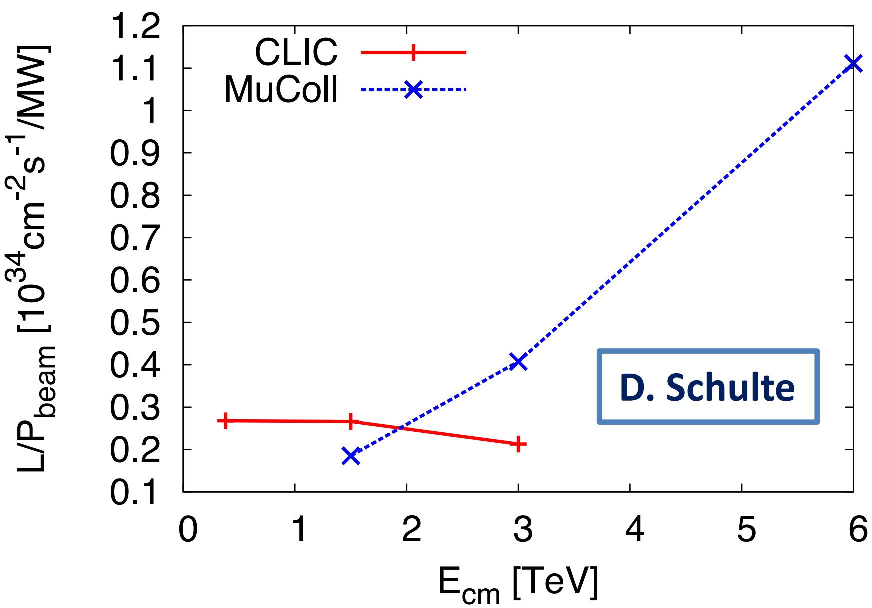
CSN1 – RD_MUCOL

CdS Torino - 6 luglio 2020

- ✓ Attività INFN in RD_FA – WP8:
  - LEMMA: bersagli e testbeam @ CERN
  - fisica e validazione esperimento ++
- ✓ **NUOVA SIGLA CSN1 dedicata a Muon Collider ➔ richieste INFN in corso**
- ✓ Situazione internazionale: EU Strategy e Collaborazione internazionale
- ✓ **Contributo di Torino e PoliTO**
- ✓ **Richieste ai Servizi 2021**



Responsabile Nazionale: Nadia Pastrone
Responsabile Locale: Nicola Amapane

Nadia Pastrone

EU Strategy

Input Document to EU Strategy Update - Dec 2018:
"Muon Colliders," **arXiv:1901.06150**
by *CERN-WG on Muon Colliders*

J.P. Delahaye et al.

FINDINGS and RECCOMENDATIONS:
Set-up an international collaboration to promote muon colliders
and **organize the effort on the development of both accelerators and detectors**
and to define the road-map towards a CDR by the next Strategy update….
Carry out the R&D program toward the muon collider

From the deliberation document of the European Strategy Update – June 2020:

High-priority future initiatives
[..]In addition to the high field magnets the accelerator R&D roadmap could contain:
[..] an **international design study** for a **muon collider**, as it represents a unique opportunity to achieve a multi-TeV energy domain beyond the reach of e+e– colliders, and potentially within a more compact circular tunnel than for a hadron collider. The biggest challenge remains to produce an intense beam of cooled muons, but novel ideas are being explored;

International Design Study @ CERN
by LDG chaired by Lenny Rivkin

CERN Laboratory Directors Group (LDG) should establish
Accelerator R&D roadmap to define a route towards implementation of the goals of the 2020 Update of the European Strategy, bringing together the capabilities of CERN and the LNLs to carry out R&D and construction and operation of demonstrators

LDG established in September 2017 the Muon Collider Working Group that states:

The compelling physics reach justifies establishment of an international collaboration to develop fully the muon collider design study and to pursue R&D priorities, according to an agreed upon work plan.

To facilitate implemention of the European Strategy LDG decided (July 2)

Lenny Rivkin

Agree to start building the collaboration for international muon collider design study

Accept the proposal of organisation

Accept the goals for the first phase

- see details in Daniel's slides that follow…

➔International Muon Collider Collaboration kick-off virtual meeting *(260 participants)*
https://indico.cern.ch/event/930508/

LDG Decisions

Lenny Rivkin

Appointment of Daniel Schulte as ad interim project leader

Will work towards strengthening cooperation and ensuring effective use of complementary capabilities

Core team (Nadia Pastrone, Lenny Rivkin and Daniel Schulte) will start collecting MoUs

Proposed Plan

- A start-to-end collider design in particular in the view that this would be the first facility of its kind.
- A machine detector interface that protects the detector from collider background while al- lowing good machine performance.
- A physics and detector study to assess the physics reach of the collider.
- The design of a demonstrator to be built in the second half of the decade.

Scope

The study aim is to develop a **baseline concept** for a muon collider at two centre-of-mass energy ranges.

- The first **around 3 TeV**, well above higgs factory
- The second **at or above 10 TeV** extends the energy reach well beyond the capabilities of normal conducting linear colliders. This would likely require more advanced technologies that might not be ready within the next 10-20 years. Try to find the energy limit.
- The potential to use the technology for other purposes such as a Higgs or neutrino factory will be explored, provided this is found synergetic with the high-energy collider study.
- The collaboration will identify an **R&D path** toward a conceptual design
- The collaboration will design a **demonstrator**

First Period

Objective:

- In time for the next European Strategy for Particle Physics Update, the study aims to establish whether the investment into a full CDR and a demonstrator is justified
- It will provide a baseline concept, well-supported performance expectations and assess the associated key risks as well as cost and power consumption drivers. It will also identify an R&D path to demonstrate the feasibility of the collider

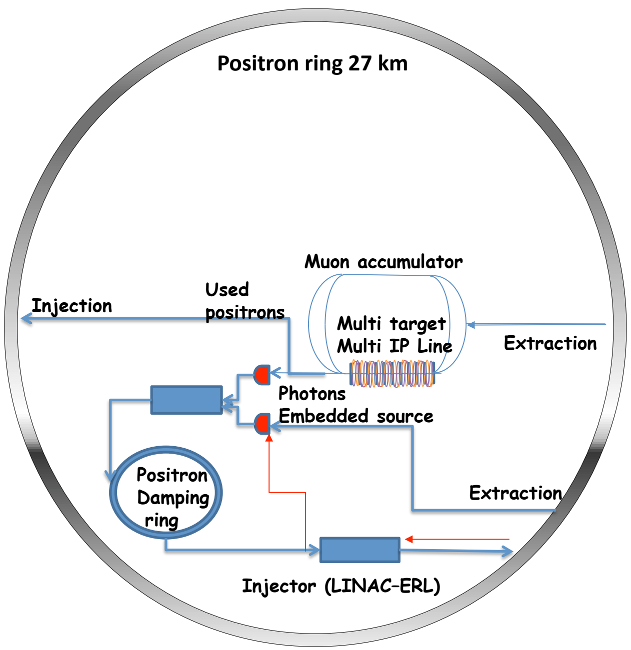
Deliverables:

- Reports assessing muon collider potential and describing R&D path to CDR including demonstrator

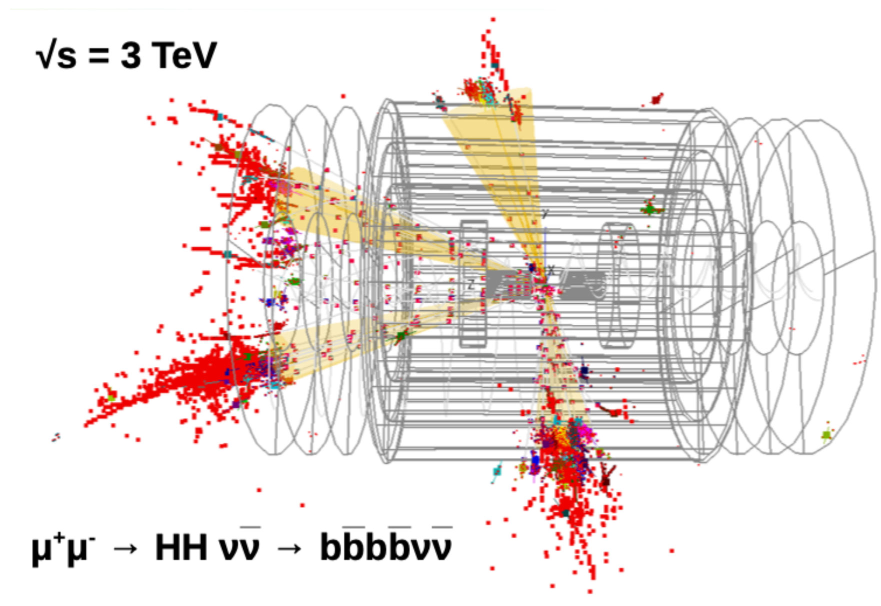
I.N.F.N. *July 3rd, 2020*

ongoing activities and interests

International Collaboration
to develop an integrated muon collider design concept
that encompasses the physics, the detectors, and the accelerator



Nadia Pastrone INFN TORINO



Ongoing activities: Physics-Experiment

- **Physics Motivation**

Torino ??

Direct/indirect discovery reach – VBF and VBS – precise Higgs measurements

A.Costantini, M.Chiesa, R.Franceschini, F.Maltoni, B.Mele, F.Piccinini, A.Wulzer et al. ++

Quartic Higgs self-coupling: arXiv:2003.13628 [hep-ph]

Vector Boson Fusion: arXiv:2005.10289 [hep-ph]

Benchmarks at different energies steer machine parameters and experiment design

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- **Experiment and Physics Validation**

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Flexible framework - background simulation, detector simulation and event reconstruction in use to study detector requirements/performances at different center of mass energies

First full-simulation study $\mu\mu \to H\nu\bar{\nu} \to b\bar{b}\nu\bar{\nu}$ @ $\sqrt{s} = 1.5\ TeV$ J. Inst. 15 P05001, 2020

D.Lucchesi et al. + US-MAP + CLICdp *the core team is growing + SnowMass21 interest*

➔ **Machine Detector Interface:** beam induced background shaped by machine optics design at different energies sets constraints on nozzles and experiment design and performances

10+ TeV is a completely new regime to explore!

Ongoing activities: Experiment-Detectors

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- **Experiment Design and Detector R&D**

Flexible framework to study detector requirements/performances at physics benchmarks
R&D to exploit state of the art "5D" detectors and beyond are mandatory
but in synergy with the on-going upgrade of existing experiments and new
on-going developments with national and international grants

INFN experts and infrastructures cover many crucial area of interest to be explored:

- Sensors and read-out for trackers + timing (DMAPS, LGAD…)
- Calorimeter developments
- Exploit new ideas for muon detection
- Common software tools for simulation and reconstruction also ML techniques

P. Andreetto, N. Bartosik, A. Bertolin, L. Buonincontri, M. Casarsa, F. Collamati,
C. Curatolo, A. Gianelle, D. Lucchesi, N. Pastrone, C. Riccardi, P. Sala, L. Sestini, I. Vai
++ al. joining

Strong synergy within the **new submitted EU project AIDAinnova**

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Ongoing activities: MDI - Machine

- **Machine Detector Interface**

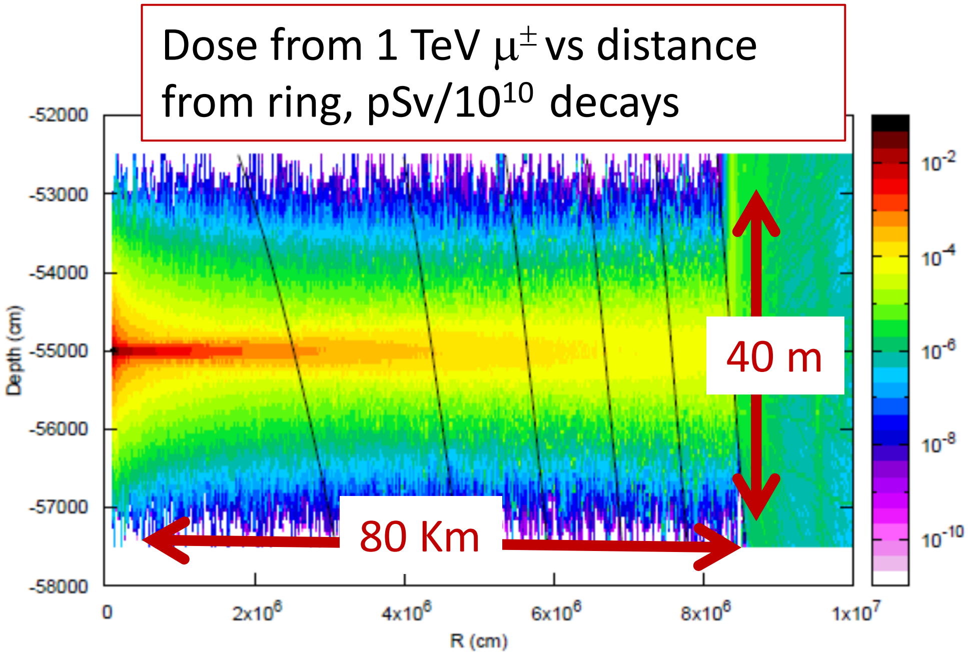
  Optics design required as part of the collider parameters studies. Fix constraints on nozzles design. Simulation tools. Strong collaboration with CERN.

  F.Collamati, et al. + A.Mereghetti CERN

- **Neutrino Radiation Hazard Studies**

  Preliminary full FLUKA simulation: μ decay (ring/straight sections), ν interactions. Checked scaling law. Next: simulations with realistic ring geometries and new orbits design. Strong collaboration with machine design.

  Alfredo Ferrari, Anna Ferrari, P. Sala et al.



Ongoing activities: LEMMA Source

- **Positron-based Muon Source – LEMMA**

Positron production and acceleration, muon targets, muon accumulation

M.Antonelli, M.E.Biagini, M.Boscolo, S.Guiducci, P.Raimondi, A.Variola et al.
arXiv:1905.05747v2 [physics.acc-ph] ➔ paper in preparation

- Positron source studies – collaboration with IJCL *+ A.Bacci, I.Drebot et al.*
  also on crystal applications: *L.Bandiera, A.Mazzolari et al.*
- Material simulations and studies for positron and muon production targets
  M.Antonelli, R.Li Voti, G.M. Cesarini et al. + PoliTO + other interested
  measurements and R&D planned using beam at LNF and CERN
  Torino
- Muon accumulator optics and multi-target new layout *+ O.Blanco, A. Ciarma*:
  FFAG – with UK multibend-achromat – with ESRF Phys. Rev. Accel. Beams 23, 051001
- CERN test beam to evaluate targets and emittance *J. Inst.* **15** P01036, 2020
  ➔ new proposal to run at CERN in 2022 with improved set-up

+ N.Amapane, F. Anulli, A.Bertolin, M.Zanetti et al.

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Resource plan towards a pre-CDR submitted by Alessandro Variola (10/19)

need consolidation to prove feasibility

to overcome technical limitations and reach higher muon intensities

Interests: Machine et al.

- **Fast-ramping SC magnet systems for accelerator ring**
  L.Rossi, P.Fabbricatore, S.Farinon, R.Musenich, M.Sorbi, M.Statera et al.
- **Material studies for targets**
- **Crystals manufacturing for targets and collimation**

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Strong synergy within the **new submitted EU project I.FAST**
➔ **MUST** – MUon colliders STrategy network
INFN, CERN, CEA, CNRS, KIT, PSI, UKRI
Delivery: International collaboration plans towards a multi-TeV muon collider

Torino

- **Synergies on exploiting neutrino beams at facilities**
  M.Bonesini, G.Catanesi, D.Orestano, L.Tortorici et al.

Torino ??

Path Forward

Highest priority is to form the collaboration

- All partners taking ownership
  - define the work programme
  - find resources
  - start to work

Web page: http://muoncollider.web.cern.ch

- Will upload information

Mailing lists:

MUONCOLLIDER_DETECTOR_PHYSICS@cern.ch

MUONCOLLIDER_FACILITY@cern.ch

E-group:

MUONCOLLIDER-DETECTOR-PHYSICS

MUONCOLLIDER-FACILITY

e-group MUONCOLLIDER-INFN

Meeting locale per discutere Interessi e sinergie @ Torino Prossima settimana ???

Richieste Servizi @ Torino 2021

Attività in crescendo a livello internazionale e nazionale:
contributi su disegno di macchina e di esperimento

- Eventuali studi e R&D sia in laboratorio che su fascio – sinergie a Torino

- **Servizio progettazione** (2 mu)

✓ Partecipazione a definire disegno/simulazioni macchina/esperimento/MDI
✓ Camera a vuoto per test bersagli – collaborazione PoliTO
✓ Sviluppo disegno esperimento – sinergia con ITS3, UFSD, Timespot, AIDAinnova,..

- **Laboratorio tecnologico** (1 mu)

✓ Parti meccaniche per R&D esperimento – da definire in sinergia
✓ Parti meccaniche per set-up testbeam @ CERN 2022 ➔ gia' in corso RD_FA

- **Servizio elettronica** (1 mu)

✓ Parti elettroniche per R&D esperimento – da definire in sinergia
✓ Parti meccaniche per set-up testbeam @ CERN 2022 ➔ gia' in corso RD_FA

- **Servizio Calcolo** – *attività cruciali da capire meglio per fine 2020*

extras

Contributo INFN da CdS 2019

Essenziale per dimostrare la potenzialità del Muon Collider come futura macchina acceleratrice nella regione multi-TeV con:

- studi di fisica, in collaborazione con il gruppo teorico;
- studi per il disegno di una sorgente di muoni positron-driven (LEMMA);
- studi del punto di interazione e degli effetti del fondo di macchina sul rivelatore e danno da radiazione indotta da neutrini - collaborazione con MAP;
- studi di nuovi materiali per i bersagli;
- ionizing cooling in MICE;
- test su fascio al CERN.

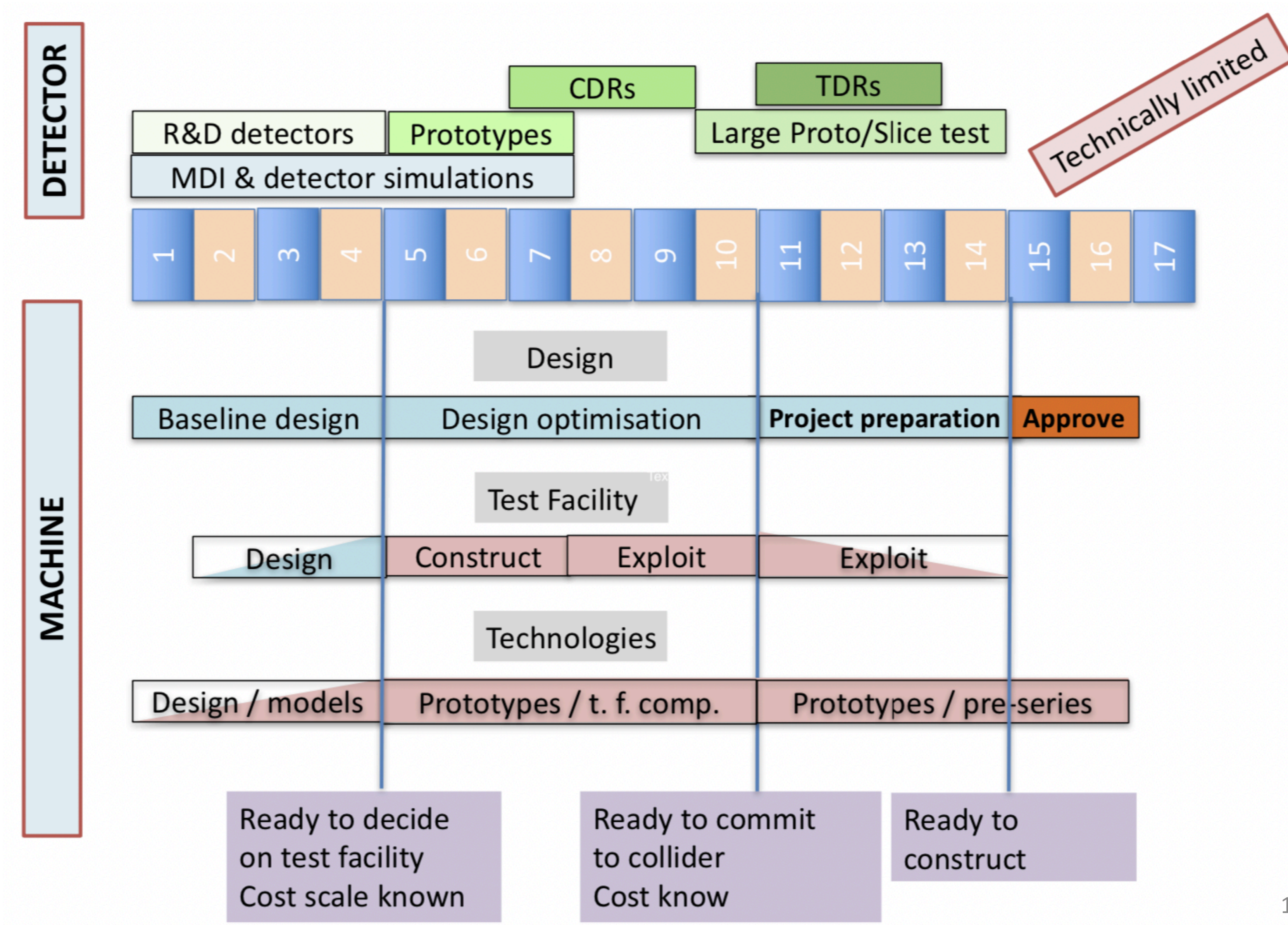
➔ **da ora occorre perseguire al meglio:**

1) Studi di fisica ed esperimento

2) Studi di macchina e nuove tecnologie

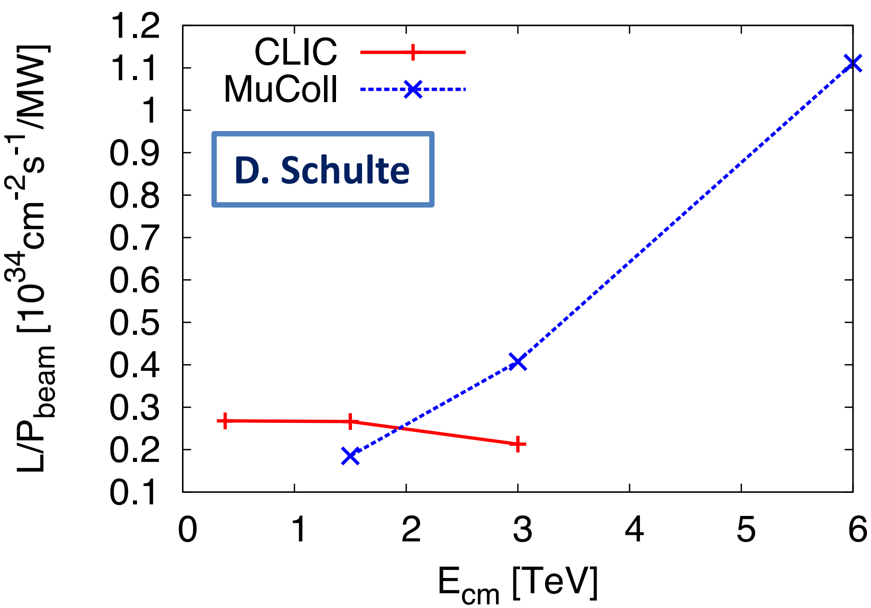
Technically Limited Potential Timeline

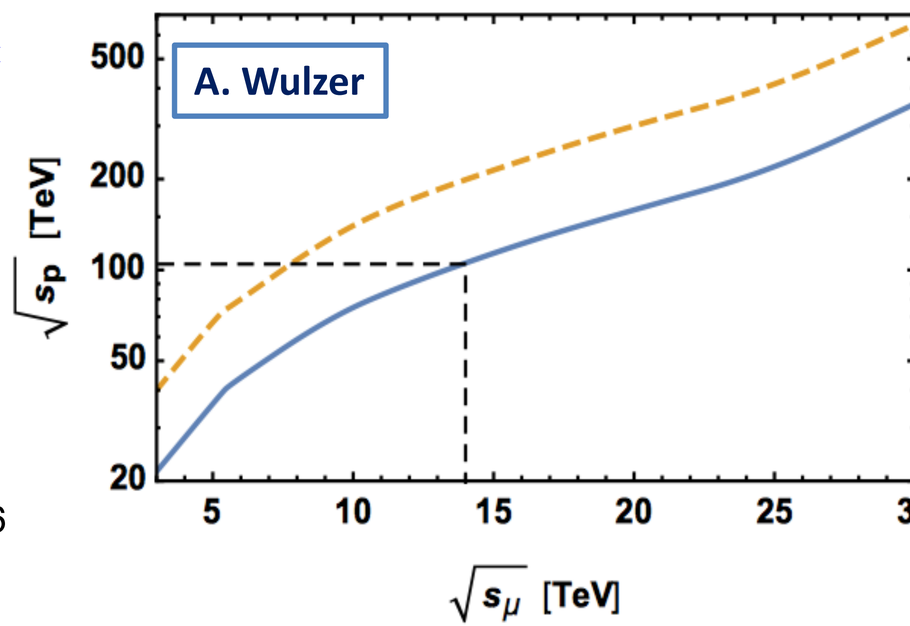
Physics Briefing Book arXiv:1910.11775v2 [hep-ex]



Why a multi-TeV Muon Collider?

cost-effective and unique opportunity for lepton colliders @$\sqrt{s}$ >3 TeV





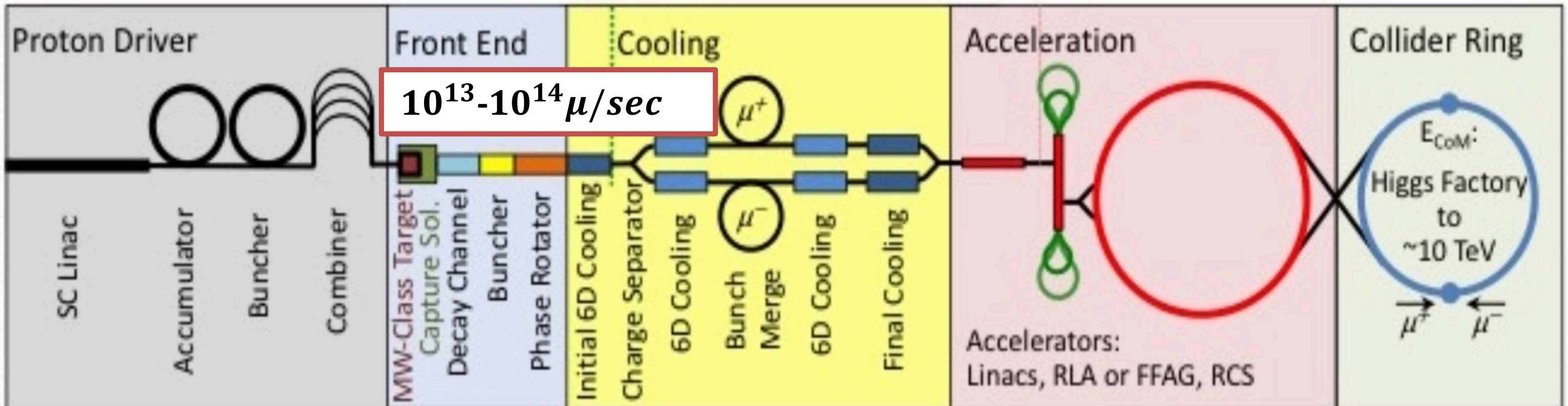
The luminosity per beam power is independent of collision energy in linear colliders, but increases linearly for muon colliders

Full collision energy available for particle production: 14 TeV lepton collisions are comparable to 100 TeV proton collisions for selected new physics process, **if sufficient luminosity is provided ~ $10^{35} cm^{-2} s^{-1}$**

Strong interest to reuse existing facilities and infrastructure (i.e. LHC tunnel) in Europe

proton (MAP) vs positron (LEMMA) driven muon source

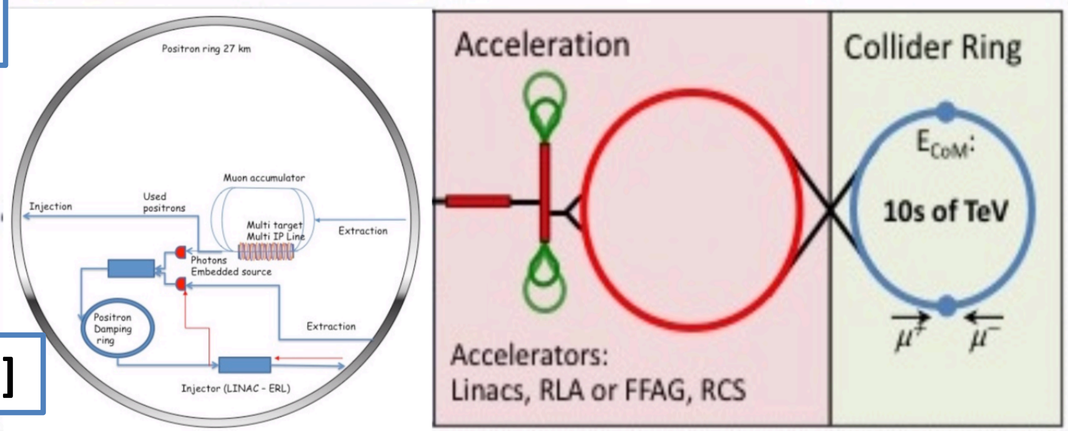
MAP



MUON JINST, shorturl.at/kxKU7

LEMMA

e+ source



arXiv:1905.05747v2 [physics.acc-ph]

➔ **need consolidation** to overcome technical limitations to reach higher muon intensities

muons produced with low emittance ➔ "no/low cooling" needed
low production **cross section**: maximum $\sigma(e^+e^- \to \mu^+\mu^-) \sim 1\ \mu b$
high heat load and **stress** in μ production target
synchrotron power O(100 MW) ← available 45 GeV positron sources

Organisation: new international collaboration

The study will be carried out in a collaboration of international partners and address the feasibility of the collider design and the physics experiments. Institutes can join by expressing their intent to collaborate through signing a light Memorandum of Understanding. The study will be initially hosted at CERN, which will provide administrative and organisational support.

Collaboration Board

- Oversees the study and approves important decisions
- One member per institute, elects it’s chair
- Elects project leader

Project leader

- Leads study
- Appoints steering committee representing physics, experiment, accelerator and technology, endorsed by Collaboration Board
- Reports regularly to the LDG on the progress

Advisory committee

- review study progress at least once per year
- recommend further actions
- reports to collaboration board

Initial Workplan

Exploratory phase (first two years)

- forming collaboration
- exploration of options
- making choices
- work on already identified key issues
- completion of key issues list
- definition of scope of demonstrator
- definition of prioritised work programme for definition phase

Definition phase

- implementation of work programme
- conceptual design of demonstrator
- conceptual design of key high-energy components, where possible
- hardware tests
- increase in resources required and redirection of work as needed

Note: will exploit synergies, e.g. with magnet development for hadron colliders

Note: Key Technologies

- Advanced detector concepts and technologies, requiring excellent timing, granularity and resolution, able to reject the background induced by the muon beams.
- Advanced accelerator design and beam dynamics for high luminosity and power efficiency
- Robust targets and shielding for muon production and cooling as well as collider and detector component shielding and possibly beam collimation.
- High field, robust and cost-effective superconducting magnets for the muon production, cooling, acceleration and collision. High-temperature super-conductors would be an ideal option
- High-gradient and robust normal-conducting RF to minimise muon losses during cooling.
- High rate positron production source and high current positron ring.
- Fast ramping normal-conducting, superferric or superconducting magnets that can be used in a rapid cycling synchrotron to accelerate the muons and efficient power converters.

Note: Key Technologies, cont.

- Efficient, high-gradient superconducting RF to minimise power consumption and muon losses during acceleration.
- Efficient cryogenics systems to minimise the power consumption of the superconducting components and minimise the impact of beam losses.
- Other accelerator technologies including high-performance, compact vacuum systems to minimise magnet aperture and cost as well as fast, robust, high-resolution instrumentation.

- Some technologies might still need to be identified

- And all the technologies required for the demonstrator

Synergies

- Important synergies exist for the key muon collider technologies
  - Magnet development for hadron colliders
    - e.g. link to high-temperature superconducting magnet development (Daniel Schoerling)
  - Superconducting RF cavities for hadron colliders and ILC
  - Normal-conducting structures for CLIC
  - Cooling for hadron colliders
  - Material, target, shielding, …
  - Instrumentation, vacuum, ...

- Synergies for physics and experiment will also be exploited
  - Physics studies for ALEGRO
  - Simulation tools
  - …

Snowmass 2021
Snowmass Planning Meeting Fermilab November 4 - 6, 2020
Snowmass Summer Study Univ. of Washington, Seattle July 11 - 20, 2021

Letters of Interest (submission period: April 1, 2020 – August 31, 2020)
Letters of interest allow Snowmass conveners to see what proposals to expect and to encourage the community to begin studying them. They will help conveners to prepare the Snowmass Planning Meeting that will take place on November 4 - 6, 2020 at Fermilab. Letters should give brief descriptions of the proposal and cite the relevant papers to study. Instructions for submitting letters are available at https://snowmass21.org/loi.
Authors of the letters are encouraged to submit a full writeup for their work as a contributed paper.

Contributed Papers (submission period: April 1, 2020 – July 31, 2021)
Contributed papers will be part of the Snowmass proceedings. They may include white papers on specific scientific areas, technical articles presenting new results on relevant physics topics, and reasoned expressions of physics priorities, including those related to community involvement. These papers and discussions throughout the Snowmass process will help shape the long-term strategy of particle physics in the U.S. Contributed papers will remain part of the permanent record of Snowmass 2021. Instructions for submitting contributed papers are available at https://snowmass21.org/submissions/.