCol Consortium

Study Leader
Management Committee

Governing Board

Advisory Committee

Project Office
WP1 – Coordination and Communication

WP3 - Proton Complex

WP5 – High-Energy Complex

WP7 – Magnets Systems

WP2 - Physics and Detector Requirements

WP4 - Muon Production and Cooling

WP6 – Radio Frequency Systems

WP8 - Cooling Cell Integration

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MoC and MuCol Partners

International
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IEIO	**CERN**
FR	**CEA-IRFU**
	CNRS-LNCMI
DE	DESY
	Technical University of Darmstadt
	University of Rostock
	KIT
UK	**RAL**
	UK Research and Innovation
	University of Lancaster
	University of Southampton
	University of Strathclyde
	University of Sussex
	Imperial College London
	Royal Holloway
	University of Huddersfield
	University of Oxford
	University of Warwick
	University of Durham

IT	**INFN**
	INFN, Univ., Polit. Torino
	INFN, Univ. Milano
	INFN, Univ. Padova
	INFN, Univ. Pavia
	INFN, Univ. Bologna
	INFN Trieste
	INFN, Univ. Bari
	INFN, Univ. Roma 1
	ENEA
	INFN Frascati
	INFN, Univ. Ferrara
	INFN, Univ. Roma 3
	INFN Legnaro
	INFN, Univ. Milano Bicocca
	INFN Genova
	INFN Laboratori del Sud
	INFN Napoli
Mal	**Univ. of Malta**
EST	***Tartu University***

SE	**ESS**
	University of Uppsala
PT	**LIP**
NL	**University of Twente**
FI	**Tampere University**
LAT	**Riga Technical University**
CH	**PSI**
	University of Geneva
	EPFL
BE	**Univ. Louvain**
AU	**HEPHY**
	TU Wien
ES	**I3M**
	CIEMAT
	ICMAB
China	***Sun Yat-sen University***
	IHEP
	Peking University
KO	**KEU**
	Yonsei University

US	**Iowa State University**
	University of Iowa
	Wisconsin-Madison
	Pittsburg University
	Old Dominion
	Chicago University
	Florida State University
	RICE University
	Tennessee University
	MIT Plasma science center
	Pittsbergh PAC
India	***CHEP***

US	FNAL
	LBL
	JLAB
	BNL

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US P5: The Muon Shot

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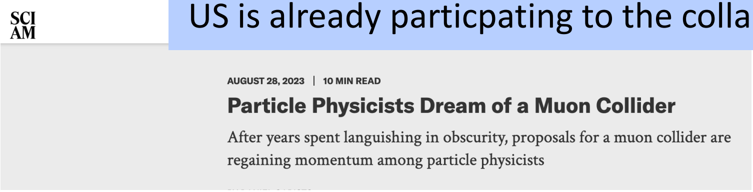
Particle Physics Project Prioritisation Panel (P5) endorses muon collider R&D: ”This is our muon shot”

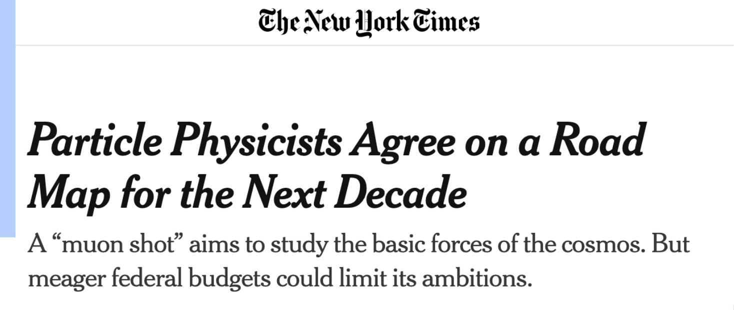
Recommend joining the IMCC
Consider FNAL as a host candidate
US is already particpating to the collaboration


SCI AM

AUGUST 28, 2023 | 10 MIN READ

Particle Physicists Dream of a Muon Collider

After years spent languishing in obscurity, proposals for a muon collider are regaining momentum among particle physicists


The New York Times

Particle Physicists Agree on a Road Map for the Next Decade

A “muon shot” aims to study the basic forces of the cosmos. But meager federal budgets could limit its ambitions.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EDITORIAL | 17 January 2024

US particle physicists want to build a muon collider – Europe should pitch in

A feasibility study for a muon smasher in the United States could be an affordable way to maintain particle physics unity.

US ambition:

- Want to reach a 10 TeV parton level collisions
- Timeline around 2050
- Fermilab option for demonstator and hosting
- Reference design in a “few” years

Informal discussion with DoE (Regina Rameika, A. Patwa):

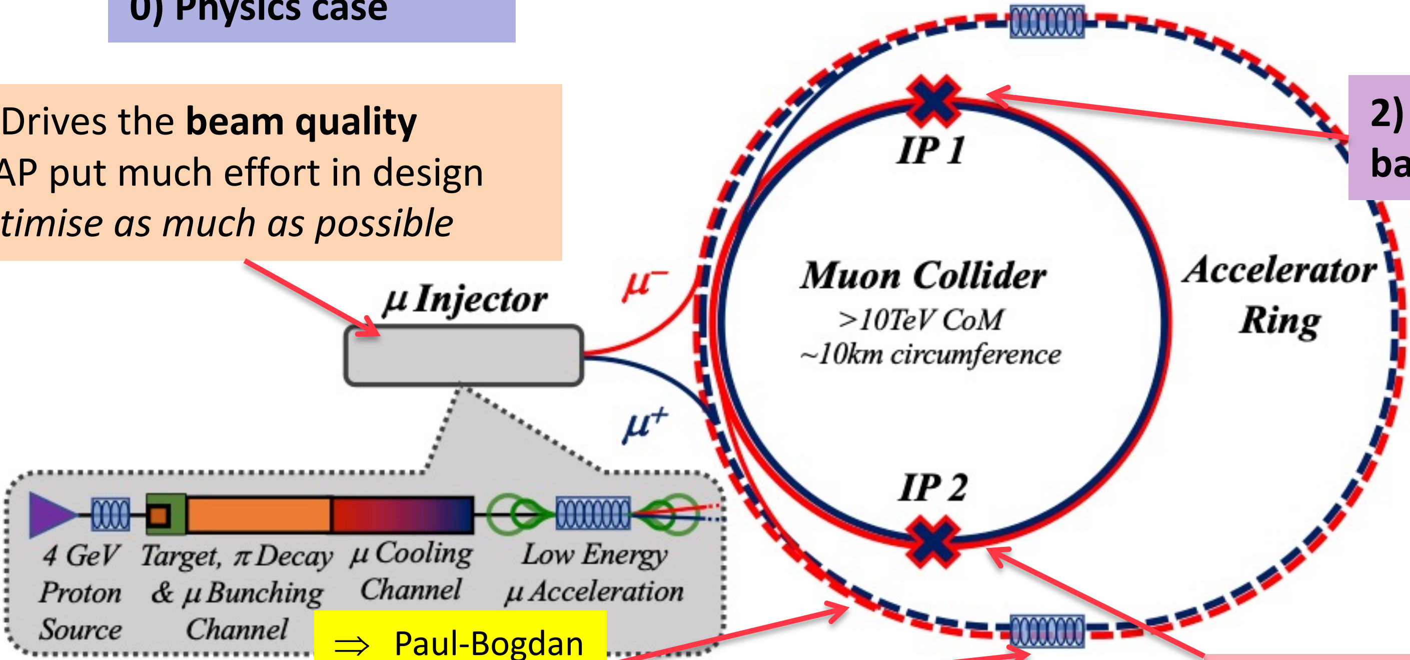
- DoE wants to maintain IMCC as a **global collaboration**
- **Addendum to CERN-DoE-NSF agreement** is in preparation

IMCC prepares options for Europe and for the US in parallel

Key Challenges

0) Physics case

4) Drives the **beam quality**
MAP put much effort in design
optimise as much as possible



2) Beam-induced background

⇒ Alessandro

⇒ Paul-Bogdan

1) Dense neutrino flux
mitigated by mover system
and **site selection**

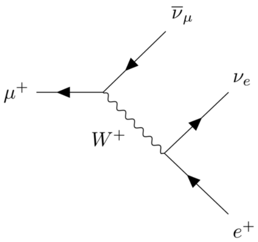
3) Cost and **power** consumption limit energy reach
e.g. 35 km accelerator for 10 TeV, 10 km collider ring
Also impacts **beam quality**

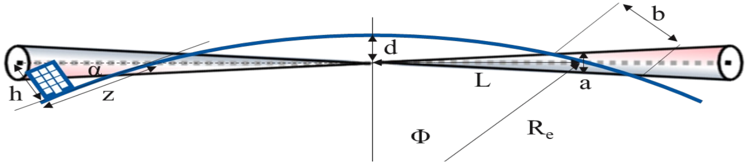
⇒ Taylor

Muon Decay and Neutrino Flux

Muon decays in collider ring

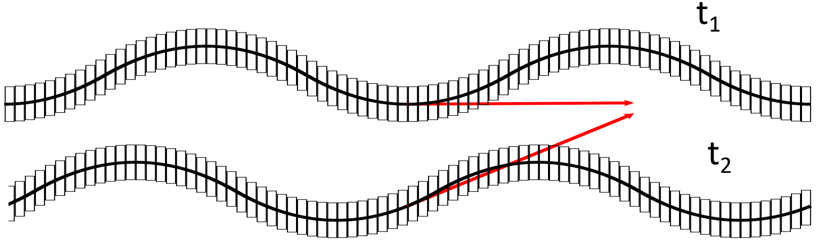
- Impact on detector, see Daniele
- Have to avoid dense neutrino flux





Aim for **negligible impact from arcs**

- Similar impact as LHC
- At 3 TeV this is the case for 200 m depth
- At 10 TeV go from acceptable to negligible with mover system
  - Mockup of mover system planned
  - Impact on beam to be checked



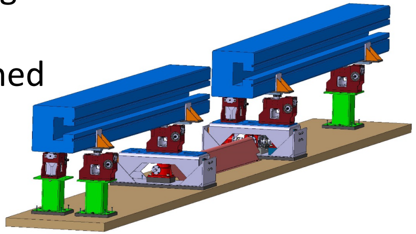
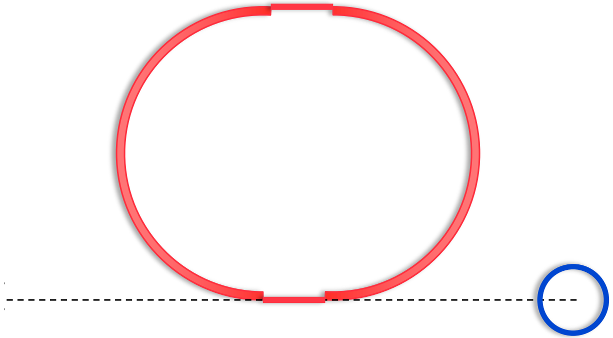


Fig. 7.23: Mock-up of the proposed magnet movement system.

Impact of experimental insertions

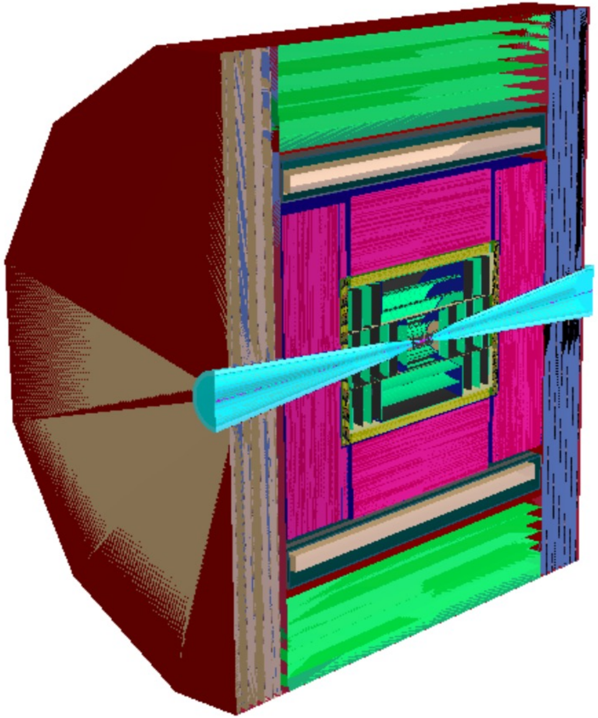
- 3 TeV design acceptable with no further work
- But better acquire land in direction of experiment, also for 10 TeV



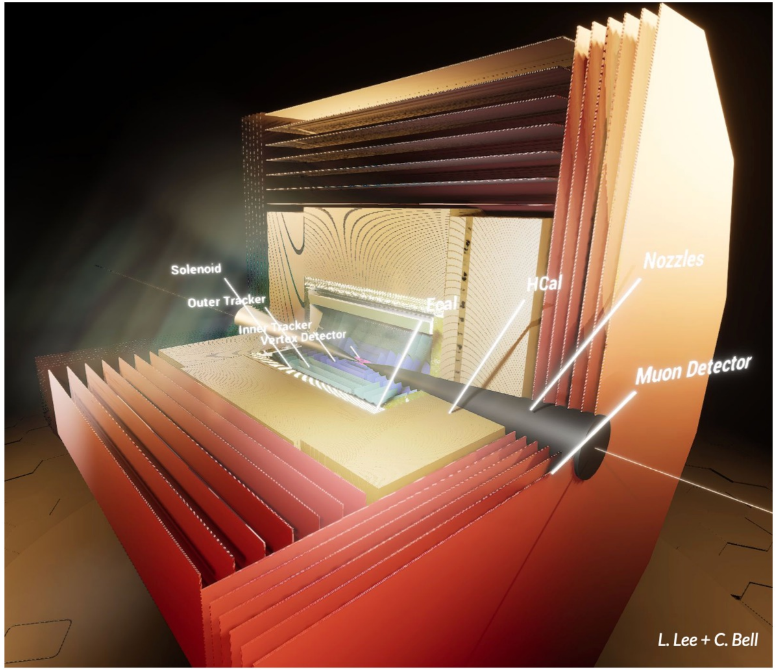
Physics and Detector Concepts

Two detector concepts are being developed

MUSIC
(MUon Smasher for Interesting Collisions)



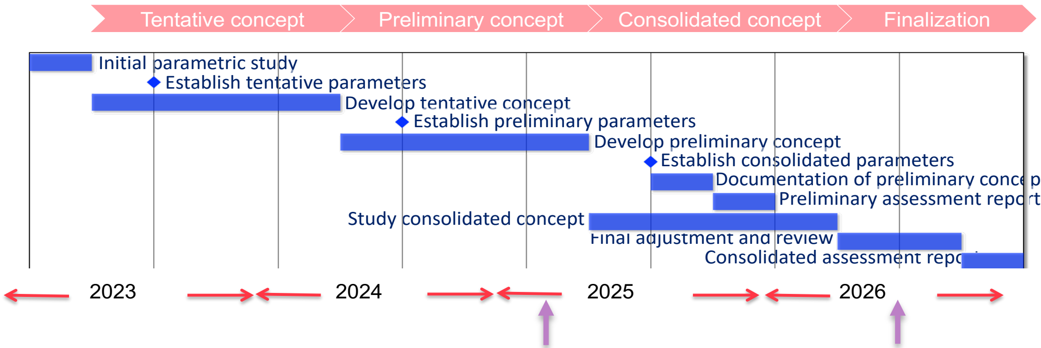
A “New Detector Concept”,
maybe a flashier name can be found



IMCC Plans

For the **ESPPU,** will deliver

- **Evaluation report**, including tentative cost and power consumption scale estimate
- **R&D plan**, including some scenarios and timelines
- Requires to push as hard as possible with existing resources



ESPPU submission

ESPPU result

After ESPPU submission:

- Will fulfill EU contract
  - **Final deliverable is report on all R&D**
- Will have some US process after the ESPPU
  - Likely requires **Reference Design**
- LDG wants to maintain momentum
  - **EU Roadmap** continues

Continue together to develop green field concept

- Avoid becoming site specific before funding agencies put the resources on the table
- Develop site specific versions as derived approaches

Note: IMCC will prepare all reports together as a global community

Technology Maturity

Important timeline drivers:

- **Magnets**
  - HTS technology available for solenoids (expect mature for production in 15 years)
  - Nb_3Sn available for collider ring, maybe lower performance HTS (expect in 15 years)
  - High performance HTS available for collider ring (may take more than 15 years)
- **Muon cooling technology and demonstrator** (expect demonstrator operational in <10 years, with enough resources, allows to perform final optimization of cooling technology)
- **Detector technologies and design** (expect in 15 years)

Other technologies are also instrumental for performance, cost, power consumption and risk mitigation

- but believe that sufficient funding can accelerate their development sufficiently

Other important considerations for the timeline are

- Civil engineering
- Decision making
- Administrative procedures

Staging

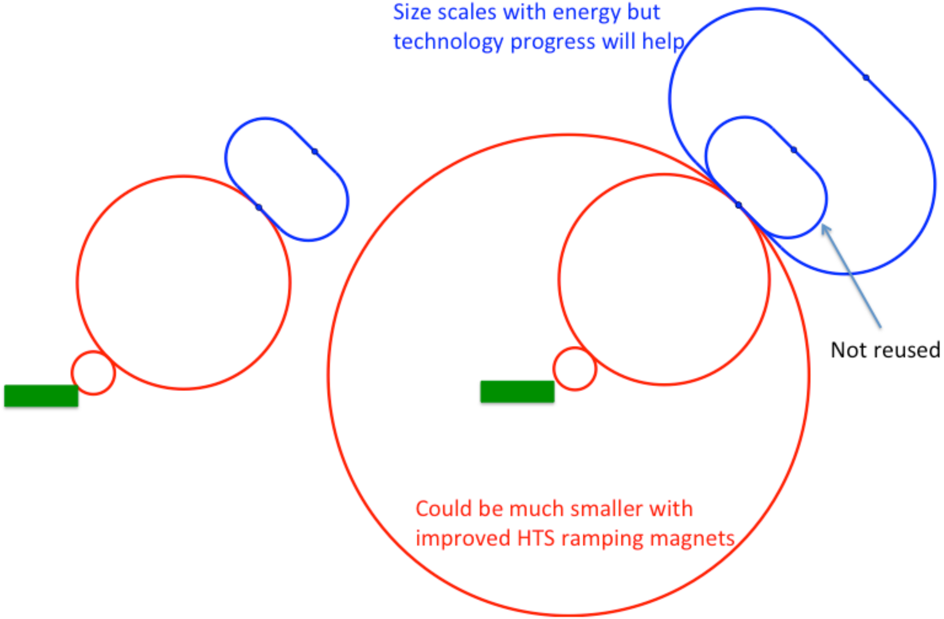
Energy staging

- Start at lower energy
- Current 3 TeV, design takes lower performance into account
- Splits cost, little increase in integrated cost

Luminosity staging

- Start at with full energy, but lower luminosity
- Main luminosity loss sources are arcs and interaction region
  - Can later upgrade interaction region (as in HL-LHC)

Consider reusing **LHC tunnel** and other infrastructures

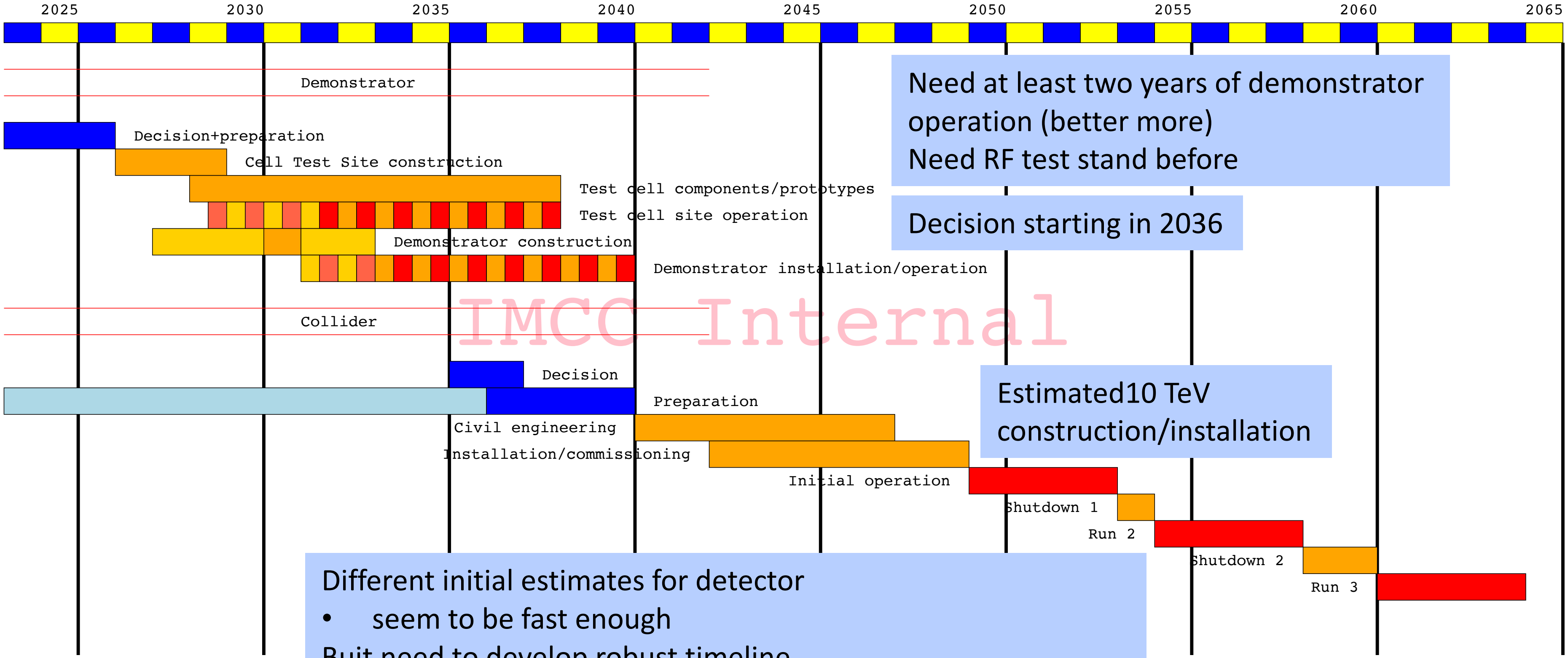

Size scales with energy but technology progress will help

Not reused

Could be much smaller with improved HTS ramping magnets

Tentative Timeline (Fast-track 10 TeV)

Only a basis to start the discussion, will review this year



Need at least two years of demonstrator operation (better more)
Need RF test stand before

Decision starting in 2036

Estimated10 TeV construction/installation

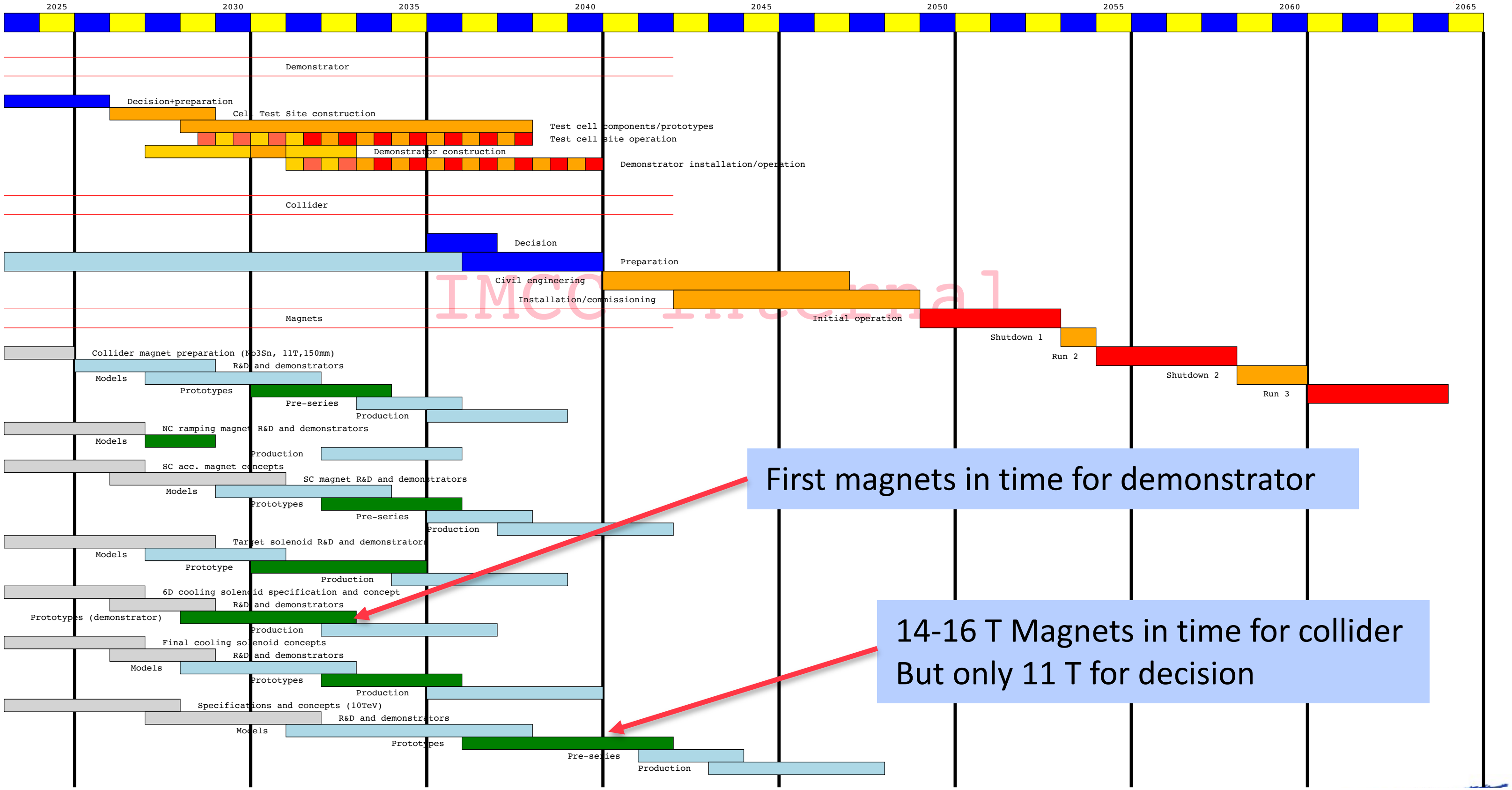
Different initial estimates for detector

- seem to be fast enough

Buit need to develop robust timeline

Timeline with Magnets

Only a basis to start the discussion, will review this year



First magnets in time for demonstrator

14-16 T Magnets in time for collider
But only 11 T for decision

Site Studies

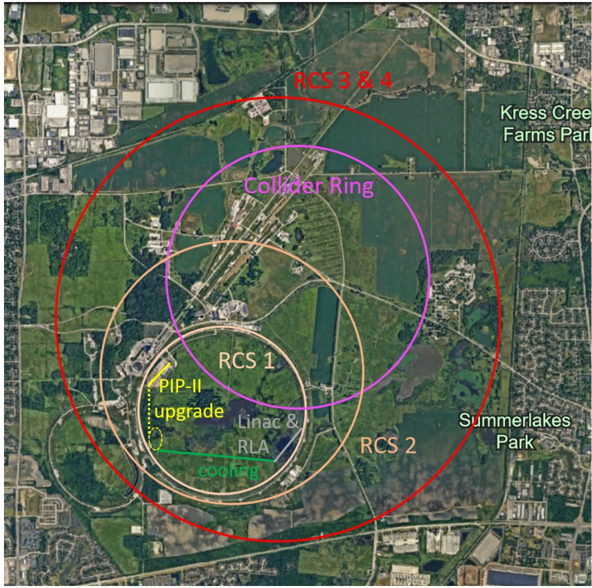
Candidate sites **CERN, FNAL,** potentially others **(**ESS, JPARC, …)

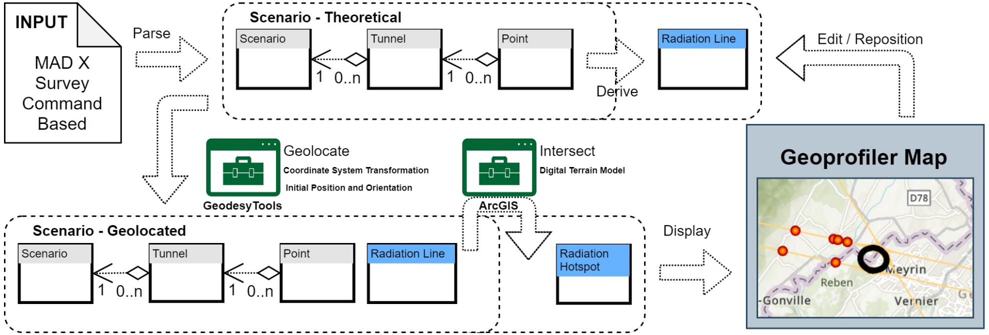
Study is mostly site independent

- Main benefit is existing infrastructure
- Want to avoid time consuming detailed studies and keep collaborative spirit
- Will do more later

Some considerations are important

- Neutrino flux mitigation at CERN
- Accelerator ring fitting on FNAL site





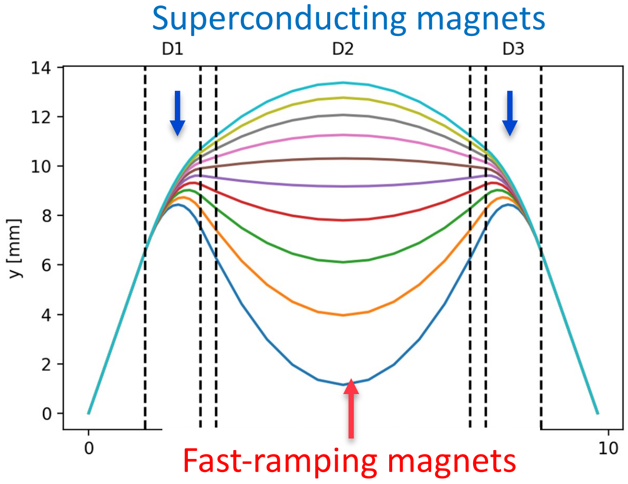
Potential site next to CERN identified

- Mitigates neutrino flux
  - Points toward mediterranean and uninhabited area in Jura
- Detailed studies required (280 m deep)

Use of SPS and LHC Tunnels

Filling factor of green field studies for the arcs
Consider hybrid and non-hybrid designs

Use robust assumptions for the magnets (10 T static and 1.8 T ramping magnets)



		Scenario 1	Scenario 2a	Scenario 2b
SPS	RCS 1	380*	380*	380*
	RCS 2	---	860	860
LHC	RCS 3	1250*	2700	2700
	RCS 4	---	---	4000

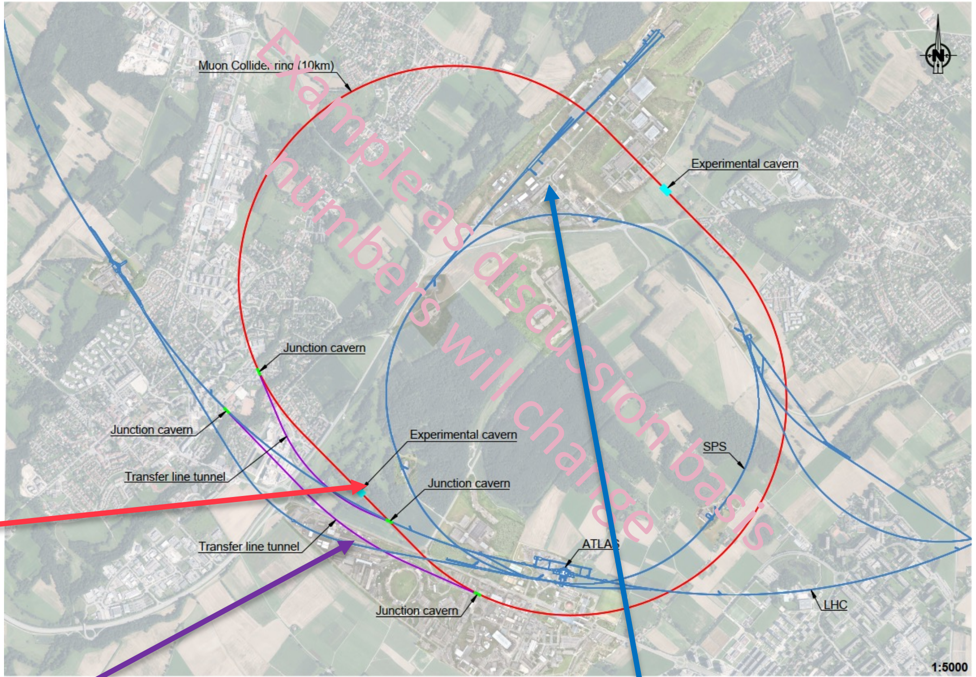
Stronger magnets or better filling factors would allow 10 TeV

Need to confirm whether LHC cross section can house two RCSs

Example CERN Site

First look is promising:

- Collider ring **mitigates neutrino flux from experiments**
    - Some work required to ensure adjacent arcs are negligible
- Good connection to LHC tunnel
- Muon beam cooling complex on CERN land injecting into SPS



Collider ring (10 TeV)
Both experiments on CERN land

Transferline maximum slope 6%

Potential location of muon cooling complex

Several studies remain to be done

Cost Estimate

Led by Carlo Rossi, who also does it for CLIC

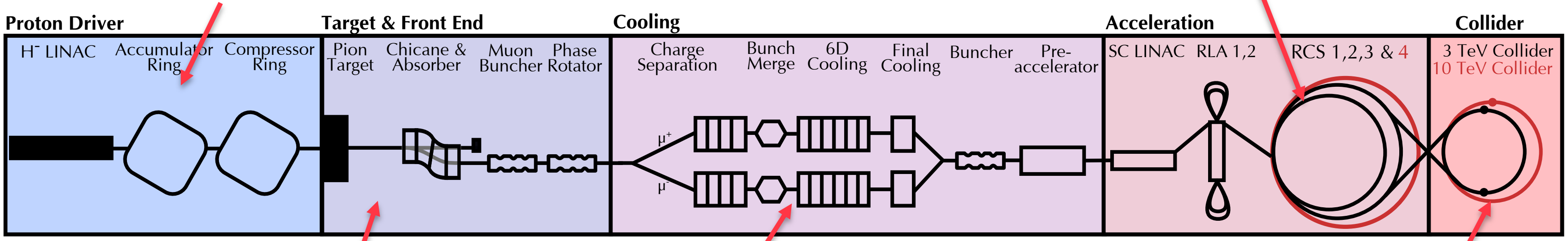
Cost estimate is based on Project Breakdown Structure

- Fill in information at the level it is available to us
- Identify uncertainties
- Make trade-offs
- But cannot optimize at this moment

Overall optimisation not yet done and probably needs time to fully conclude

Detailed studies ongoing of fast-ramping magnet and RF cost and trade-off

Proton complex similar to SPL



Mostly driven by magnet cost

Input data exists, but no optimisation for cost

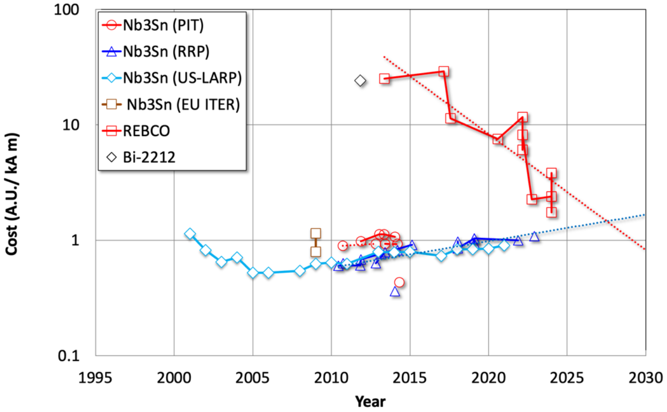
Magnet cost estimates exist for different configurations

Collider Ring Magnets

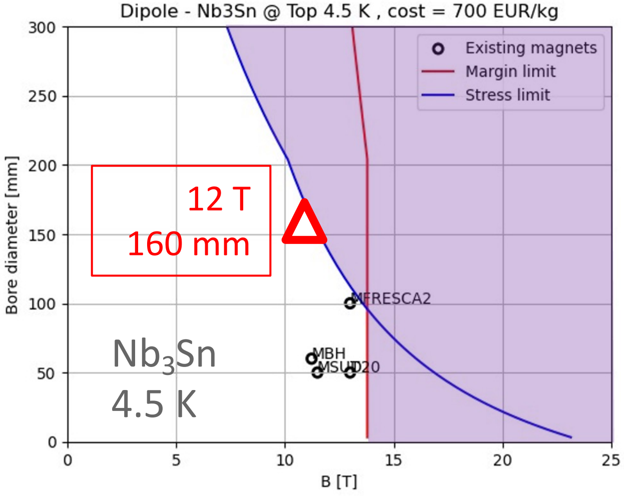
Common assumptions about cost of superconductor development for FCC-hh and muon collider would be beneficial

We currently assume:

- Nb3Sn cost remains constant
- HTS reduces by factor 3

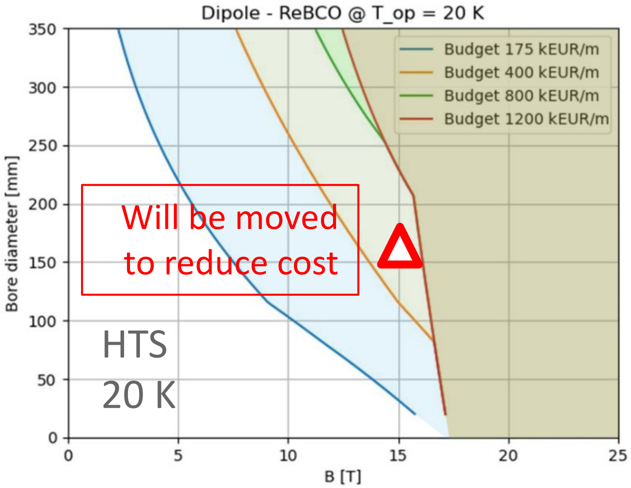


3 TeV Design



12 T
160 mm

Nb_3Sn
4.5 K

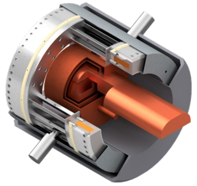


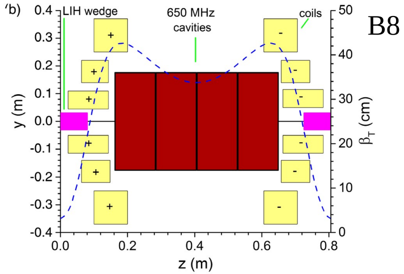
Will be moved to reduce cost

HTS
20 K

R&D Programme

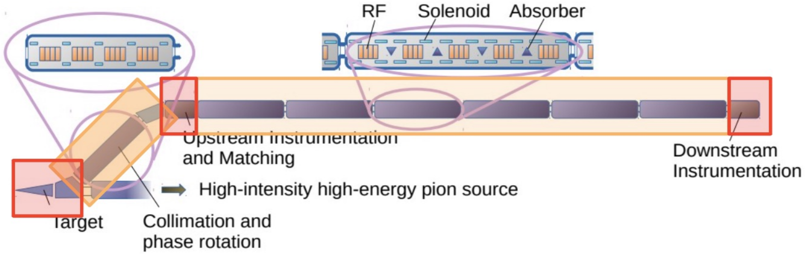
Broad R&D programme can be distributed world-wide





Muon cooling technology

- **RF test stand** to test cavities in magnetic field
- **Muon cooling cell** test infrastructure
- **Demonstrator**
  - At CERN, FNAL, ESS, JPARC, …
  - Workshop in October at FNAL



Magnet technology

- HTS solenoids
- Collider ring magnets with Nb3Sn or HTS

Detector technology and design

- Can do the important physics with near-term technology
- But available time will allow to improve further and exploit AI, MI and new technologies

Many **other technologies** are equally important now to support that the muon collider can be done and perform

Training of **young people**

Strong synergy with HFM Roadmap and RF efforts

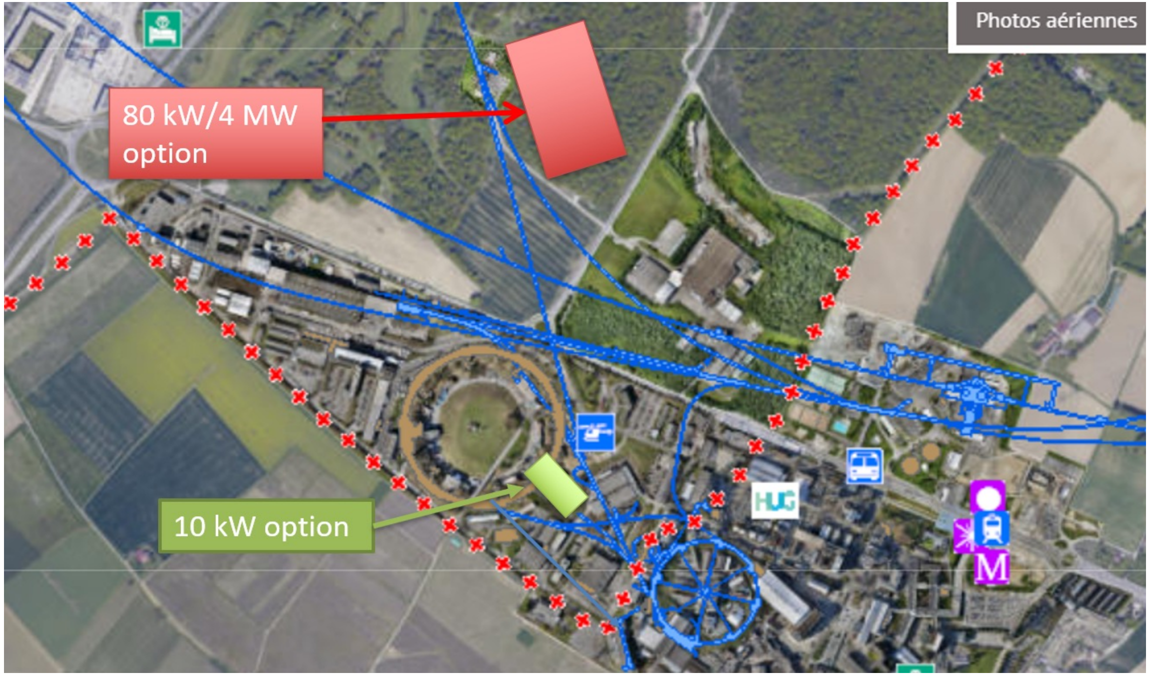
Demonstrator

Two potential sites at CERN

1) On CERN land but outside of fence
- 80 kW from PS
- Site could handle 4 MW if SPL where installed
- Requires civil enginnering

2) In existing tunnel
- 10 kW from booster
- Using existing tunnel
- Need to explore how far we can go
  - Requires resources

Best strategy is to use site 2 initially and then later transfer equipment to site 1 if required



Synergies and Outreach

Training of young people

- Novel concept is particularly challenging and motivating for them

Technologies

- Muon collider needs HTS, in particular solenoids
- Fusion reactors
- Power generators
- Nuclear Magnetic Resonance (NMR)
- Magnetic Resonance Imaging (MRI)
- Magnets for other uses (neutron spectroscopy, detector solenoids, hadron collider magnets)
- Target is synergetic with neutron spallation sources, in particular liquid metal target (also FCC-ee)
- High-efficiency RF power sources and power converter
- RF in magnetic field can be relevant for some fusion reactors
- High-power proton facility
- Facilities such as NuStorm, mu2e, COMET, highly polarized low-energy muon beams
- Detector technologies
- AI and ML

Physics

Conclusion

R&D progress is increasing confidence that the collider is a unique, sustainable path to the future

P5 strongly supports this view

- Plan to increase collaboration with the US

Started exploring the implementation at CERN using existing infrastructure

- Looks promising including neutrino flux mitigation

Cost estimate has started

We expect that a first collider stage can be operational by 2050

- If the resources ramp up sufficiently
- If decision-making processes are efficient

Need to continue ramping up the momentum

Reserve

Power and Environment

The compact footprint, limited cost and power consumption are intrinsic features that motivate the muon collider study in the first place. Reuse of existing infrastructure is further reducing the impact on the environnement.

Specific studies address the key power consumers:

- Superconducting magnets, fast-ramping magnets, normal- and superconducting RF systems, cooling of the components and their shielding

Can give some numbers on CO_2, where common database is available

Neutrino flux mitigation is being studied

Tentative Staged Target Parameters

Target integrated luminosities

$\sqrt{s}$	$\int \mathcal{L}dt$
3 TeV	$1\ \mathrm{ab}^{-1}$
10 TeV	$10\ \mathrm{ab}^{-1}$
14 TeV	$20\ \mathrm{ab}^{-1}$

Need to spell out scenarios

Need to integrate potential performance limitations for technical risk, cost, power, …

Parameter	Unit	3 TeV	10 TeV	10 TeV	10 TeV
L	**10^{34} cm^{-2}s^{-1}**	**1.8**	**20**	**tbd**	**13**
N	10^{12}	2.2	1.8	1.8	1.8
f_r	Hz	5	5	5	5
P_{beam}	**MW**	**5.3**	**14.4**	**14.4**	**14.4**
C	km	4.5	10	15	15
<B>	T	7	10.5	7	7
ε_L	MeV m	7.5	7.5	7.5	7.5
σ_E / E	%	0.1	0.1	tbd	0.1
σ_z	mm	5	1.5	tbd	1.5
β	mm	5	1.5	tbd	1.5
ε	µm	25	25	25	25
$\sigma_{x,y}$	µm	3.0	0.9	1.3	0.9

Examples as discussion basis

numbers will change

Proposal: EuMAHTS

Luca Bottura et al.

Submitted to INFRA-2024-TECH-01-01

Focus on HTS development
O(10 Meur) request

Strategy and context

- WP1 - Coordination and Communication (L. Bottura, P. Vedrine)
- WP2 – Strategic Roadmap (A. Ballarino, L. Rossi)
- WP3 – Industry Co-innovation (J.M. Perez, S. Leray)
- WP4 – HTS Magnets Applications Studies (P. Vedrine, M. Statera)

Material and technology

- WP5 – Materials and Technologies (D. Bocian, A. Bersani)

Three core components (6 MEUR)

- **40 T solenoid, 50 mm bore**
- **10 T/10 MJ/300 mm solenoid**
- **HTS undulator**

- WP6 – 40T-class all-HTS solenoid (B. Bordini, P. Vedrine)
- WP7 – 10T/10MJ-class all-HTS solenoid (S. Sorti, C. Santini)
- WP8 – K=2 all-HTS undulator (S. Casalbuoni, M. Calvi)

Test infrastructure

- WP9 – Test Infrastructures (G. Willering, E. Beneduce)

Short name	Country	Status
CERN	IERO	B
EMFL	Belgium	B
TAU	Finland	B
CEA	France	B
ESRF	France	B
EUXFEL	Germany	B
GSI	Germany	B
KIT	Germany	B
INFN	Italy	B
UMIL	Italy	B
UTWENTE	Netherlands	B
IFJ-PAN	Poland	B
PK	Poland	B
CIEMAT	Spain	B
CSIC	Spain	B
PSI	Switzerland	A
TERA-CARE	Switzerland	A
UNIGE	Switzerland	A
CNRS	France	A
HZDR	Germany	A
RU-NWO	Netherlands	A

IMCC Organisation

Collaboration Board (ICB)

- Elected chair: **Nadia Pastrone**
- **50 full members, 60+ total**

Steering Board (ISB)

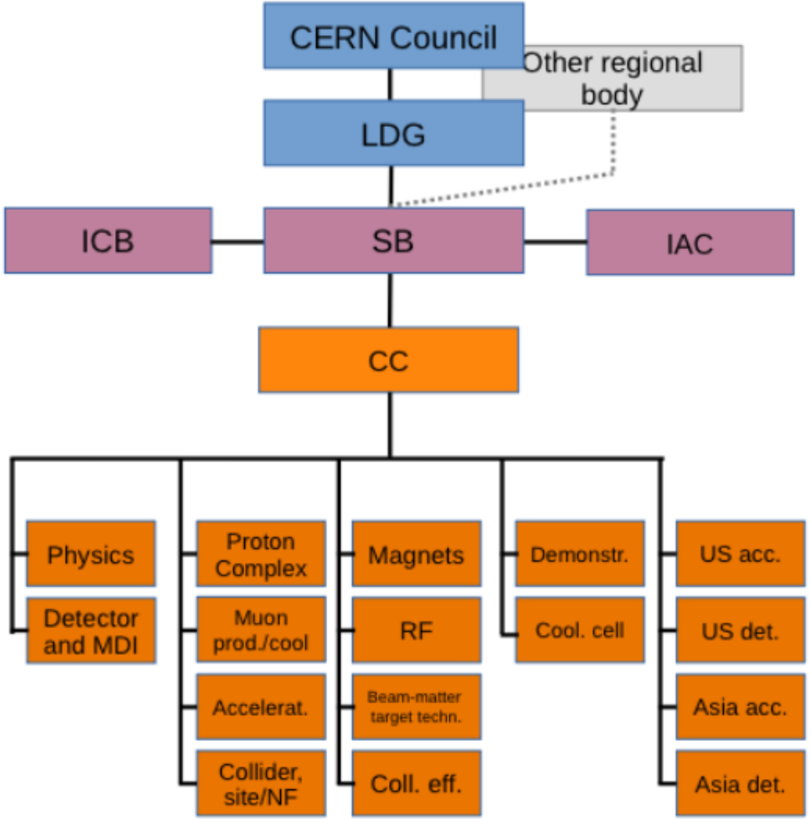
- Chair **Steinar Stapnes**
- CERN members: Mike Lamont, Gianluigi Arduini
- ICB members: Dave Newbold (STFC), Mats Lindroos (ESS), Pierre Vedrine (CEA), N. Pastrone (INFN), Beate Heinemann (DESY)
- Study members: SL and deputies

Advisory Committee

Coordination committee (CC)

- Study Leader: **Daniel Schulte**
- Deputies: Andrea Wulzer, Donatella Lucchesi, Chris Rogers

Will integrated the US also in the leadership



CERN Council

Other regional body

LDG

ICB

SB

IAC

CC

Physics

Detector and MDI

Proton Complex

Muon prod./cool

Accelerat.

Collider, site/NF

Magnets

RF

Beam-matter target techn.

Coll. eff.

Demonstr.

Cool. cell

US acc.

US det.

Asia acc.

Asia det.

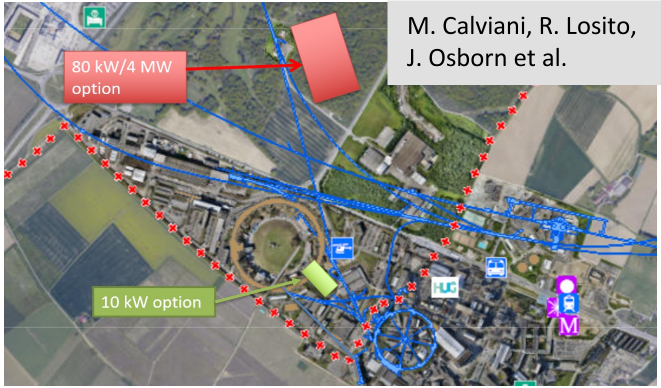
CDR Phase, R&D and Demonstrator Facility

Broad R&D programme can be distributed world-wide
- **Models** and **prototypes**
  - Magnets, Target, RF systems, Absorbers, …
- **CDR** development
- **Integrated tests**, also with beam

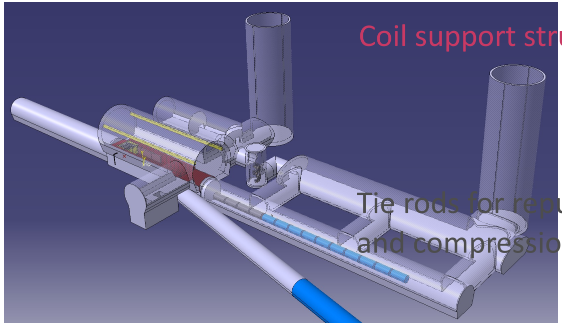
Cooling demonstrator is a key facility
- look for an existing proton beam with significant power

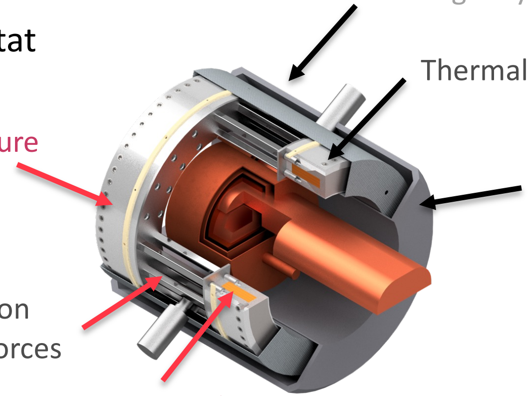
Different sites are being considered
- CERN, FNAL, ESS …
- Two site options at CERN

Muon cooling module test is important
- INFN is driving the work
- Could test it at CERN with proton beam



M. Calviani, R. Losito, J. Osborn et al.





US P5: The Muon Shot

Particle Physics Project Prioritisation Panel (P5) supports US ambition to host a 10 TeV parton-parton collider

- Endorses muon collider R&D: ”This is our muon shot”

Recommend joining the IMCC
Consider FNAL as a host candidate
US is already particpating to the collaboration

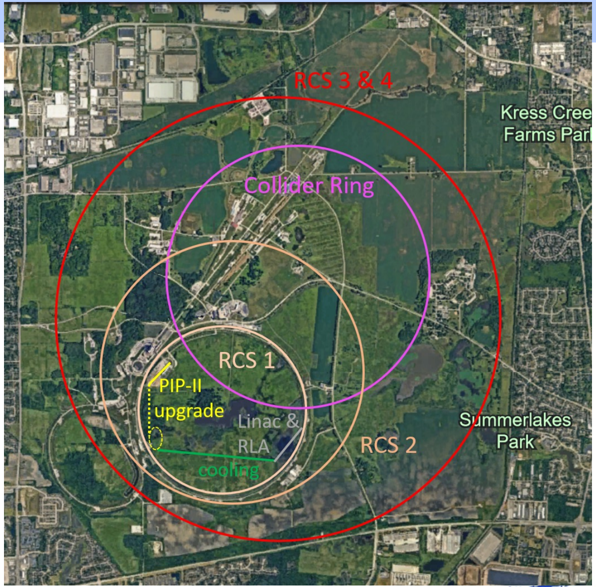
US ambition:

- Want to reach a 10 TeV parton level collisions
- Timeline around 2050
- Fermilab option for demonstator and hosting
- Reference design in a “few” years

Informal discussion with DoE (Regina Rameika, A. Patwa):

- DoE wants to maintain IMCC as a **global collaboration**
- **Addendum to CERN-DoE-NSF agreement** should be in preparation

IMCC prepares options for Europe and for the US in parallel



MuCol

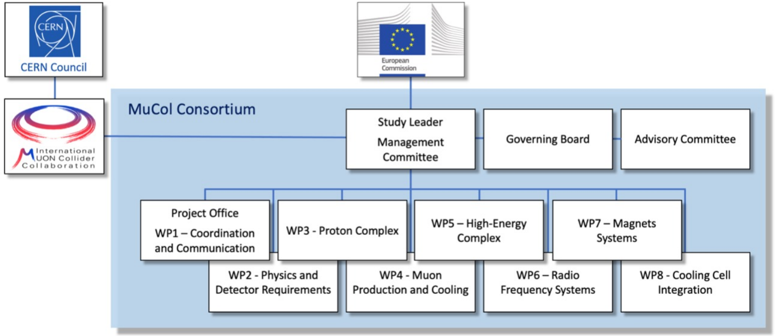
MuCol (EU co-funded)

International
MUON Collider
Collaboration

Started March 2023, lasts until early 2027

3 MEUR from the EU, the UK and Switzerland, about 4 MEUR from the partners, CERN leads and contributes

Final deliverable is a report on the full IMCC R&D results
EU officer will come on 19th June.



CERN Council

European Commission

MuCol Consortium

Study Leader
Management Committee

Governing Board

Advisory Committee

Project Office
WP1 – Coordination and Communication

WP3 - Proton Complex

WP5 – High-Energy Complex

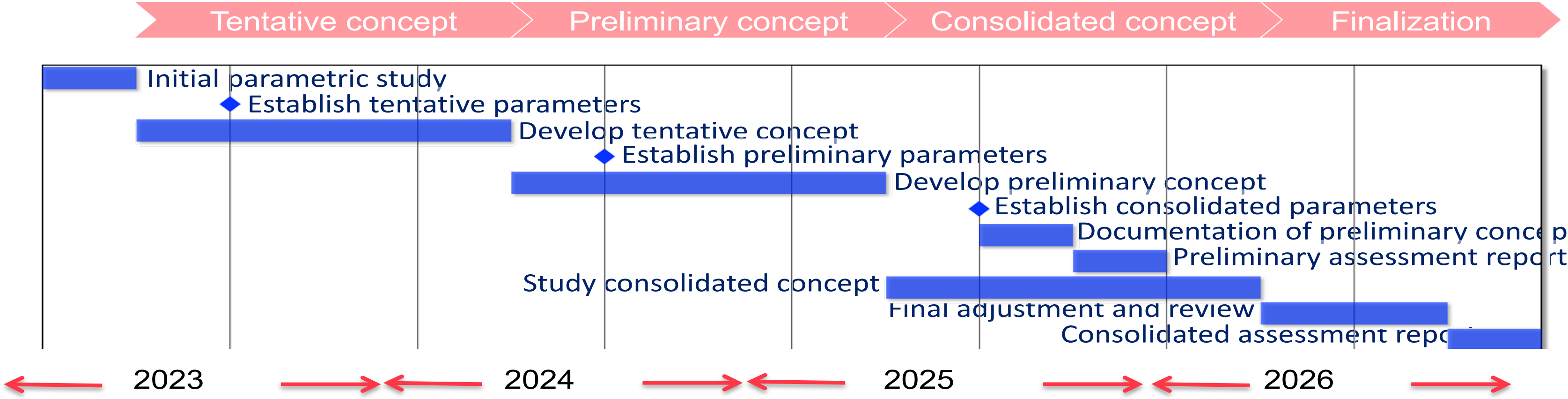
WP7 – Magnets Systems

WP2 - Physics and Detector Requirements

WP4 - Muon Production and Cooling

WP6 – Radio Frequency Systems

WP8 - Cooling Cell Integration



Tentative concept → Preliminary concept → Consolidated concept → Finalization

Initial parametric study
Establish tentative parameters
Develop tentative concept
Establish preliminary parameters
Develop preliminary concept
Establish consolidated parameters
Documentation of preliminary concept
Preliminary assessment report
Study consolidated concept
Final adjustment and review
Consolidated assessment repo

2023
2024
2025
2026

Plan for ESPPU

Continue to perform studies on **green field** designs

- Collaboration with the US
- Lattice designs, component designs, beam dynamics

Provide parameter tables for the green field

Perform example **civil engineering studies** for CERN (collider and demonstrator)

- Looks promising at this moment
- The US will do similar studies for FNAL

Provide parameters tables for the implementation at CERN

- Scaled from green field design
- Do not have the resources and time to make detailed designs for CERN for ESPPU

Check cost for green field and CERN option

- Know early the relative cost because it may impact decisions

Muon Decay and Neutrino Flux

Muon decays in collider ring
- Impact on detector
- Have to avoid dense neutrino flux

Aim for **negligible impact from arcs**
- Similar impact as LHC
- At 10 TeV go from acceptable to negligible with mover system
  - Mockup of mover system planned
  - Impact on beam to be checked

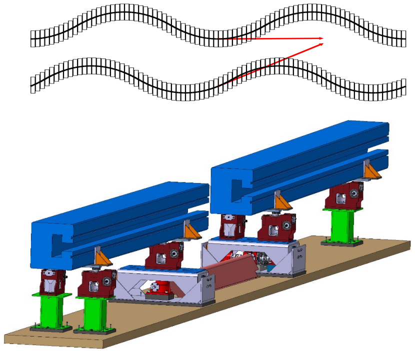
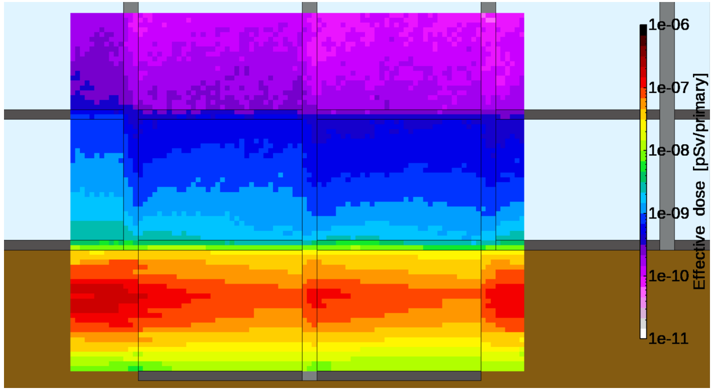
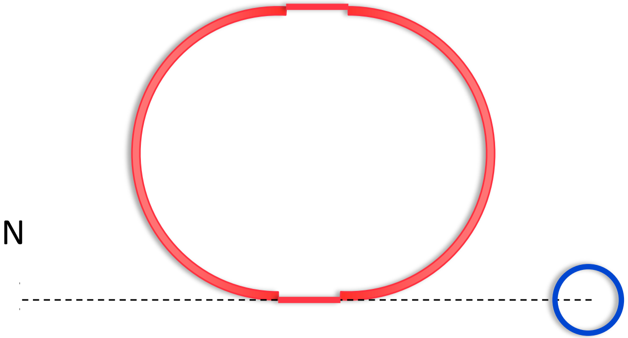


Fig. 7.23: Mock-up of the proposed magnet movement system.

Detailed studies by RP and FLUKA experts
- Impact on surface
- Considering buildings



Impact of experimental insertions
- 3 TeV design acceptable with no further work
- But better acquire land in direction of straights, also for 10 TeV
- Detailed studies identified first location and orientation close to CERN
  - Poiint to uninhabited area in Jura and Mediterranian sea



Cost Uncertainty

Key cost drivers are based on sound models

- E.g. RCS with trade-off between RF and magnet cost

A part of the cost will be based on scaling from other projects

A part of the cost depends on future developments of technology beyond our study

- E.g. cost of superconductor

Major cost optimisations remain to be done in the design