Istituto Nazionale di Fisica Nucleare

Sezione di Pavia

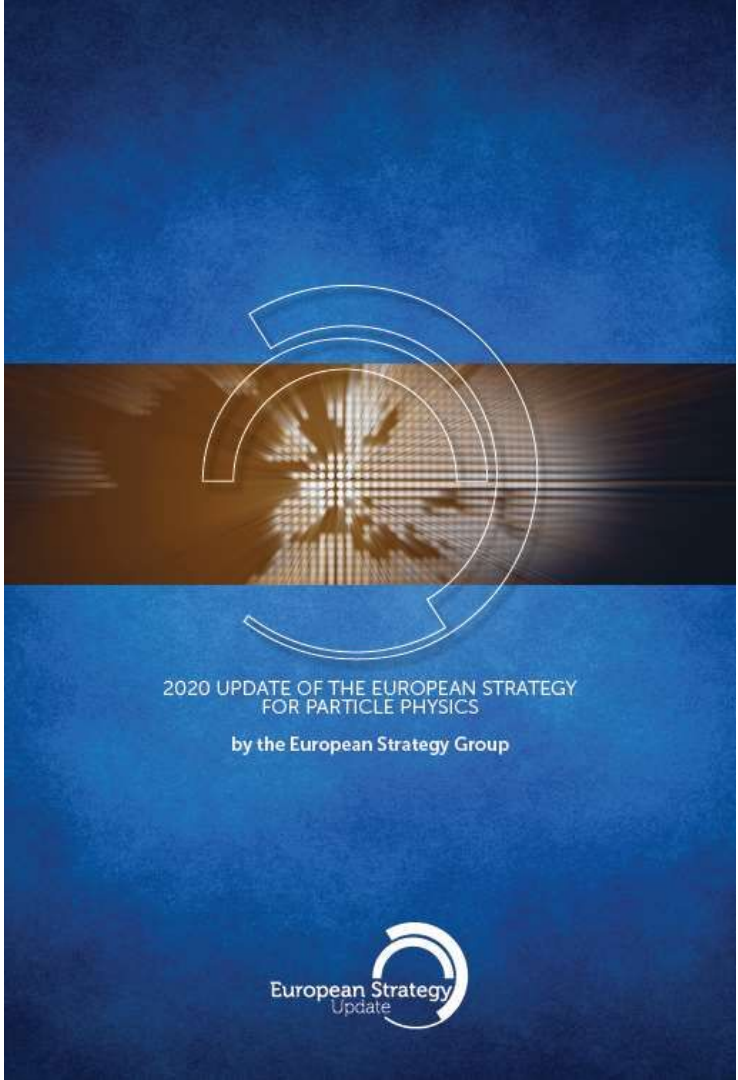
Preventivi scientifici 2021: RD_FCC, RD_MUCOLL, MUonE

Andrea Negri

Pavia, 14 Luglio 2020

European Strategy Update

- L’update dell’European Strategy for Particle Physics è stato reso pubblico il 19 Giugno
  - Web page: link
  - Strategy statements: link
  - Deliberation document: link
  - Presentazione Tenchini@gr1: link



Andrea Negri

In breve

- Priorità allo sfruttamento delle potenzialità di **HL-LHC**
  - Rimane il supporto per la Neutrino Platform con esperimenti fuori dall'Europa, LBNF (Japan) e DUNE (USA)
- Centralità di **FCC-hh** (e **FCC-ee**)
  - *"investigate the technical and financial feasibility of a future hadron collider at CERN with a √s of at least **100 TeV** with an **e^+e^- Higgs** and electroweak **factory** as a possible 1st stage"*
  - Timescale studi fattibilità: prossima strategy update
- Se i tempi saranno compatibili: collaborare con ILC
  - Come dire: se c'è ILC, allora FCC-ee è più a rischio

In breve

- **R&D** sui **magneti** superconduttori
  - Inclusi quelli ad alta temperatura
- **R&D** sugli **acceleratori**
  - *“A roadmap should prioritise the technology”*
  - *“... coordinated among CERN and **national laboratories** ...”*
  - *“... breakthrough in plasma acceleration schemes … compatible with university capacities and **small and medium laboratories**”*
- Rientro in auge del **muon collider**
  - *“an international design study for a muon collider, as it represents a unique opportunity to achieve a multi-TeV energy domain”*

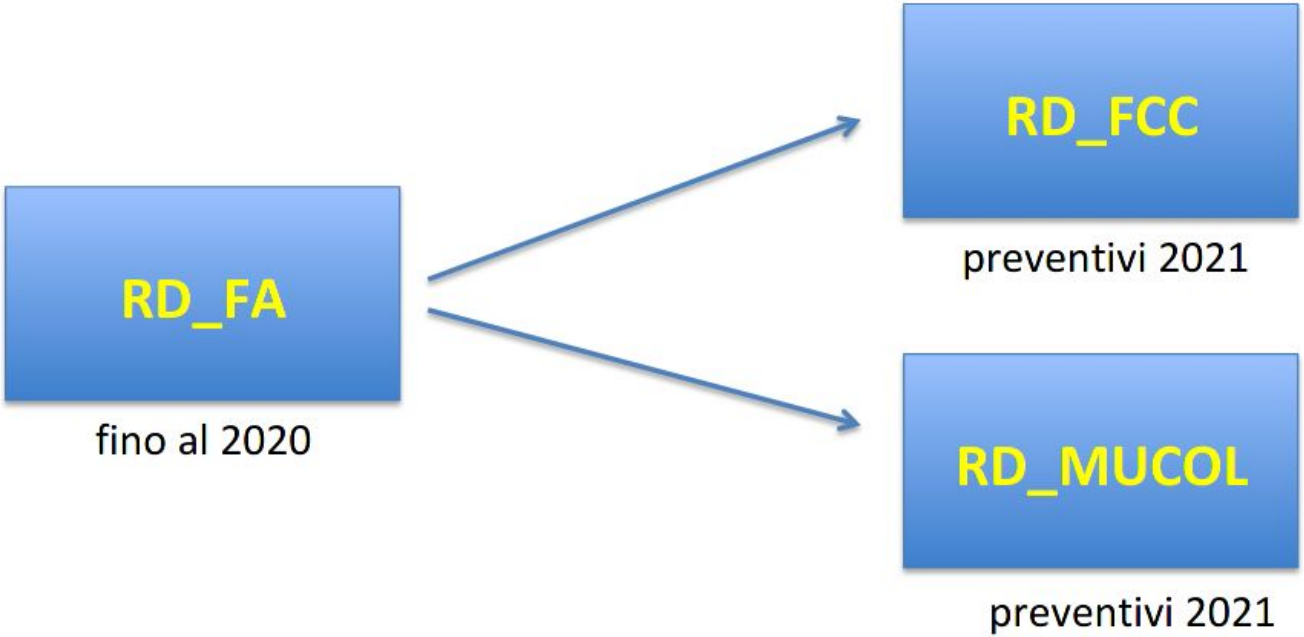
Osservazioni del presidente di GR1

- **FCC** ha un ruolo centrale in questo update
  - Stagione TRD per FCC-ee/hh e la fase preparatoria per il tunnel
- **CLIC** viene messo in secondo piano
  - Non menzionato nel documento di sommario
- La **Beam Dump Facility** non entra nel piano
  - *“such a project would be difficult to resource within the CERN budget, considering the other recommendations of this Strategy “*
- Non si parla piu’ di **HE-LHC**
  - consistente con il risultato degli studi fatti per Granada

RD_FA (Tenchini)

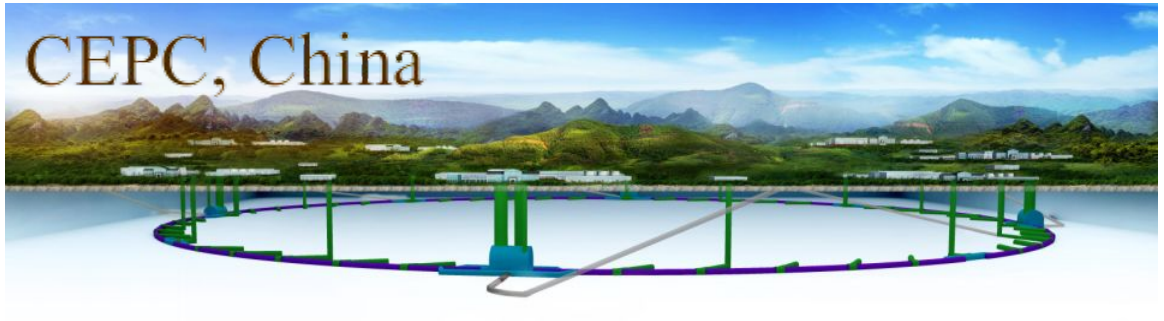
- Il contributo INFN ai CDR di **FCC** e' stato di primordine
  - sviluppato uno dei due detector concepts per FCC-ee (**IDEA**)
  - studi di physics -> requirements dei detector per FCC-hh/ee
  - Prossimo passo: TDR
- INFN fondamentale per rinascita dell'idea di **Muon Collider**
  - Prossimo pass: CDR
- Importante trovare il modo per continuare ad avere grande impatto, coinvolgendo i **postdoc**
  - NdR: non banale senza cambiare le obsolete politiche sulle opportunità di carriera

Conseguenze EU strategy su sigle in CSN1



RD_FCC


FCC, Cern
FUTURECIRCULARCOLLIDER
CONCEPTUAL DESIGN REPORT
fcc.web.cern.ch


CEPC, China

Anagrafica

9 persone

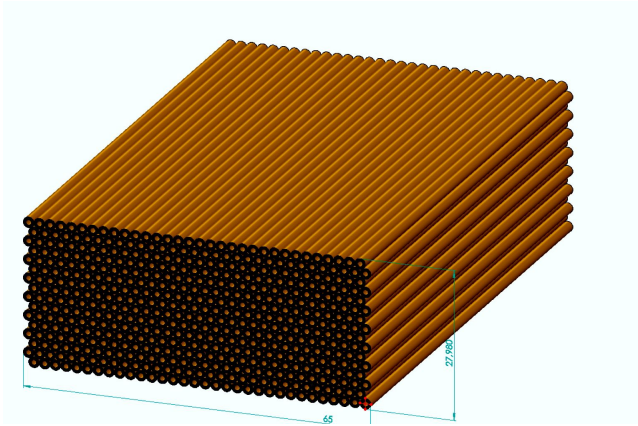
1.7 FTE

R.L. G. Gaudio

	Ricercatori	%
1	Jinky Agarwala	30
2	Roberto Ferrari	30
3	Gabriella Gaudio	20
4	Andrea Negri	10
5	Lorenzo Pezzotti	30
6	Fulvio Piccinini	5
7	Giacomo Polesello	20
8	Simone Sottocornola	20
	Tecnologi	%
1	Carlo Carloni Calame	5
	FTE	1.7

Attività previste 1/4

- Call CSN 5 → prototipo adronico full-containment
    - ~ 65 × 65 × 200 cm^3 → ~87 k tubetti / fibre
  - building block → “mini-modulo”
    - 32 × 16 = 512 tubetti / fibre
    - ~ 2.8 × 6.5 × 200 cm^3
- Piano B (CSN 1) → 2021:
  - costruzione di 4 mini-moduli



- Maggiori dettagli nel talk di Bob@CSN1: link

Attività previste 2/4

- Obiettivi:
  - Studio procedura di assemblaggio
  - Analisi riproducibilità dei mini-moduli
  - Studio supporti meccanici

  (in collaborazione con Milano e Pisa)

  Inoltre:

  - Studio elettronica di readout (BO, CT, MI, PV, CAEN)

Attività previste 3/4

- SW, performance e analisi dati (MI, PV, RM1)
  - Integrazione nel framework FCCSW
  - Largo programma di sviluppo di full-simulation (Geant4)
  - Sviluppo analisi di stati finali con bosoni massivi. In particolare (benchmark):
    - $Z/W/H \to jj$, $H \to ZZ^*/WW^* \to 4j$, $HZ \to 6j$, $H \to \gamma\gamma$, $Z/H \to \tau\tau$
  - Algoritmi deep-learning per ricostruzione dati

(tutte attività già iniziate con risultati molto interessanti)

Attività previste 4/4

- Altre novità:
  - Sviluppo contatti con colleghi americani → cristalli dual-readout
    - Interesse crescente → CEPC workshop settimana prossima
    - Proposta (americana) per inserimento opzione in IDEA
  - Sviluppo contatti con colleghi di FCC France e del CERN (FCCSW)

Responsabilità

- Responsabile nazionale: Franco Bedeschi
- Responsabile WP calorimetria dual-readout: Roberto Ferrari
- Sezioni coinvolte: BO, CT, MI, PI, PV, RM1
- Responsabile locale: Gabriella Gaudio

Richieste finanziarie

RD_FCC

Sviluppi meccanica (PI, PV):

	CONSUMO	INVENTARIABILE	MISSIONI	SEDI	
	k€	k€	k€		
tubetti	3,5			PV	
scintillanti	11,8			PI	
cherenkov	1,5			PI	
colla	0,5			PV	
PMT		5		PI	
Sistema Costruzione		15		PV	
Sistema Test fibre		5		PI	
Sistema Test mecc.		2		PV	
meeting, contatti ditte, conf			2,5	PV	
meeting, contatti ditte, conf			1	PI	
SUM	**17,3**	**27,0**	**3,5**		**47,8**

[23.5 k€ Pavia + 24.3 k€ Pisa]

Richieste Servizi Sezione

RD_FCC

- Officina meccanica: **5 m.u**.
- Elettronica: **5 m.u.**

RD_MUCOLL

- Lucchesi@gr1: slide
- Pastrone@gr1: slide

Anagrafica

RD_MUCOLL

Sezioni INFN: **BA, BO, FE, LNF, MI, MIB, PD, PV, RM1, RM3, TO, TS + (CA,GE,LNL)**

Responsabile nazionale : **Nadia Pastrone**

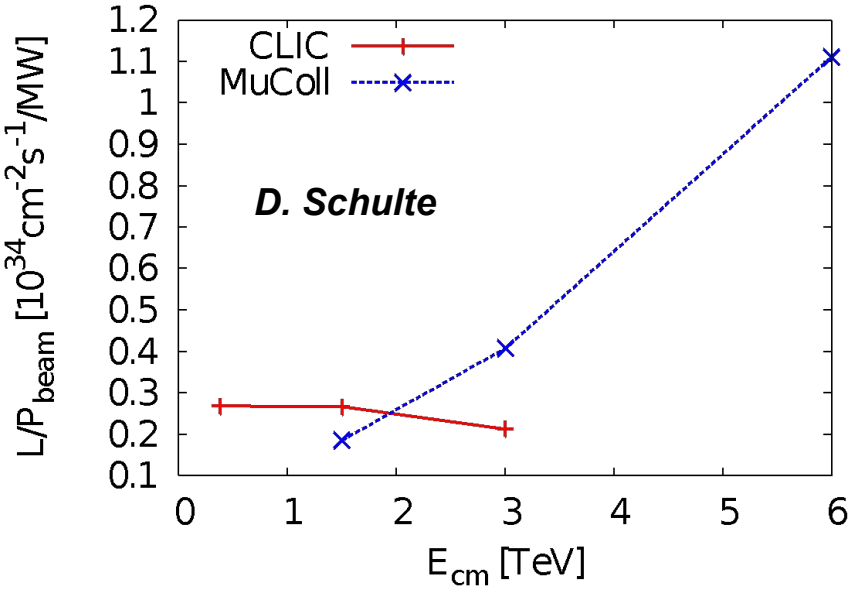
Ricercatori						
	Nome	Età	Contratto	Qualifica	Aff.	%
1	Aimè Chiara		Associato	Dottorando	CSN I	20
2	Piccinini Fulvio		Dipendente	Dirigente di Ricerca	CSN IV	5
3	Riccardi Cristina		Associato	Prof. Associato	CSN I	30
4	Salvini Paola		Dipendente	Ricercatore	CSN I	25
5	Vitulo Paolo		Associato	Prof. Associato	CSN I	10
				Numero Totale Ricercatori	5	FTE: 0.9

Tecnologi						
	Nome	Età	Contratto	Qualifica	Aff.	%
1	Vai Ilaria		Associato	Ricercatore A Tempo Determinato Tipo A	CSN I	30
				Numero Totale Tecnologi	1	FTE: 0.3

Why a multi-TeV Muon Collider?

RD_MUCOLL

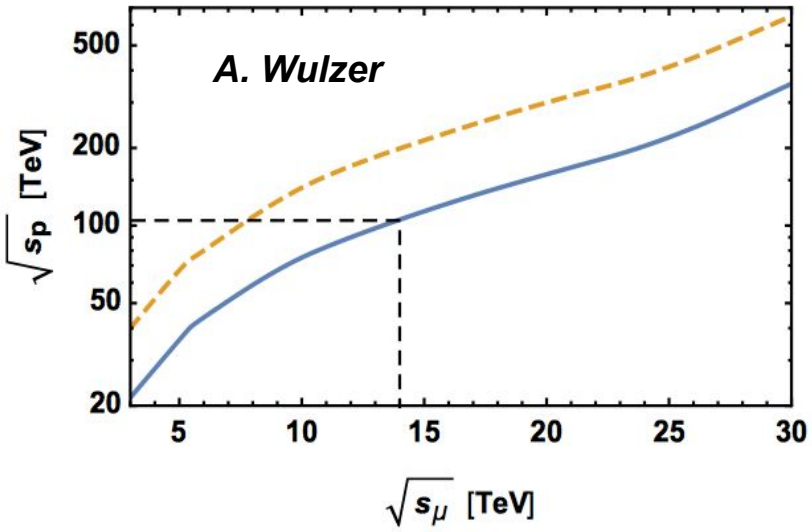
- Cost effective & unique opportunity for lepton collider $\sqrt{s}$>3TeV
- The luminosity per beam power
  - independent of collision energy in linear colliders
  - increases linearly for circular muon colliders
- Strong interest to reuse existing facilities and infrastructure
  - i.e. LHC tunnel in Europe



Why a multi-TeV Muon Collider?

RD_MUCOLL

- Cost effective & unique opportunity for lepton collider $\sqrt{s}$>3TeV
- Full collision energy available for particle production
  - **14 TeV** lepton collisions comparable to **100 TeV** proton collisions for selected new physics process
  - if sufficient luminosity is provided ~10^{35} cm^{-2} s^{-1}



EU Strategy

- Input Document to EU Strategy Update - Dec 2018:
  - “Muon Colliders,” arXiv:1901.06150 by CERN-WG on Muon Colliders
- ESU: finding and recommendations:
  - **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

EU Strategy

- 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.

CERN Laboratory Directors Group

RD_MUCOLL

- Should establish an Accelerator R&D roadmap
  - to define a route towards goals of 2020 ESU
  - bringing together capabilities of **CERN and LNLs** to carry out R&D and construction and operation of demonstrator
- Muon Collider Working Group (Sep 2017) 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

CERN Laboratory Directors Group

RD_MUCOLL

- LDG decided (July 2)
  - Agree to start building the **collaboration** for international muon collider design study
  - Accept the proposal of organisation
    - Daniel Schulte as ad interim project leader
    - Core team (Nadia Pastrone, Lenny Rivkin and Daniel Schulte) will start collecting **MoUs**
  - Accept the goals for the first phase: in time for the next ESU, the study aims to establish whether the investment into a full CDR and a demonstrator is justified

Scope

RD_MUCOLL

- Develop a baseline concept for a muon collider at two √s
- Around **3 TeV**, well above higgs factory
- Above **10 TeV**, beyond capabilities of normal linear colliders
  - Requires technologies not be ready within 10-20 years.
- Explore potential for other purposes: Higgs or neutrino factory
  - provided synergetic with the high-energy collider study.
- Identify an **R&D path** toward a conceptual design
- The collaboration will design a **demonstrator**

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

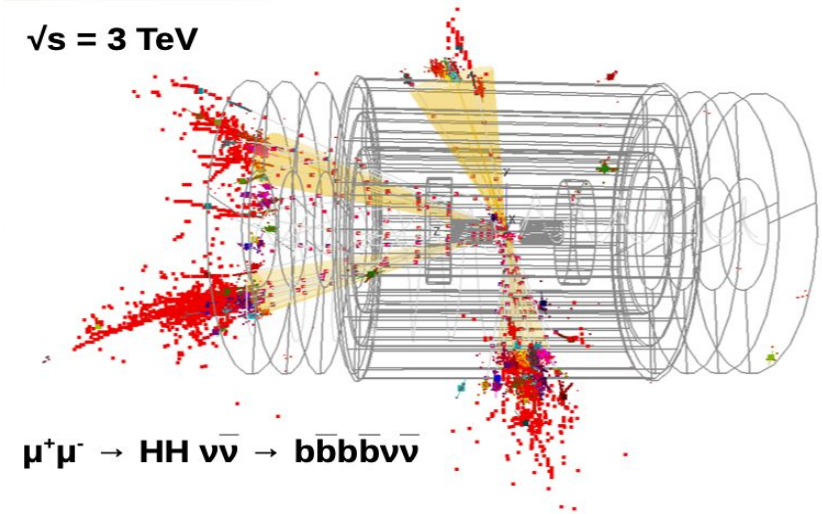
Experiment and Physics Validation RD_MUCOLL

- Flexible framework: background and detector simulation, event reconstruction to study detector requirements/performances
  - D.Lucchesi et al. + US-MAP + CLICdp
    → the core team is growing + SnowMass21 interest
  - 1st full-simulation study μμ→Hνν→bbνν @1.5 TeV; [J. Inst. 15 P05001]
- 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!

Study detector requirements

RD_MUCOLL

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



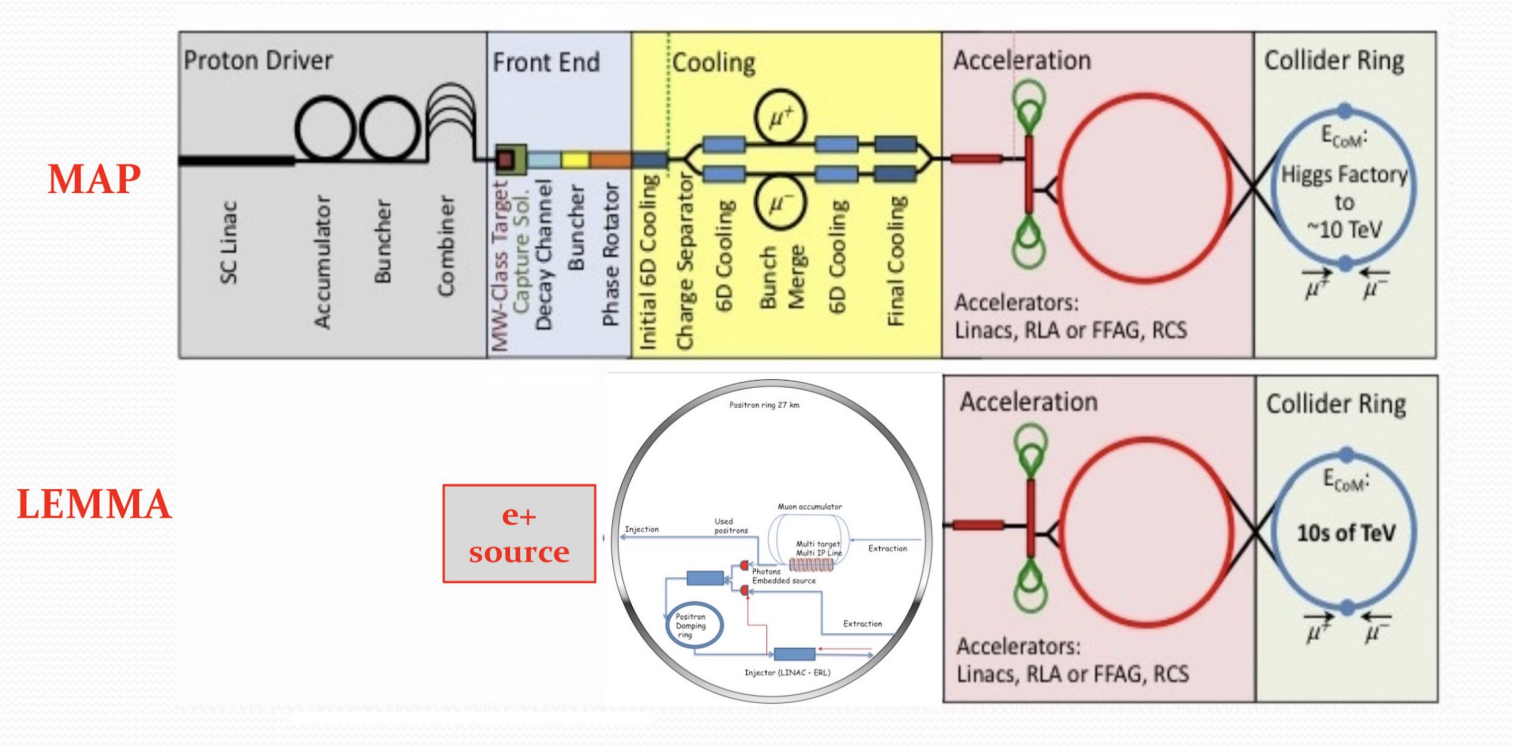
P. Andreetto, N. Bartosik, A. Bertolin, L. Buonincontri, M. Casarsa, F. Collamati, C. Curatolo, A. Gianelle, D. Lucchesi, N. Pastrone, ***C. Riccardi****, P. Sala, L. Sestini,* ***I. Vai*** *++ al. joining* **+ P. Salvini, C. Aimè**

Strong **synergy** within the new submitted EU project AIDAinnova and upgrade of existing experiments

Muon sources

RD_MUCOLL

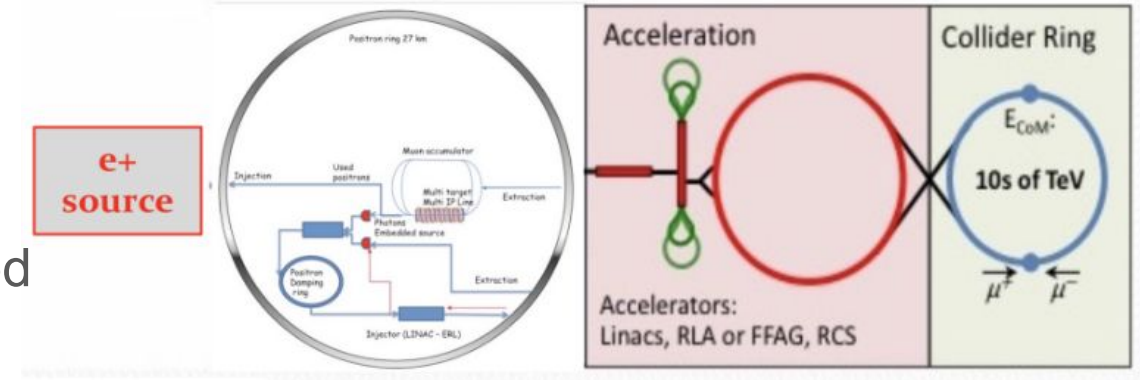
- proton (MAP) vs positron (LEMMA) driven muon source



LEMMA

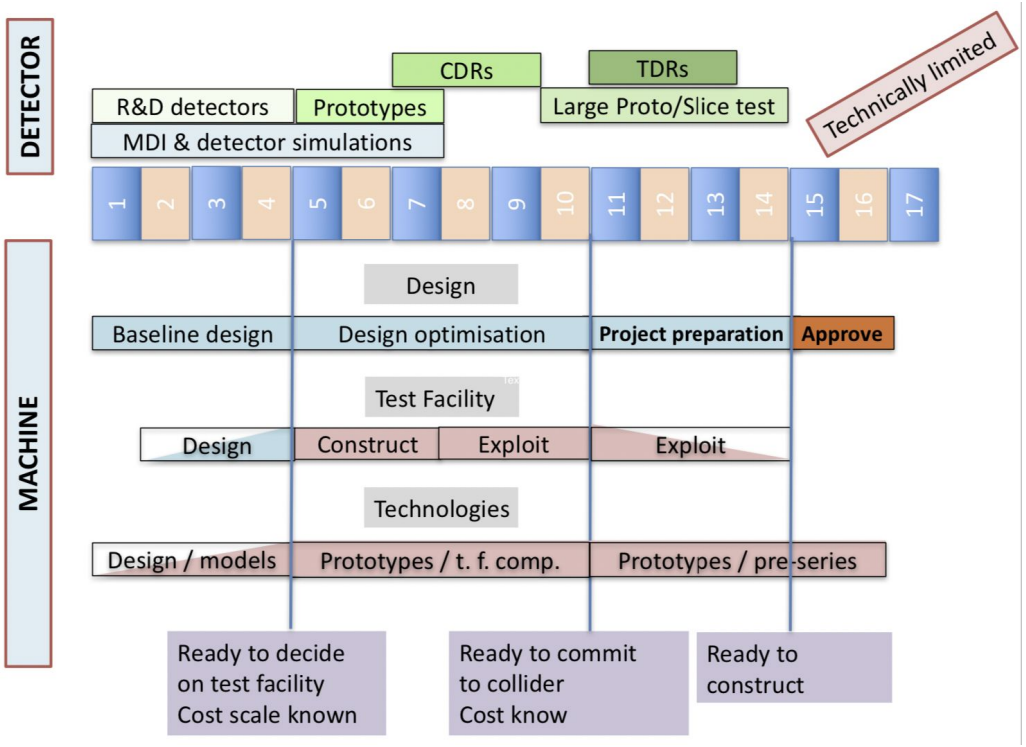
RD_MUCOLL

- Asymmetric collisions $e^+e^- \rightarrow \mu^+\mu^-$ at $\mu^+\mu^-$ thr: $\sqrt{s} \approx 0.212$ GeV
  - maximize $\mu^+\mu^-$ pairs production cross section
  - minimize $\mu^+\mu^-$ beam angular divergence and energy spread
- Extremely promising
  - Muon produced with low emittance -> no/low cooling needed
- But difficult
  - Low production cross section: maximum $\sigma(e^+e^- \rightarrow \mu^+\mu^-) \sim 1$ μb
  - High load and stress in μ production target



Timeline

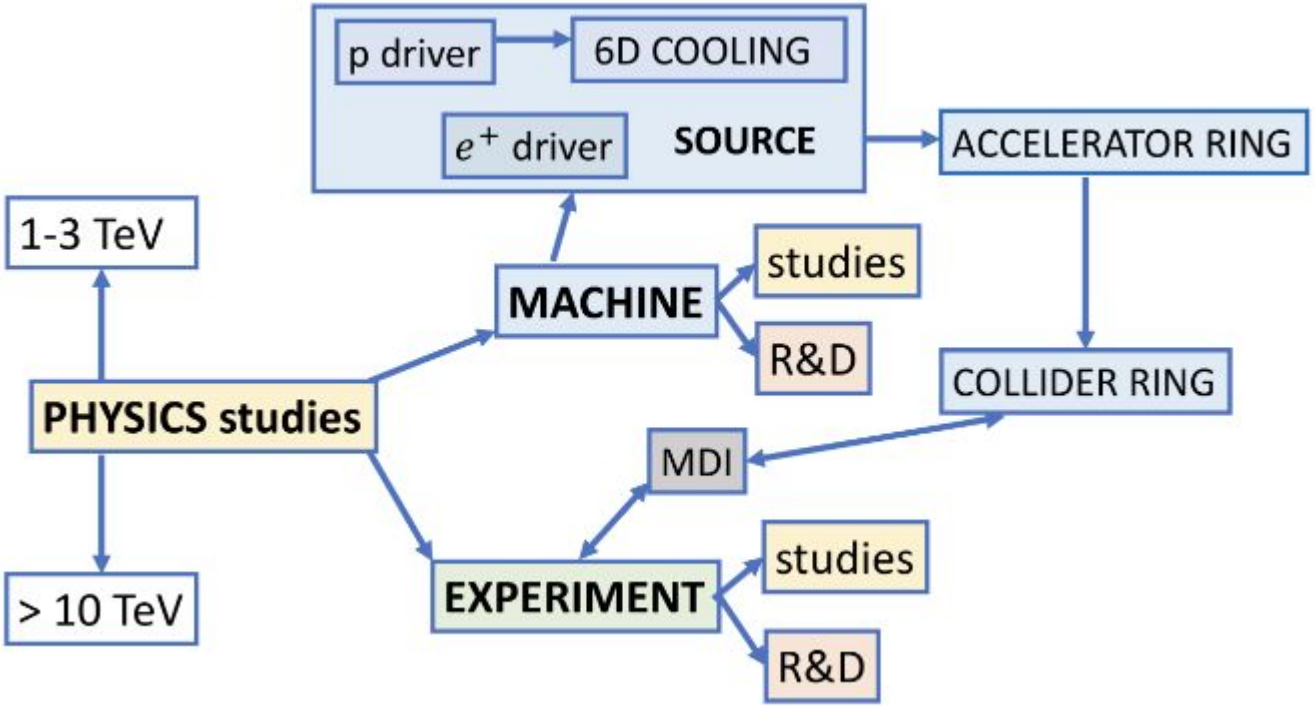
- Technically Limited Potential Timeline



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

Progetto

RD_MUCOLL



Richieste finanziarie

RD_MUCOLL

- Missioni per riunioni in Italia e al Cern, conferenze e preparazione test beam:
  - 4kE (concordato con il responsabile nazionale)

The MUonE project

Measuring at CERN the Hadronic Leading Order contribution to the muon g-2 via a single elastic scattering experiment

$\mu^{\pm}$ (150 GeV) e^{-} (at rest)$\rightarrow\mu^{\pm}$ e^{-}

Carlo Carloni Calame

Anagrafica

MUonE

Ricercatori

	Nome	Età	Contratto	Qualifica	Aff.	%
1	**Montagna Guido**		Associato	Prof. Ordinario	CSN IV	**10**
2	**Nicrosini Oreste**		Dipendente	Dirigente di Ricerca	CSN IV	**10**
3	**Piccinini Fulvio**		Dipendente	Dirigente di Ricerca	CSN IV	**5**
	Numero Totale Ricercatori			3	FTE: 0.3	

Tecnologi

	Nome	Età	Contratto	Qualifica	Aff.	%
1	**Carloni Calame Carlo Michel**		Dipendente	Tecnologo	CSN IV	**5**
	Numero Totale Tecnologi			1	FTE: 0.1	

Attività previste

MUonE

Main steps in the project

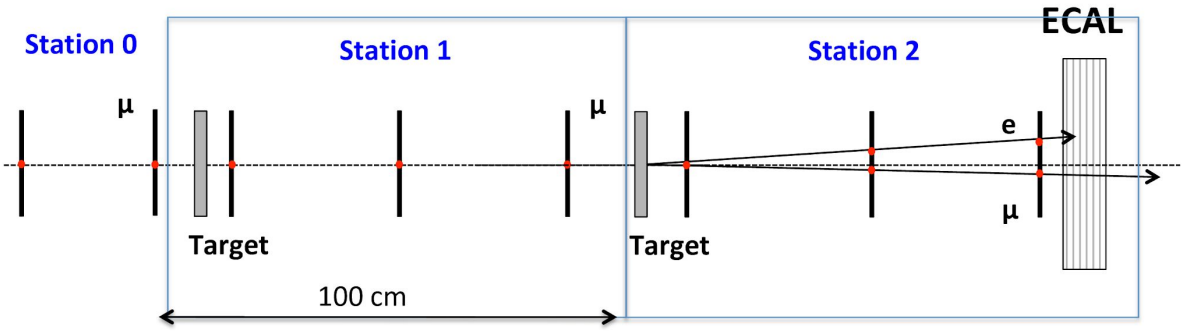
1. Multiple scattering studies (TB 2017 and MC simulation)
2. Test beam at M2 in 2018
3. Baseline Si detector defined (moduli 2S CMS)
4. LO and NLO Studies
5. Location at EHN2
6. LOI submitted to SPSC (June 2019)
7. **Test Run approved by CERN, to be held in the end of 2021**
8. Theory progress ("Theory for muon-electron scattering at 10ppm: A report of the MUonE theory initiative", P. Banerjee et al, 2004.13663)

From U. Marconi, CSN1, July 9-10, 2020

Attività previste

MUonE

Test Run in 2021



Test run set up

CMS 2Smodule
10 cm x 10 cm

Tracking station

Station 0 : station without target, to track the incoming muons at the entrance

From U. Marconi, CSN1, July 9-10, 2020

Attività previste

MUonE

- Il gruppo pavese di fenomenologia HEP è fra i **proponenti** del progetto
- La **precisione** richiesta per essere competitivi è di almeno 10ppm
- E' necessario un **generatore Monte Carlo** che includa al meglio le correzioni radiative di QED, fino al NNLO più ordini superiori, per estrarre i dati con la precisione richiesta.

Attività previste

- L’analisi dei dati verrà eseguita mediante un *template fit* per l’estrazione del **contributo adronico** al running di **α**
- Stretta e continua collaborazione con colleghi sperimentali per l’implementazione del *template fit* e l’interfaccia degli strumenti teorici al software di simulazione dell’esperimento

Richieste finanziarie

- Si richiedono su DOT1/MUonE, circa 3 settimane (totali) di missione (per collaboration meeting al CERN, workshop, collaborazioni)
- D’accordo con il Responsabile Nazionale Umberto Marconi (BO), si richiedono

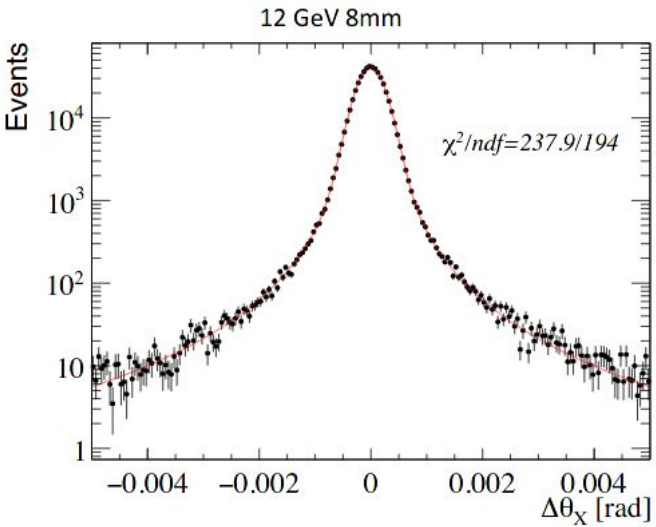
3k euro

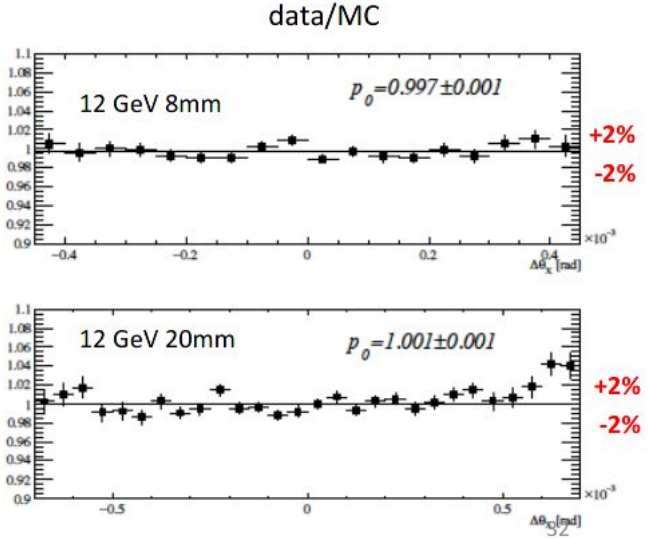
Results on Multiple Coulomb Scattering from 12 and 20 GeV electrons on Carbon targets (8, 20 mm)

JINST 14 (2020) 01, 01

arXiv:1905.11677

G. Abbiendi[a], J. Bernhard[b], F. Betti[a,c], M. Bonanomi[d], C. M. Carloni Calame[e], M. Garattini[b,g], Y. Gavrikov[f], G. Hall[g], F. Iacoangeli[h], F. Ignatov[i], M. Incagli[j], V. Ivanchenko[b,k], F. Ligabue[j,l], T. O. James[g], U. Marconi[a], C. Matteuzzi[d], M. Passera[m], M. Pesaresi[g], F. Piccinini[e], R. N. Pilato[j,n], F. Pisani[a,b,c], A. Principe[a,c], W. Scandale[b], R. Tenchini[j], and G. Venanzoni[j,1]





Backup

Analysis

- Goal: get the leptonic contribution to the running of $\alpha(q^2)$.
- The analysis is based on a template fit method of the 2D angular distribution of the scattering angles in the (θ_e,θ_μ) plane.
- With 4 -5 days of a fully efficient data taking, corresponding to 5/pb (1-2 x 10^9 events), we could reach the sensitivity to the hadronic component.
- We are presently assessing the main systematic contributions.
  - A systematic error in the average beam energy is one of the most dangerous effect to us.
  - Uncertainty on the beam energy spread: related to the BMS resolution uncertainty
  - Longitudinal size of the station
  - Detector intrinsic resolution
  - Multiple Coulomb Scattering