LEMMA
Low EMittance Muon Accelerator

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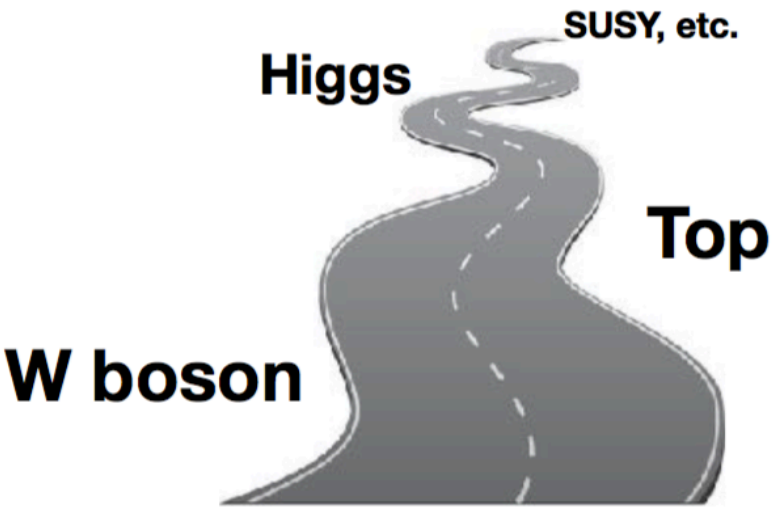
outline

1. **Introduction**
2. **LEMMA Challenges**
3. **WG organization**
4. **Status**
5. **plans**

Ideology

A. Wulzer at last
LEMMA meeting, 20/4/18

HEP before the LHC

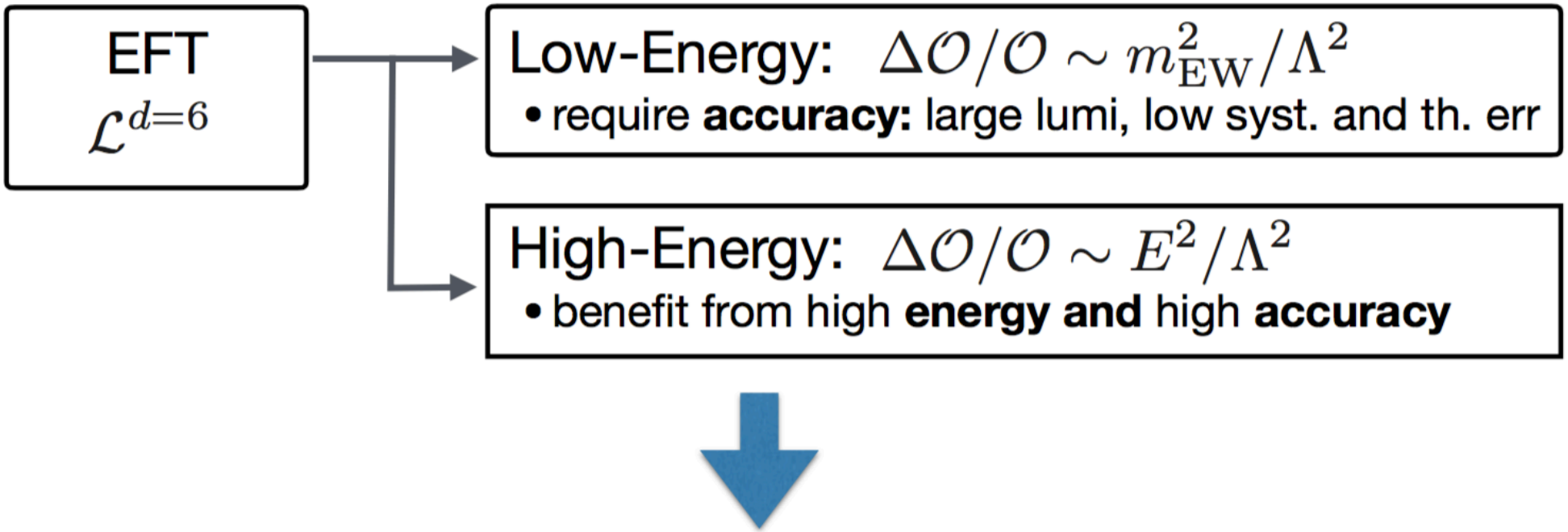


HEP before the F.C.

If Everything Fails

A. Wulzer at last LEMMA meeting, 20/4/18

The FC must have indirect reach superior to direct one, on BSM scale, by at least a few



Must be able to **measure** SM proc.'s, at **few% at least**

Muon Colliders

A. Wulzer at last LEMMA meeting, 20/4/18

We should remind everybody about pdf's!

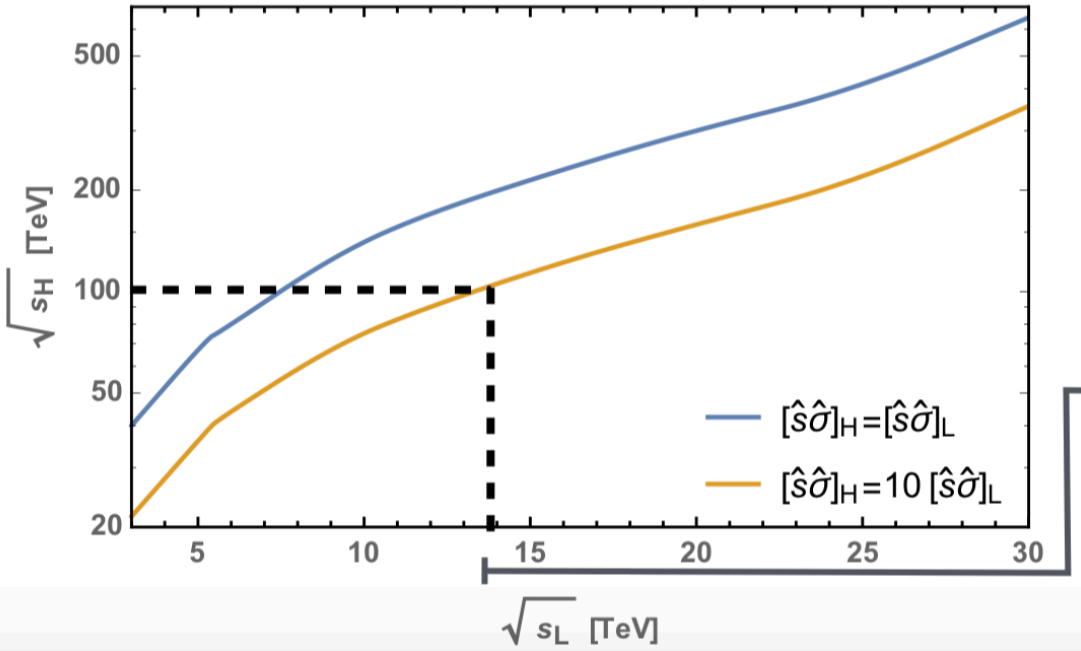
Lepton coll. operating at energy $\sqrt{s_L}$.
Cross section for reaction at E~$\sqrt{s_L}$
(e.g., production of BSM at M=E)

$$\sigma_L(s_L) = \frac{1}{s_L}\left[\hat{s}\hat{\sigma}\right]_L$$

Hadron coll. operating at energy $\sqrt{s_H}$.
Cross section for reaction at E.
Parton Luminosity suppression

$$\sigma_H(E, s_H) = \frac{1}{s_H}\int_{E^2/s_H}^1 \frac{d\tau}{\tau}\frac{dL}{d\tau}\left[\hat{s}\hat{\sigma}\right]_H$$

Find **equivalent $\sqrt{s_H}$** for Had. Coll. have **same cross-section** as Lep. Coll. for reactions at E~$\sqrt{s_L}$. Use that $\left[\hat{s}\hat{\sigma}\right]$ is nearly constant in τ.



QCD-coloured BSM can easily have much larger partonic XS.

Comparison even more favourable for **QCD-neutral BSM**

14 TeV μ-collider nearly as good as the FCC at 100 TeV?

Muon Colliders Requirements Specification

A. Wulzer at last LEMMA meeting, 20/4/18

The muon collider must:

0) Run for a reasonable time: $10^{34}\text{cm}^{-2}\text{s}^{-1} \rightarrow 900\text{fb}^{-1}$
"reasonable" here means 3*LHC

1) Pair produce more than 100 EW particles:
sufficient to probe "**easy**" decay modes (e.g., for top partners/stops)

$$N = 1300 \left(\frac{10\ \text{TeV}}{\sqrt{s}}\right)^2 \left(\frac{L}{10^{34}\text{cm}^{-2}\text{s}^{-1}}\right) \quad \Rightarrow \quad L > \frac{1}{13}\left(\frac{\sqrt{s}}{10\ \text{TeV}}\right)^2 10^{34}\text{cm}^{-2}\text{s}^{-1}$$

2) Measure SM cross-sections:
simple estimate for 2 → 2, but what about WW scattering, HH prod…?

$$L > \left(\frac{\sqrt{s}}{10\ \text{TeV}}\right)^2 10^{34}\text{cm}^{-2}\text{s}^{-1}$$

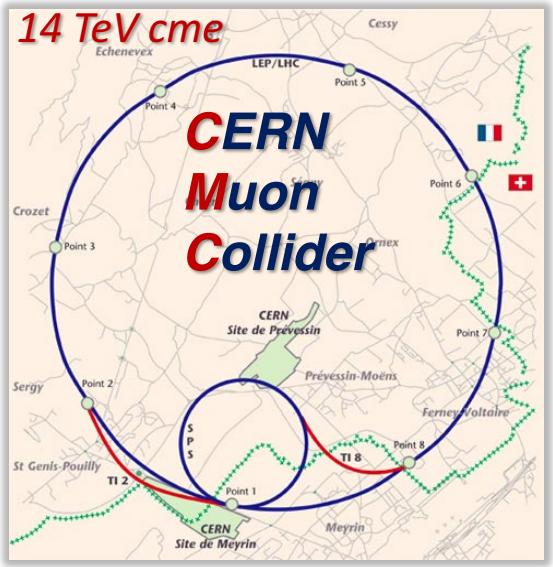
3) Probe DM in mono-γ/W/Z, EW singlets, …

L>? This should be assessed!

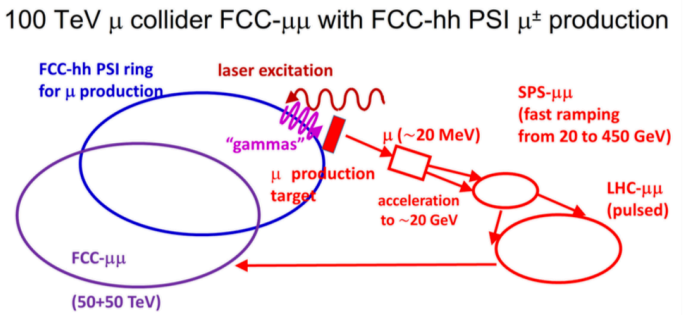
Recent activities on high-energy muon collider

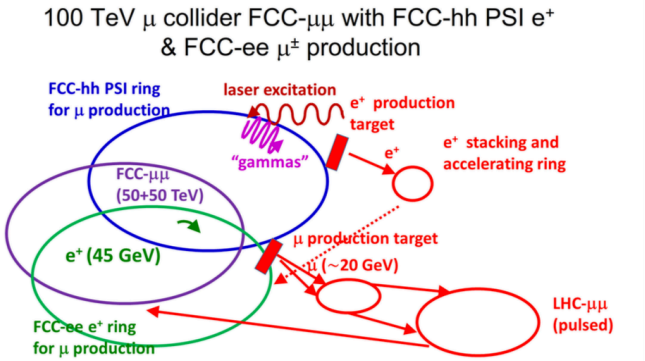
Muon Collider WG for European Strategy Update:

N. Pastrone, INFN, Italy, chair, M. Diemoz, INFN. Italy, A. Skrinsky, BINP, Russia, K. Long, Imperial College, UK, JP Delahaye, CERN, D. Schulte, CERN, A. Wulzer, CERN, B. Mansoulie, IRFU, France



MOPMF072, IPAC18, V. Shiltzev





MOPMF065,IPAC18, F. Zimmermann

Coming soon:

- M. Boscolo, M. Palmer and JP Delahaye, '*The future prospects of muon collider and neutrino factory*', *in* **Reviews of Accelerator Science and Technology journal**
- **ARIES Topical Workshop on Future Muon Colliders,** in collaboration with the WG on Muon Colliders for the ESU, **Padova, 2-3 July 2018**

Idea for low emittance μ beam

from **proton on target:** p + target→ π/K → μ

typically $\mathbf{P_\mu \approx 100\ MeV/c}$ (π, K rest frame)

whatever is the boost P_T will stay in Lab frame → **very high emittance** at production point → **cooling needed**!

from **direct μ pair production**:

Muons produced from $\mathbf{e^+e^-\rightarrow\mu^+\mu^-}$ at √s around the $\mu^+\mu^-$ threshold **(√s ≈ 0.212GeV)** in asymmetric collisions (to collect μ^+ and μ^-)

NIM A reviewer (2016) : *"*A major advantage of this proposal is the lack of cooling of the muons…. the idea presented in this paper may truly revolutionise the design of muon colliders…"

PR-AB reviewer *(still in review process, April 2018):* `I believe this is an important contribution to the literature on muon colliders as a means of delivering multi-TeV lepton-anti-lepton collisions. It is also important at this time because it has re-initiated the discussion of a muon collider as a potential route to energy-frontier lepton-antilepton collisions in advance of the update to the European Strategy for Particle Physics. .... Overall, I was impressed by this paper and am convinced that it should be published.'

LEMMA scheme

Goal:

@T ≈ 10^{11} μ/s

Efficiency ≈ 10^{-7} (with Be 3mm)→

10^{18} e^+/s needed @T →

e^+ stored beam with T

to minimize positron source rate

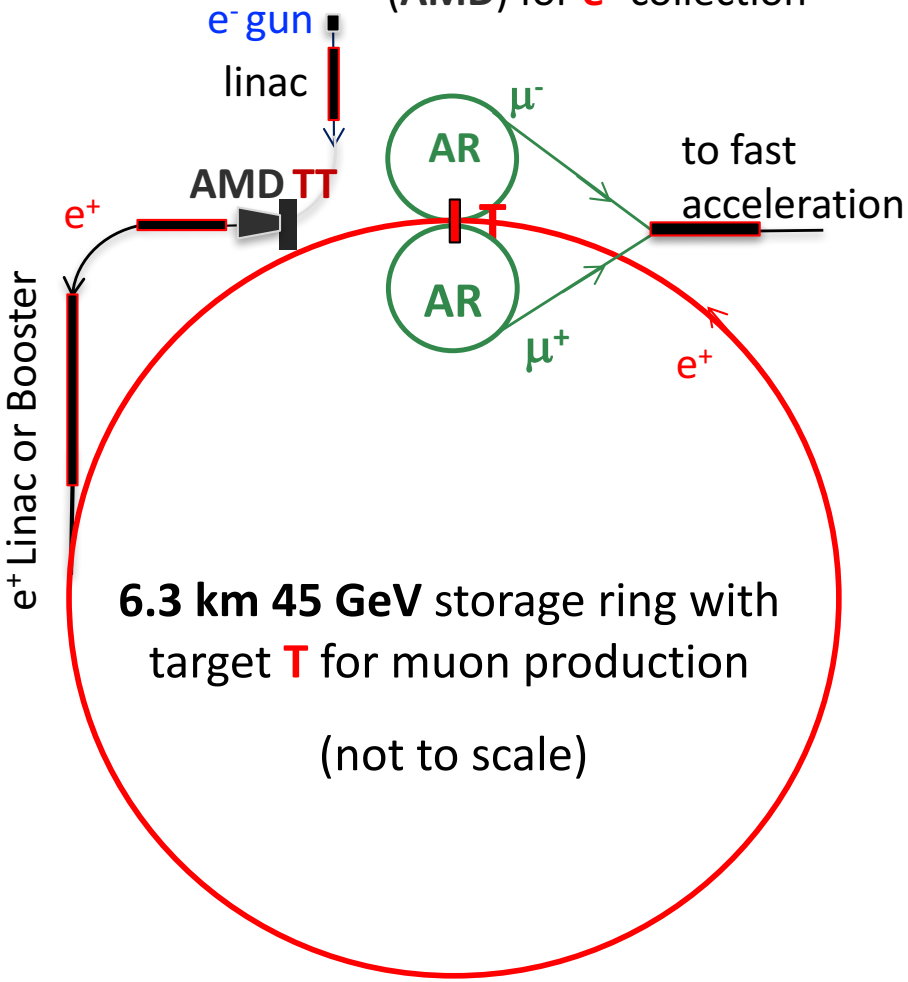
Goal: mom. aperture +/-12%

lifetime(e+) ≈ 250 turns

from μ^+ μ^- production to collider

- produced by the **e^+** beam on target **T** with **E(μ) ≈ 22 GeV**, $\gamma(\mu) \approx 200 \rightarrow \tau_{lab}(\mu) \approx 500\mu s$
- **AR**: **60 m** isochronous and high mom. acceptance rings will recombine μ bunches for ~ 1 τ_μ^{lab} ≈ 2500 turns
- fast acceleration
- muon collider

e^- on conventional Heavy Thick Target (**TT**) for e^+e^- pairs production.
Adiabatic Matching Device (**AMD**) for **e^+** collection



WG1: accelerator design (M. Boscolo)

WG1 has to design the whole accelerator complex and to determine the ultimate parameters set to reach the required brilliance for the muon beams.

It can be sub-divided in the following main topics:

a) **45 GeV e^+ ring**,

b) **muon accumulator rings**

c) **e^+ source and injection**

d) **parameters optimization**

additional **3 FTE** needed (minimal program) 1 each item(a,b,c)

a) Improvement on current 45 GeV ring design in terms of energy acceptance and target region optics.

b) First design of muon accumulator rings.

c) First design of positron source scheme including the investigation of the embedded positron source.

WG2: target design (LNF, RM1, PoliTo)

WG2 includes the issues concerning the muon and positron target, and required efficiency. Engineering study is needed to simulate thermo-mechanical stress and heat load, together with mechanical design of its support.

It can be sub-divided in the following two main topics:

a) muon source target

b) e^+ source target

additional **2 FTE** needed (minimal program) 1 each item(a,b)

a) Preliminary target design

b) Definition of parameters necessary for the target experimental tests

c) First study of targets for positron production.

WG3: experimental tests (F. Anulli, M. Zanetti, M. Boscolo)

WG3 is dedicated to experimental tests, it is strictly connected with WG1 and WG2.

Proper diagnostic for experimental tests must also be studied.

It can be sub-divided in the following two main topics:

a) **CERN tests with 45 GeV e^+** (F. Anulli, M. Zanetti)

b) **DAFNE test of ring-plus-target scheme** (M. Boscolo)

c) **Additional tests (e^+ in SPS ?)**

additional **1 FTE** needed (minimal program) beam diagnostic

a) The characteristics of the muons produced by positron on target are planned to be measured if the request for at least one week of data taking period is approved.

b) The experimental test on target thermo-mechanical stress

c) The experimental test at DAFNE has to be defined and technical aspects have in an advanced phase.

Finanziamenti

- 3 possibilita':
  - **PRIN** LEMS: Low Emittance Muon Source PI A. Variola
  - **CALL CSN5** SLEM: PI M. Biagini, deputy M. Boscolo
  - **CSN1 RD_FA** o sigla separata

- Se le call falliscono le richieste a CSN1 diventano effettive
- Ovviamente nel prin e nella call csn5 ci sono i costi del personale
- Per le attivita' sperimentali occorre:
  - Test a DAFNE
    - 200 KEuro (iniezione, diagnostica, pipe) PRIN, CALL G5
    - 200 Keuro (termocamere ,targhette) CALL G5
  - Altre spese sono inferiori a 100 Keuro

Richieste call gruppo 5 wp1-3

WP1	INFN site	Funding type	Desciption	2019	2020	2021	Totale
				(k€)	(k€)	(k€)	(k€)
	LNF	Missioni	Management, meetings, workshops	2.0	2.5	2.0	**6.5**
	Milano	Missioni	Meetings, workshops	0.5	0.5		**1.0**
	Roma 1	Missioni	Meetings, workshops		0.5		**0.5**
		Totale		**2.5**	**3.5**	**2.0**	**8.0**

WP2	INFN site	Funding type	Desciption	2019	2020	2021	Totale
				(k€)	(k€)	(k€)	(k€)
	Ferrara	Missioni	Meetings, workshops	0.5	0.5	0.5	**1.5**
	LNF	Missioni	Management, meetings, workshops	1.0	1.0	1.0	**3.0**
		Consumo	Prototypes construction	10.0	20.0	0.0	**30.0**
		Inventariabile	Optical system for photothermal reflectance measurements	15.0	0.0	0.0	**15.0**
		Inventariabile	Infrared camera FLIR X8500sc with high time (270 ns) and space (<10um) resolutions	70.0	0.0	0.0	**70.0**
	Padova	Missioni	Meetings, workshops	1.0	1.0	1.0	**3.0**
		Consumo	Target production with AM, thermal treatments, test, measurements and characterization	2.0	5.0	5.0	**12.0**
	Roma1	Missioni	Meetings, workshops	1.0	1.5	1.0	**3.5**
	Torino	Missioni	Meetings, workshops	1.0	1.0	1.0	**3.0**
		Consumo	Material test preparation and mechanical supports	1.0	1.0	1.0	**3.0**
		Inventariabile	Pirometer (10 k€) + server with GPU for simulation (10 k€)	10.0	10.0	0.0	**20.0**
		Inventariabile	Vacuum pump and vacuum chamber	10.0	20.0	0.0	**30.0**
		Totale		**122.5**	**61.0**	**10.5**	**194.0**

WP3	INFN site	Funding type	Desciption	2019	2020	2021	Totale
				(k€)	(k€)	(k€)	(k€)
	LNF	Missioni	Management, meetings, workshops	2.5	2.5	2.5	**7.5**
		Consumo	Diagnostic system upgrade (20 k€) and workshop/laboratory consumables (10 k€)	5.0	20.0	5.0	**30.0**
		Inventariabile	Kicker Power supply (40 k€)	40.0	0.0	0.0	**40.0**
		Costr. App.	New beam pipe section (50 K€)	20.0	30.0	0.0	**50.0**
	Padova	Missioni	Dafne tests, meetings, workshops	0.5	0.5	0.5	**1.5**
	Roma1	Missioni	Dafne tests, meetings, workshops	1.5	1.5	1.0	**4.0**
	Torino	Missioni	Dafne tests, meetings, workshops	1.5	1.0	1.0	**3.5**
		Totale		**71.0**	**55.5**	**10.0**	**136.5**

SLEM: Source of Low Emittance Muons (CSN5 call)

- **R&D to produce low emittance muon beams for a future muon collider**
- New idea based on 45 GeV *low emittance/high energy acceptance* **positron beam** impinging a **target** to produce low emittance **muon pairs.** Muons can be then collected in two large acceptance **accumulator rings**, accelerated and finally injected in the **collider rings**
- **SLEM** will focus on key challenges that need to be demonstrated to prove its feasibility:
  - positron ring studies,
  - positrons and muons production target studies,
  - tests of targets at DAΦNE,
  - collider muon decay induced background studies
- **LNF + 5 INFN structures (RM1, PD, TO, FE, MI) + PoliTO** involved
- Several international laboratories interested (**CERN, LAL/Orsay, SLAC**) a proto-collaboration to be setup soon

Work Packages structure

- The proposal is structured in 5 WPs
- PI: *M.E.Biagini (LNF)*, deputy *M. Boscolo (LNF)*
- WP1 (*M. Boscolo, LNF*): beam dynamics studies of muon source
- WP2 (*M. Antonelli, LNF*): positron and muons production targets
- WP3 (*S. Guiducci, LNF*): plan for experimental tests at DAFNE
- WP4 (*D. Lucchesi, PD*): background studies from muons decay in collider
- WP5 (*N. Pastrone, TO*): evaluation of global performance and comparison with alternative designs

GANNT chart

			2019				2020				2021			
WP	task n.	Description	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
WP1														
	1.1	Report on the positron ring + target simulations						M1		D1				
	1.2	Report on muon accumulator rings studies								M2				
	1.3	Report on positron source scheme											M3	
	1.1, 1.2,1.3	Report on final production scheme and muon beams parameters												D2
WP2														
	2.1	Setup for solid target simulation					M4							
	2.2	Setup for liquid target simulation					M5							
	2.3	Comparison of options and plans for dedicated RD									D3			M6 D4,5
WP3														
	3.1	DAFNE lattice and beam dynamics simulations with target			M7				M8					D6
	3.2	DAFNE modifications for the test						M9,10						
	3.3	Target diagnostics						M11						D7
WP4														
	4.1	Characterization of the problem					M12							
	4.2	Framework set up						D8	M13	D9				
	4.3	Backgrounds simulation												M14 D10
WP5	5.1	Definition of the evaluation metric												
	5.2	Evaluation of the performances				D11	M15	M16			D12			M17

LNF personnel involved

- Proposal for LNF personnel (PM and percentages on 11 months) for the 3 years project

Participant	Person/month	Percentage (%)
D. Alesini	4	10
M. Antonelli	14	40
M.E. Biagini	16	50
M. Boscolo	29	80
A. Ghigo	4	10
S. Guiducci	9	20
M. Iafrati	6	20
L. Pellegrino	4	10
M. Rotondo	4	10
A. Stella	4	10