RD_MUCOL

INFN activities for Muon Colliders
Referee Meeting

RD_FA WP8 *2016-2020 Mario Antonelli (LNF)*

- ✓ Status of the International Collaboration forming @ CERN
- ✓ Muon Collider @ SnowMass 2021
- ✓ INFN Activities:
  - RD_FA – WP8 till 2020:
    - LEMMA: optics design – targets – testbeam @ CERN
    - Physics – full simulation and experiment validation ++
  - On-going – starting
  - 2020
  - 2021

Nadia Pastrone
INFN TORINO

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 – 19 June 2020:

3 High-priority future initiatives

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

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

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

Accept the proposal of organisation

Accept the goals for the first phase

Daniel Schulte ad interim project leader

Strengthening cooperation and ensuring effective use of complementary capabilities

Core team:

Nadia Pastrone, Lenny Rivkin and Daniel Schulte

→ **International Muon Collider Collaboration kick-off virtual meeting**

(260 participants) https://indico.cern.ch/event/930508/

Muon Collider plan: Objective and Scope

Daniel Schulte

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 scientifically 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.

Deliverable:

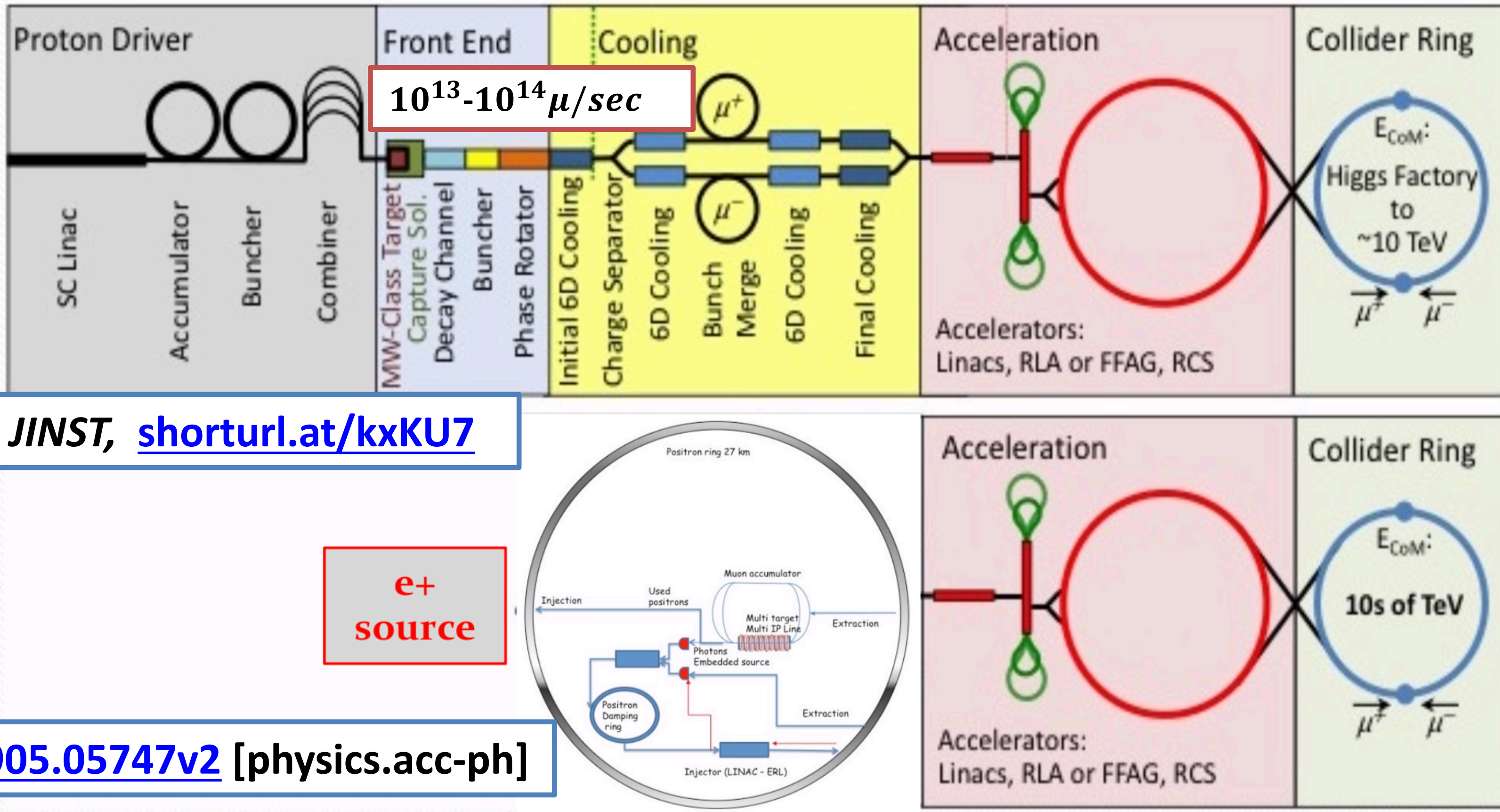
Report assessing muon collider potential and describing R&D path to CDR

Scope:

- Focus on two energy ranges:
  - 3 TeV, if possible with technology ready for construction in 10-20 years
  - 10+ TeV, with more advanced technology
- Explore synergy with other options (neutrino/higgs factory)
- Define R&D path

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

MAP



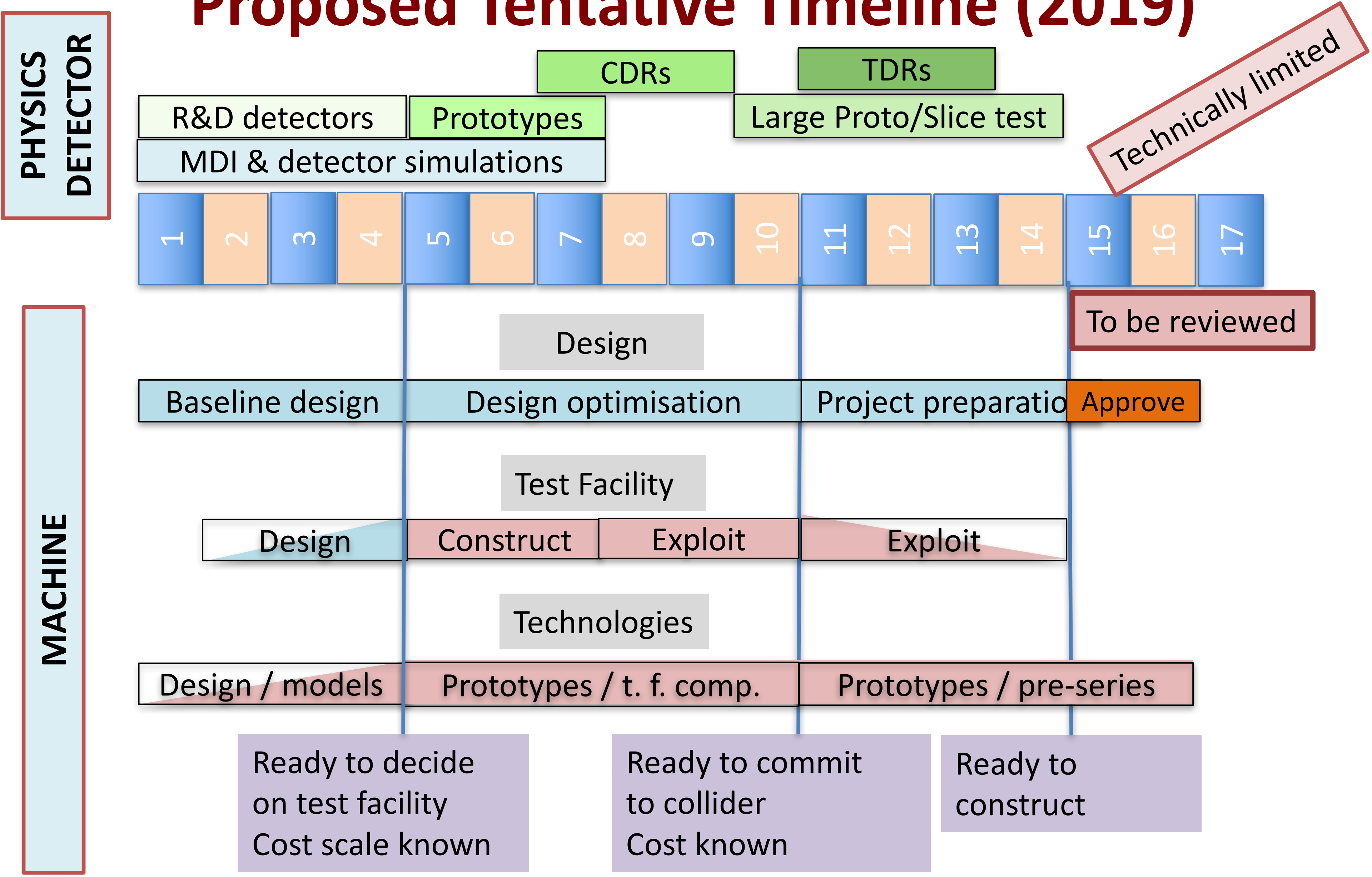
MUON JINST, shorturl.at/kxKU7

LEMMA

arXiv:1905.05747v2 [physics.acc-ph]

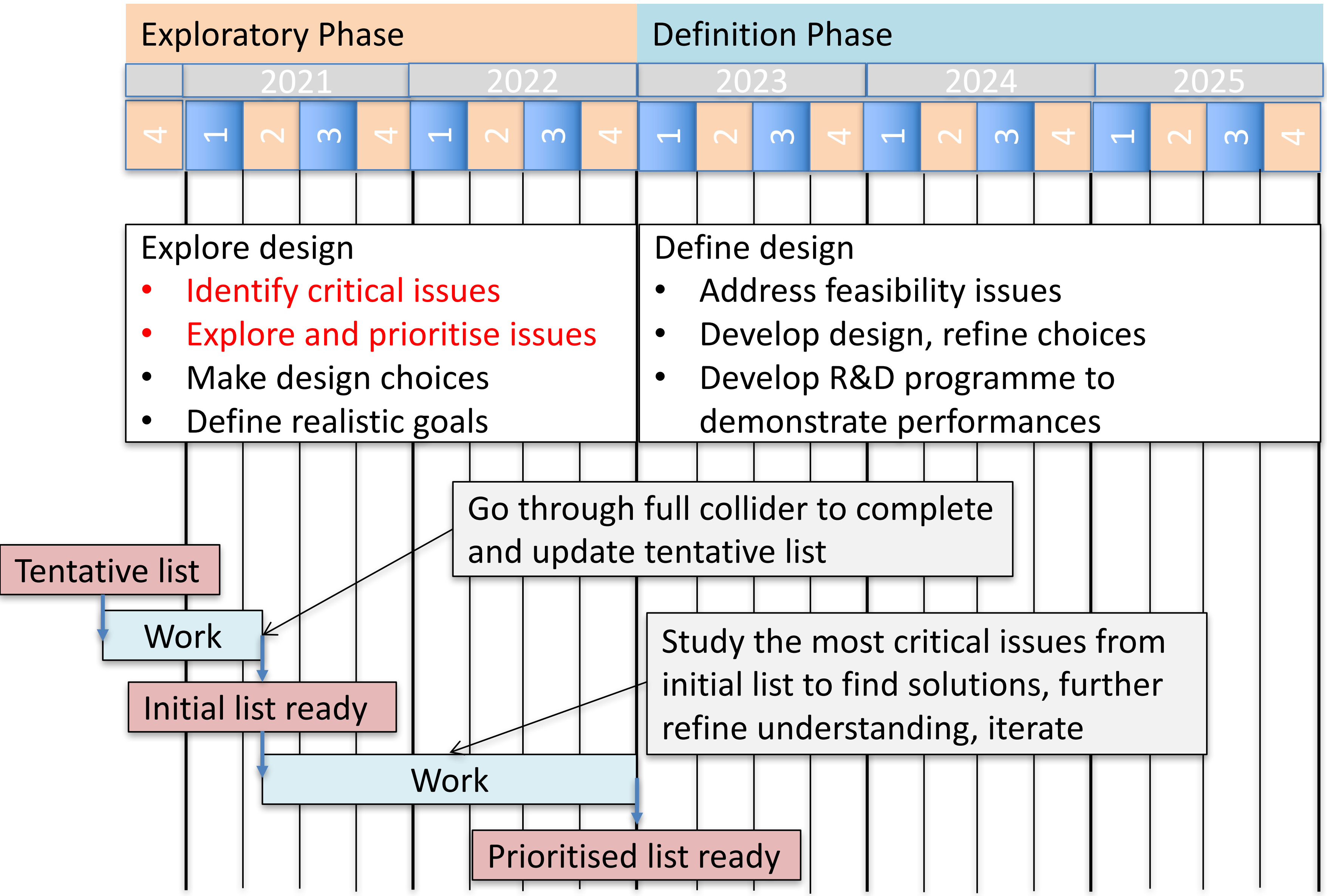
➔ **need consolidation** to overcome technical limitations to reach higher muon intensities

Proposed Tentative Timeline (2019)



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

Tentative Timeline



Initial Workplan

International Muon Collider Design Study, CERN, July 3, 2020

Daniel Schulte

Exploratory phase (first two years)

- forming collaboration
- exploration of options → **LEMMA**
- making choices
- work on already identified key issues → **see list**
- 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

Fields of interest

- **Physics Motivation.** Physics potential of the collider, physics benchmark points, requirements for energy and luminosity.
- **Experiment and Physics Simulation.** Performance of collider and detector, event reconstruction, simulation tools, performance benchmark points, detector performance goals.
- **Detector Design and R&D.** Detector development, prototypes, detector performance goals, . . .
- **Machine Detector Interface.** Background, . . .
- **High-energy Collider Design.** Experimental insertion, collider ring, accelerator ring, linacs, . . .
- **Proton-based Muon Source.** Proton complex, muon production, muon cooling, bunch merging
- **Positron-based Muon Source.** Positron production, positron acceleration, muon target, muon accumulation
- **Magnets.** High-field superconducting magnets, final focus quadrupoles, collider ring dipoles/combined function magnets, cooling solenoids, fast ramping magnet systems in accelerator, . . .
- **Radio Frequency Technology.** Superconducting RF for high energy acceleration and and normal-conducting high-gradient RF for the cooling, proton and positron RF, . . .
- **Radiation, Shielding, Losses, Targets, Collimation, Materials.** Detector/magnet shielding, high-power production target, neutrino radiation, beam losses, background, . . .
- **Other Technologies.** Including efficient cooling, good vacuum, robust instrumentation, . . .
- **Civil engineering and Infrastructure.**
- **Synergies.** Includes application of muon collider technology for other purposes, such as a neutrino factory.

attività INFN

- **Simulazioni di fisica**

(collaborazione con CSN4)

➔ **reach di fisica vincolato dal disegno dell'esperimento**

- **Disegno dell'esperimento**

(simulazioni e R&D in sinergia)

- **Machine Detector Interface**
- **Studi di radiazione da neutrino**
- **Sorgente LEMMA - disegno:**

fascio di positroni - bersagli – accumulatore

- **Test Beam @ CERN per 2022**

NEW

- **R&D tecnologia per magneti ++ dedicati al muon collider**

Ongoing activities: Physics-Experiment

International Muon Collider Design Study, CERN, July 3, 2020

- **Physics Motivation**

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

- **Experiment and Physics Validation**

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 $\mu\mu \rightarrow H\nu\overline{\nu} \rightarrow b\overline{b}\nu\overline{\nu}$ @ $\sqrt{s} = 1.5\ TeV$ 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

- **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**

Ongoing activities: MDI - Machine

- **Machine Detector Interface**

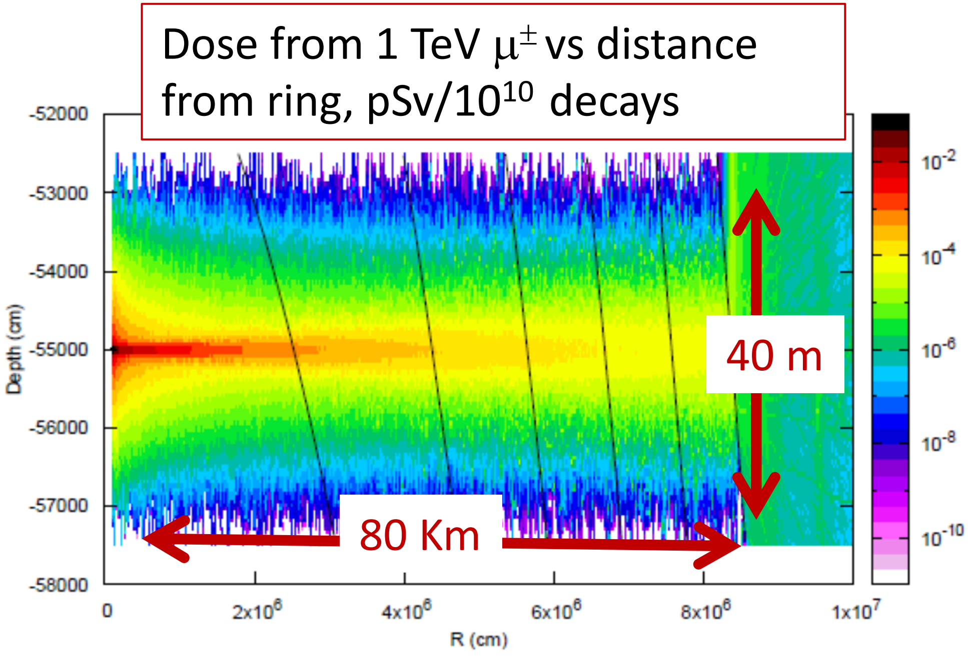
  Optics design required as part of the collider parameters studies. Fix constraints on nozzles design. Simulation tools. Strong collaboration with CERN.

  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

- 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, 20

  ➔ new proposal to run at CERN in 2022 with improved set-up

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

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

- **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**

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

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

Exploratory Phase – Key Topics

- Impact on the environment
  - The neutrino radiation and its impact on the site. This is known to require mitigation strategies for the highest energies.
  - Power consumption (accelerating RF, magnet systems, cooling)
- The impact of machine induced background on the detector, as it might limit the physics reach
- High-energy systems that might limit energy reach or performance
  - Acceleration systems, beam quality preservation, final focus
- High-quality beam production
  - Target and target area
  - Cooling, in particular final cooling stage that does not yet reach goal

Tentative Target Parameters

Parameter	Unit	3 TeV	10 TeV	14 TeV
L	10^{34} cm^{-2}s^{-1}	1.8	20	40
N	10^{12}	2.2	1.8	1.8
f_r	Hz	5	5	5
P_{beam}	MW	5.3	14.4	20
C	km	4.5	10	14
<B>	T	7	10.5	10.5
ε_L	MeV m	7.5	7.5	7.5
σ_E / E	%	0.1	0.1	0.1
σ_z	mm	5	1.5	1.07
β	mm	5	1.5	1.07
ε	µm	25	25	25
$\sigma_{x,y}$	µm	3.0	0.9	0.63

Based on extrapolation of MAP parameters

Note: The study will have to verify that these parameters can be met

Develop emittance budgets

Initial Organisation: IRAP

"Interim R&D Advisory Panel"

The IRAP will work during the initial phase of the study, mostly in two subgroups: one on detector and physics, one on the accelerator complex. Its mandate is to:

- propose initial detector performance specifications
- establish a list of critical issues for the detector
- suggest initial priorities for the identified critical issues
- propose the scope of the work on the most critical issues
- propose initial accelerator complex performance specifications
- establish a list of critical issues for the accelerator complex
- suggest initial priorities for the identified critical issues
- propose the scope of the work on the most critical issues

Members representing large laboratories and communities as well as critical technical expertise

- include all regions

Physics and Detector

Physics at 10+ TeV is in uncharted territory

- need important effort, theorists are motivated

Explore what can be done to develop physics case, also in comparison to other options

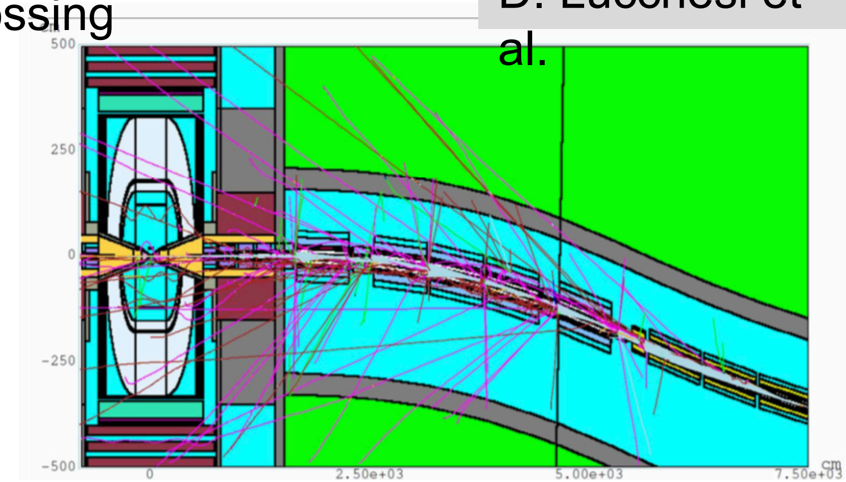
Need to include realistic assumptions about the detector performance

- use synergies with technologies that will be developed for other detectors
- identify additional needs for muon collider

Main detector challenge in machine detector interface (MDI)

At 14 TeV: 40,000 muons decay per m and bunch crossing
At 3 TeV: 200,000 muons per m and bunch crossing

D. Lucchesi et al.



Detector must be designed for robustness

- effective masking
- high granularity
- fast timing
- clever algorithms

Detailed design of machine is required for this

Accelerator Themes/Working Groups

- **MDI**
- **High-energy complex**
- **Muon cooling**
- **Target area**
- **Proton complex**
- **LEMMA specific activities**
  - generally integrate with other working groups (e.g. targets)
  - LEMMA is an alterative

- **Magnets (and power converters)**
- **RF (normal and superconducting)**
- **Targets, shielding, collimation, vacuum, cooling, …**
- **Technologies: Exploratory technology review: Instrumentation, beam transfer, …**

- **Beamdynamics, simulation codes, …**
- **Layout, environment, infrastructure**

Some Collaboration Discussions (Machine)

France
- CEA: RCS accelerator ring, RF, high-field solenoid
- CNRS: GUINEA-PIG, maybe wandering snake with Annecy

UK
- Cooling, FFAGA, (final focus), could do some source work

Germany
- KIT, Darmstadt, magnets, cooling
- Rostock: high-energy acceleration, MPI: muon cooling
- DESY waiting for discussion

Italy
- INFN: MDI, collective effects, magnets, targets, LEMMA

Switzerland
- beam-beam (EPFL), some more interest to be discussed

Spain
- some interest in the physics, need to follow up on machine

Sweden, Norway
- Uppsala some interest (proton complex), ESS would require add. funding, Oslo

Austria
- some interest in physics, student on machine

US
- SLAC, JLAB, providing old design files

Sorry to have started mainly in Europe
CERN is going to be reorganised …
Need to discuss with other regions

Meetings / Working Groups

Project meeting

- Includes physics, detector and machine
- Report about important progress in the project
- Present and discuss important decisions
- Half-day long
- Every few months
- Next one maybe end of October/beginning of November

Design meeting

- Follow the overall design of the accelerator facility
- Facilitate contacts between all accelerator activities
- Allow to have technical discussions in a common timeslot
- Specialised accelerator and technology working groups will report here
- Timeslot Monday 16:00 CET
- Weekly/biweekly
- Typically one main subject, but also short news

Specialised working groups

- Spawn in the design meeting, as needed
- Design the machine and its components
- Organise their meetings according to the preferences of their members

International Collaboration

- IMPORTANT e-group cern

MUONCOLLIDER-DETECTOR-PHYSICS

MUONCOLLIDER-FACILITY

Please register for the mailing lists interesting for you
- Go to http://e-groups.cern.ch/
- Sign in with your institute (you find a list at the bottom of the sign-in page)
- Then search for "muoncollider"

- Indico: https://indico.cern.ch/category/11818/
- Website: https://muoncollider.web.cern.ch/

- MoU in preparation
- Plan presented to LDG, to be discussed in September during Council week
- Machine meeting are starting: September 14 Kick-off
- Soon planned to set-up an Interim R&D Advisory Panel to work during the initial phase of the study as representing the activities and the communities
- Plan first project meeting (maybe in November?)

Attività

SEDE	**RL**	**PHYSICS**	**FULL SIM**	**TARGETS**	**XTAL**	**LEMMA**	**Lumi**	**MDI**	**Exper**	**Tracker**	**Calo**	**Muons**	**TestBeam-LEMMA**	**Calcolo**	**Magnets R&D**
BA	A. Colaleo	x	x	x					x			x	x	x	
BO	F. Maltoni	x													
FE	A. Mazzolari			x	x										
LNF	M. Boscolo			x		x					x		x		
LNL	S. Corradetti			x											
MI	A. Bacci					x									
MIB	M. Bonesini			x											
PD	D. Lucchesi	x	x				x	x	x		x		x	x	
PV	C. Ricciardi	x	x				x	x	x			x	x		
RM1	F. Anulli	x	x	x				x	x				x		
RM3	A. Passeri			x											
TO	N. Amapane	x	x	x			x	x	x	x	x		x		
TS	S. Levorato	x	x				x	x	x	x				x	

Anagrafica

SEZIONE	NOME COGNOME	TIPO	CONTRATTO	QUALIFICA	RICERCATORI		TECNOLOGI		TOT. PERS.	FTE	FTE / PERS.
BA					0.95 fte	9 pers.	0 fte	pers.	9	1.0	0.106
BO					0.95 fte	4 pers.	0 fte	pers.	4	1.0	0.238
FE					0.4 fte	3 pers.	0.1 fte	1 pers.	4	0.5	0.125
LNF					1.8 fte	6 pers.	1.1 fte	4 pers.	10	2.9	0.290
LNL					0.15 fte	1 pers.	0.25 fte	4 pers.	5	0.4	0.080
MI					0.25 fte	2 pers.	0 fte	pers.	2	0.3	0.125
MIB					0.3 fte	2 pers.	0.1 fte	1 pers.	3	0.4	0.133
PD					3.65 fte	12 pers.	0.75 fte	3 pers.	15	4.4	0.293
PV					0.9 fte	5 pers.	0.3 fte	1 pers.	6	1.2	0.200
RM1					2.05 fte	7 pers.	0 fte	pers.	7	2.1	0.293
RM3					0.4 fte	5 pers.	0 fte	pers.	5	0.4	0.080
TO					1.9 fte	14 pers.	0.2 fte	2 pers.	16	2.1	0.131
TS					0.2 fte	1 pers.	0.2 fte	1 pers.	2	0.4	0.200
TOTALE					13.9 FTE	71 PERS.	3 FTE	17 PERS.	88	16.9	0.192

Sinergie con sigle/progetti in corso:

INFN-MC **TimeSPOT**

ERC e UFSD

AMUSE

Outreach – progetto CC3M

in fase di approvazione:

AIDAinnova **I.FAST**

CA e GE hanno espresso interesse

SnowMass LoI and activities

Planning Meeting SnowMass 5-8 ottobre
https://indico.fnal.gov/event/44870/

- Marica Biagini contact per LEMMA
- Donatella Lucchesi contact for Muon Collider software

➔ Software tutorial SnowMass Muon Collider ➔ **September 30 at 5pm CET**
https://indico.fnal.gov/event/45187/

- Sottomessse LoI:
  - Fisica
  - Detector
  - Luminosità
  - MDI
  - LEMMA
  - Bersagli

Richieste Complessive 2021

In K€

Struttura	A carico dell'I.N.F.N.													A carico di altri enti
	missioni		consumo	altri_cons	seminari	trasporti	licenze-SW	manutenzione	inventario	apparati	spservizi	**TOTALI**		
BA.DTZ	13.50		13.50									**27.00**		
BO	6.00											**6.00**		
FE	9.00		25.00					11.00				**45.00**		
LNF	17.00		10.00									**27.00**		
LNL	7.00		5.00									**12.00**		
MI	10.00											**10.00**		
MIB	4.50		5.00					4.00				**13.50**		
PD	20.00		30.00						5.00			**55.00**		
PV.DTZ	8.00											**8.00**		
RM1	12.00		2.00									**14.00**		
RM3.DTZ	6.00		4.50									**10.50**		
TO	16.00	45.00	65.00									**81.00**	**45.00**	
TS.DTZ	3.00								5.00			**8.00**		
	132.00	*45.00*	**160.00**					**15.00**	**10.00**			***317.00***	***45.00***	

Calcolo Tier1: Disco e CPU

Principali richieste

- Calcolo (PD e TS ➔ Richiesto anticipo) + T1
- Bersagli – Materiali (RM1, RM3,LNL, MIB)
  ➔ da riasssegnare 50 keu ora a LNF
- Cristalli (FE)
- R&D rivelatori – Tracciatore e Calorimetro – (LNF ➔ richiessta anticipo, PD e TO)
- Test Beam LEMMA – preparazione in corso

Test Beam @ CERN

- 2020 – acquisto pixel ~ 21 kCHF ➔ 25 keu assegnati
  restano 5 keu destinati alla meccanica
  richiesta di anticipare l'acquisto di 1 componente DAQ

- 2021 richieste
  - BA GEM 13.5 keu ➔ si potrebbe anticipare al 2020 acquisto fino a 3 camere (3.5 keu/ciascuna)
  - PD DAQ 20 keu ➔ si chiede di poter avviare acquisto e/o anticipare
  - TO Trigger 5 keu
  - RM1 meccanica

CERN-SPSC-2020-004

LEMMA-TB: an experiment to measure the production of a low emittance muon beam

N. Amapane[a,b], M. Antonelli[c], F. Anulli[d], N. Bacchetta[h], N. Bartosik[b], M. Bauce[d], A. Bertolin[h], M. Bianco[m], C. Biino[b], O. R. Blanco-Garcia[c], M. Boscolo[c], A. Braghieri[q], A. Cappati[a,b], F. Casaburo[l,d], M. Casarsa[i], G. Cavoto[l,d], N. Charitonidis[*m], A. Colaleo[p], F. Collamati[d], G. Cotto[a,b], D.Creanza[p], C. Curatolo[h], N. Deelen[t], F. Gonella[h], S. Hoh[n,h], M. Iafrati[c], F. Iacoangeli[d], B. Kiani[b], D. Lucchesi[n,h], V. Mascagna[e,f], S. Mersi[m], A. Paccagnella[n,h], N. Pastrone[b], J. Pazzini[n,h], M. Pelliccioni[b], B. Ponzio[c], M. Prest[e,f], C. Riccardi[q,r], M. Ricci[c], R. Rossin[n,h], M. Rotondo[c], P. Salvini[q], O. Sans Planell[a,b], L. Sestini[h], L. Silvestris[p], A. Triossi[o], I. Vai[q,s], E. Vallazza[f], R.Venditti[p], S. Ventura[h], P. Verwilligen[p], P. Vitulo[q,r], and M. Zanetti.[n,h]

Request for 3-weeks beam time in H4 submitted to SPSC
http://cds.cern.ch/record/2712394

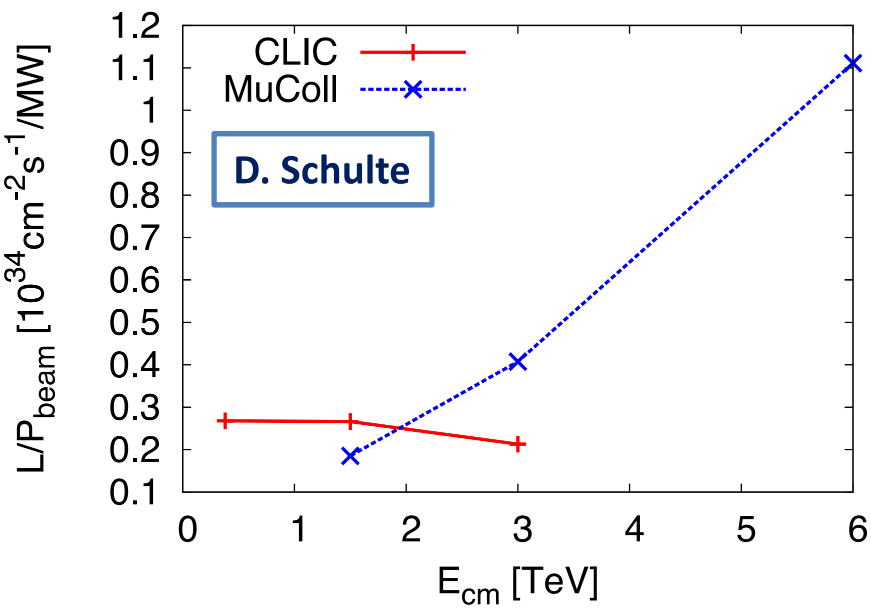
Conclusioni

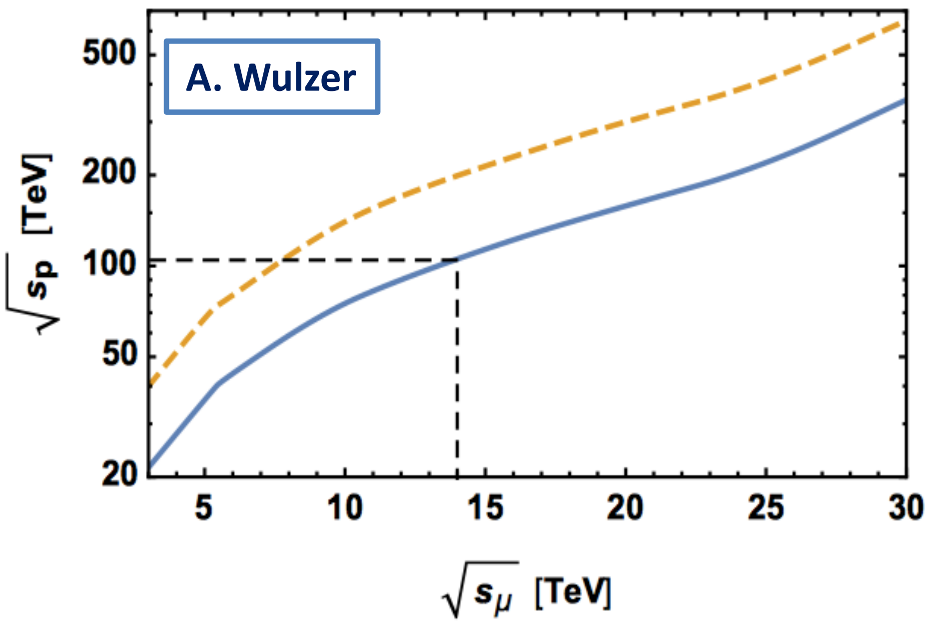
- **Approvato progetto RISE – AMUSE**
  - in collaborazione con FNAL Muon Campus
  - Donatella Lucchesi (Univ. PD) per Muon Collider con FNAL, BNL, SLAC
- Collaborazione internazionale in formazione
  - Preparazione Roadmap R&D Acceleratori e Rivelatori → per estate 2021
- Incontro a breve con INFN-Acceleratori
- Forte contributo a SnowMass 2021: LoI e attività in corso
  - Tutorial software muon Collider – 30 settembre
  - Planning Meeting: Fisica – Acceleratore – Rivelatori (https://indico.fnal.gov/event/44870/)

extras

Why a multi-TeV Muon Collider?

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





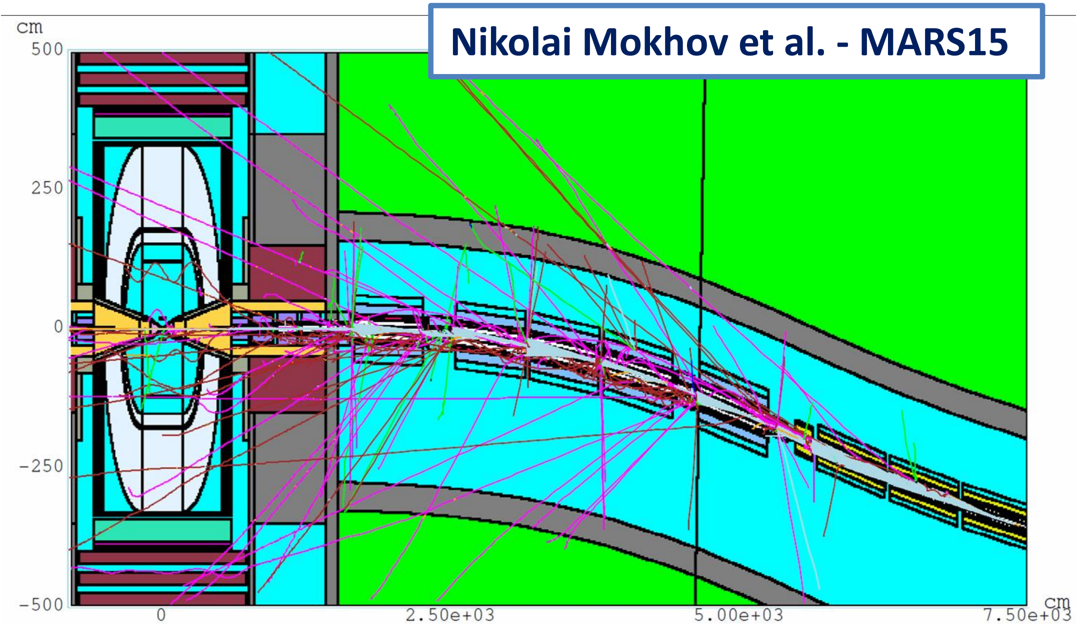
The luminosity per beam power is independent of collision energy in linear colliders, but increases linearly for muon colliders

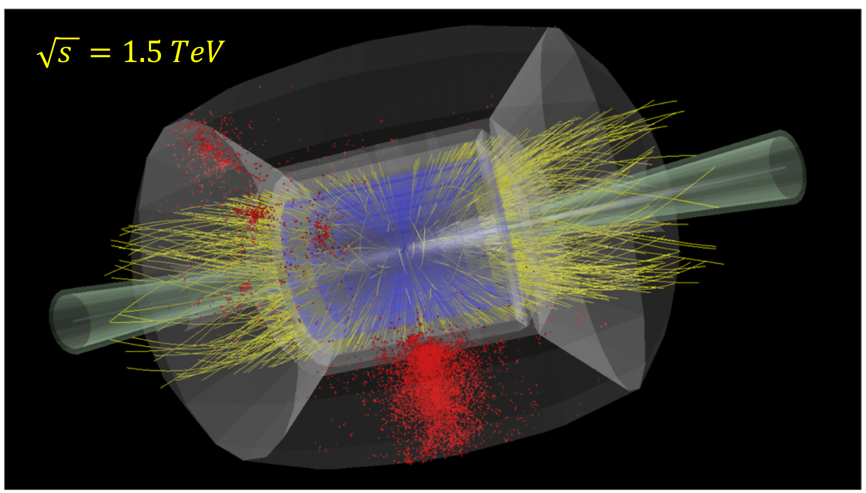
Full collision energy available for particle production: 14 TeV lepton collisions are comparable to 100 TeV proton collisions for selected new physics process, **if sufficient luminosity is provided ~ $10^{35} cm^{-2} s^{-1}$**

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

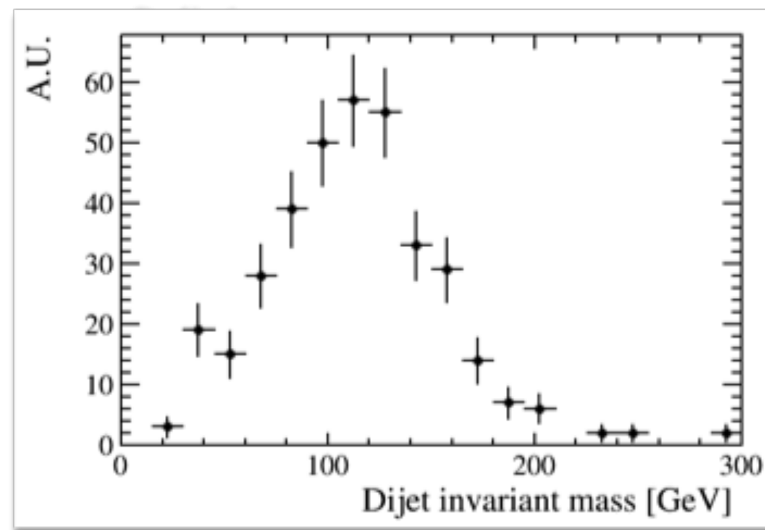
Muon Beams Induced Background

Nikolai Mokhov et al. - MARS15





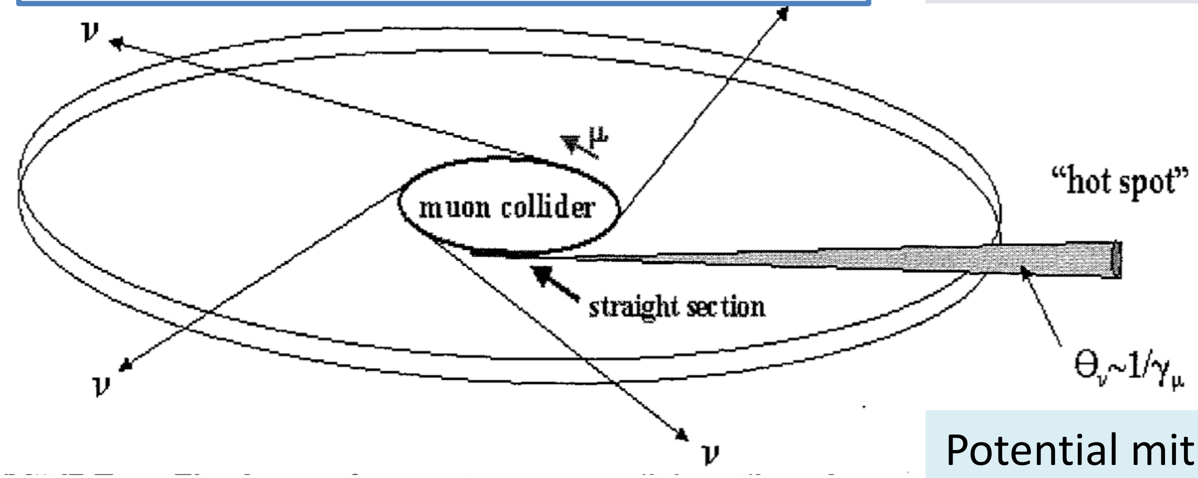
$\mu^+\mu^- \to H\nu\bar{\nu} \to b\bar{b}\nu\bar{\nu}$ + beam-induced background fully simulated



Challenge: Neutrino Radiation Hazard

Youri Robert – Paola Sala – Daniel Schulte
CERN Muon Collider Meeting
https://indico.cern.ch/event/886491/

Neutrinos from decaying muons can produce showers just when they exit the earth



Particularly bad in direction of straights
But also an issue in the arcs

Becomes more important at higher energies (scaling E^3)

US study concluded that 6 TeV parameters are OK

Reasonable goal is 0.1 mSv/ year, but to be verified

Potential mitigation by
- Site choice
- Owning the land in direction of experimental insertion

- Having a dynamic beam orbit so it points in different directions at each turn in the arcs
  - Or at least paint the beam in the the straights to dilute radiation

On-going simulations and studies for mitigation even with existing/future tunnels

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

Critical Machine Issues Include:

- **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 (LEMMA).
- **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.
- **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**.

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.
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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