LEMMA
Low EMittance Muon Accelerator

M. Antonelli (LNF)

Istituto Nazionale di Fisica Nucleare

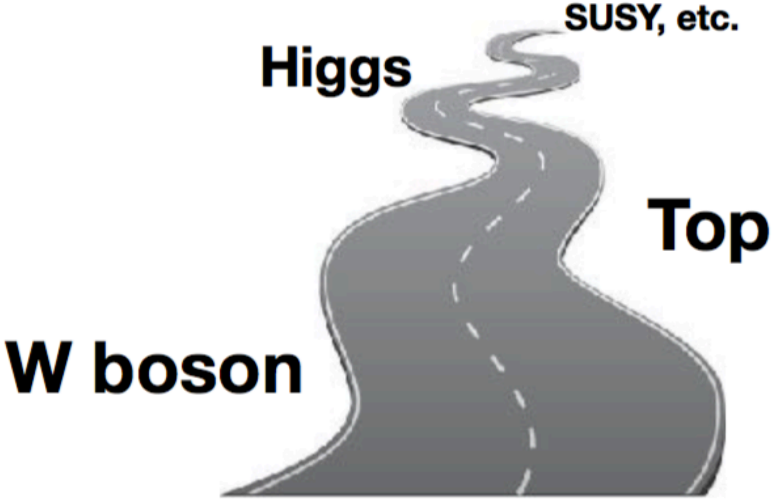
outline

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

EFT
$\mathcal{L}^{d=6}$

Low-Energy: $\Delta\mathcal{O}/\mathcal{O} \sim m_{\mathrm{EW}}^2/\Lambda^2$
- require **accuracy:** large lumi, low syst. and th. err

High-Energy: $\Delta\mathcal{O}/\mathcal{O} \sim E^2/\Lambda^2$
- benefit from high **energy and** high **accuracy**

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!

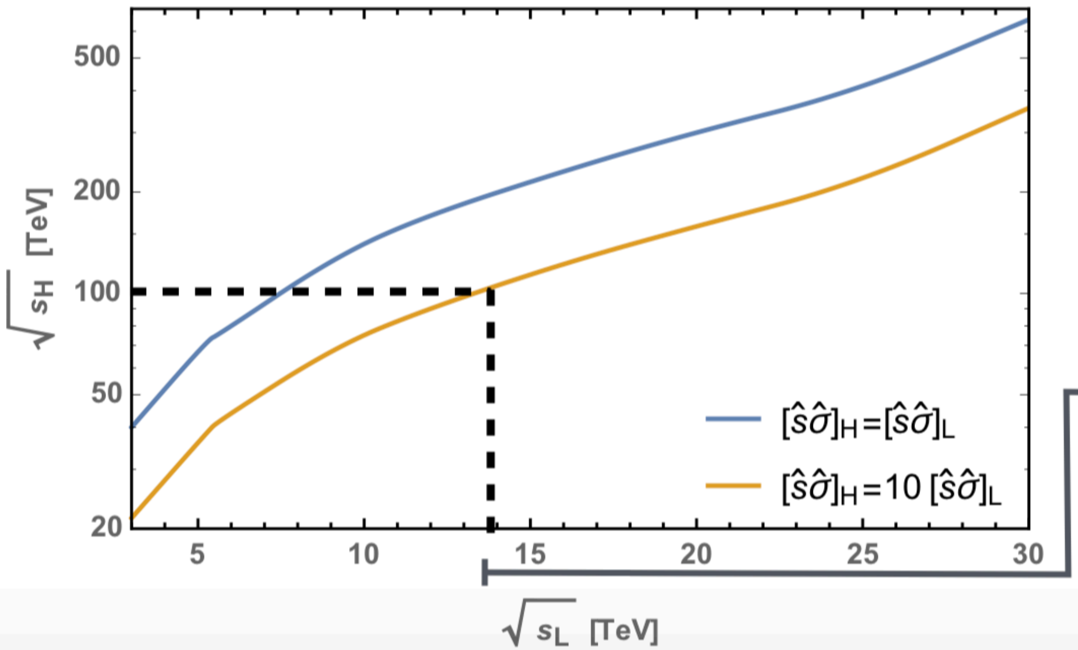
Lepton coll. operating at energy $\sqrt{s_L}$.
Cross section for reaction at E~$\sqrt{s_L}$
(e.g., production of BSM at M=E)

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

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

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

Find **equivalent $\sqrt{s_H}$** for Had. Coll. have **same cross-section** as Lep. Coll. for reactions at E~$\sqrt{s_L}$. Use that $[\hat{s}\hat{\sigma}]$ 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: $10^{34}cm^{-2}s^{-1} \rightarrow 900fb^{-1}$

"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)

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

2) Measure SM cross-sections:

simple estimate for $2 \rightarrow 2$, but what about WW scattering, HH prod…?

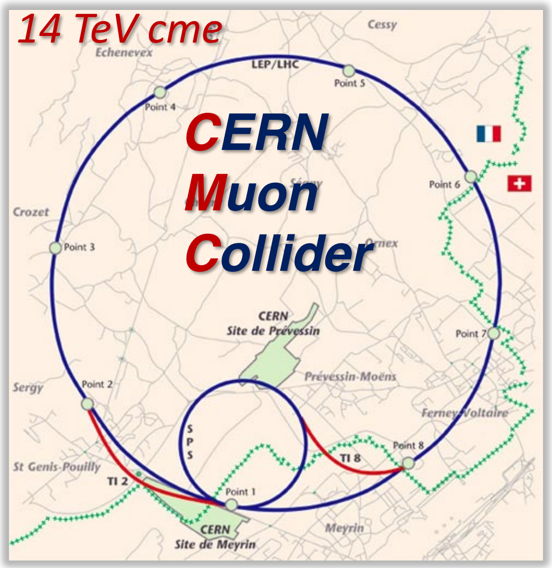
$$L > \left(\frac{\sqrt{s}}{10\ \mathrm{TeV}}\right)^2 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$$

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

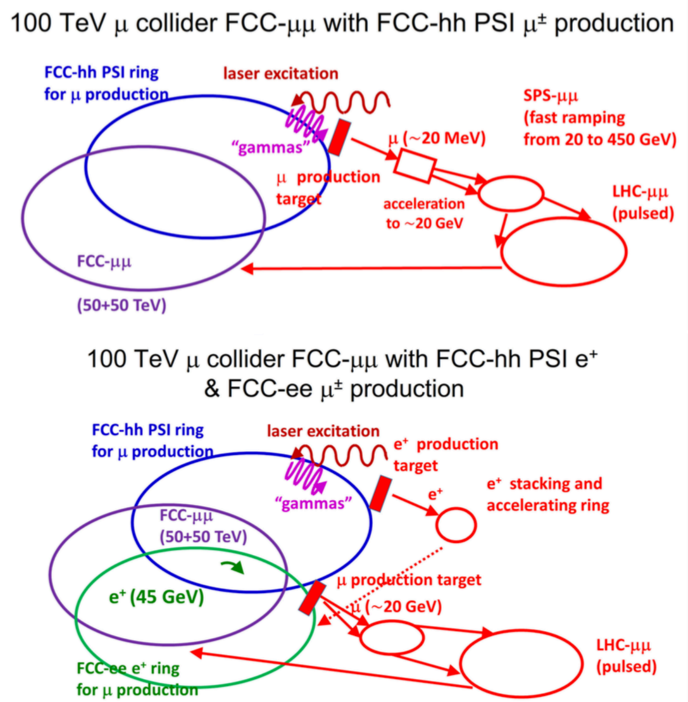
L>? This should be assessed!

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 **P_{μ} ≈ 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 **$e^+e^- \to \mu^+\mu^-$** 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 *(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:

$@T \approx 10^{11}\ \mu/s$

Efficiency $\approx 10^{-7}$ (with Be 3mm)→

$10^{18}\ e^+/s$ needed @T →

e^+ stored beam with T

to minimize positron source rate

Goal: mom. aperture +/-12%

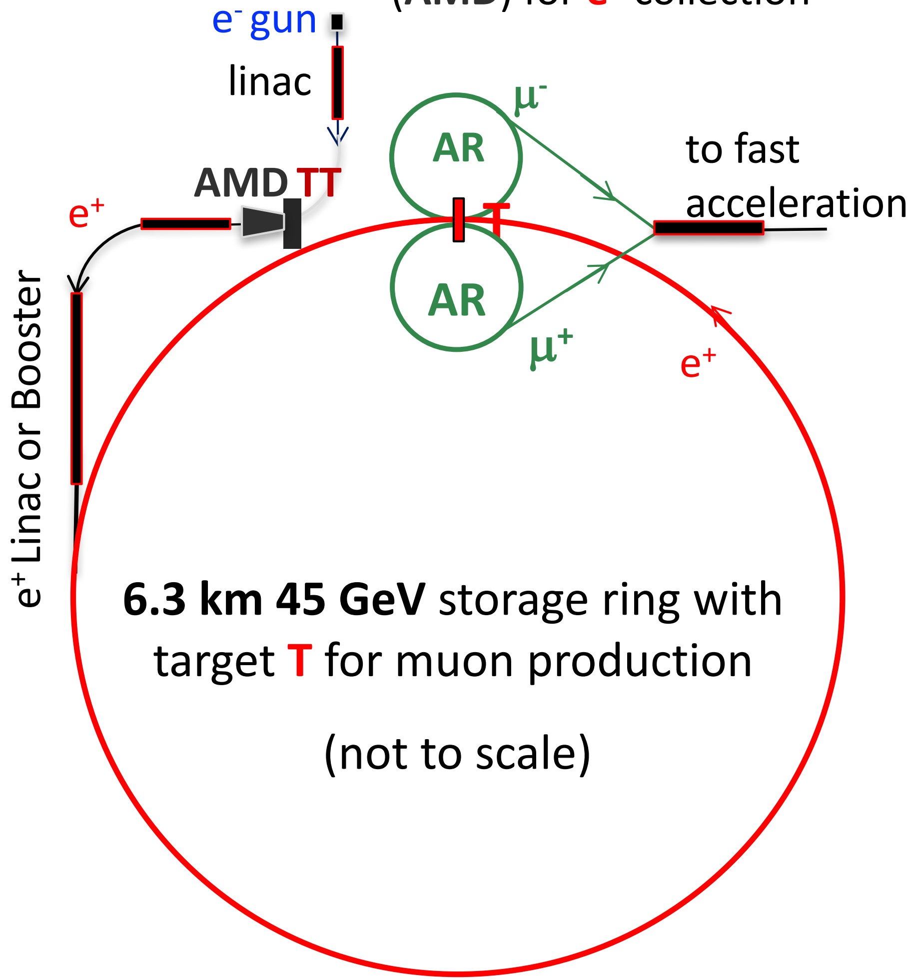
lifetime(e+) ≈ 250 turns

from $\mu^+ \mu^-$ 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 $\tau_\mu^{lab} \approx 2500$ turns
- fast acceleration
- muon collider

e^- on conventional Heavy Thick Target (**TT**) for e^+e^- pairs production.

Adiabatic Matching Device (**AMD**) for e^+ collection



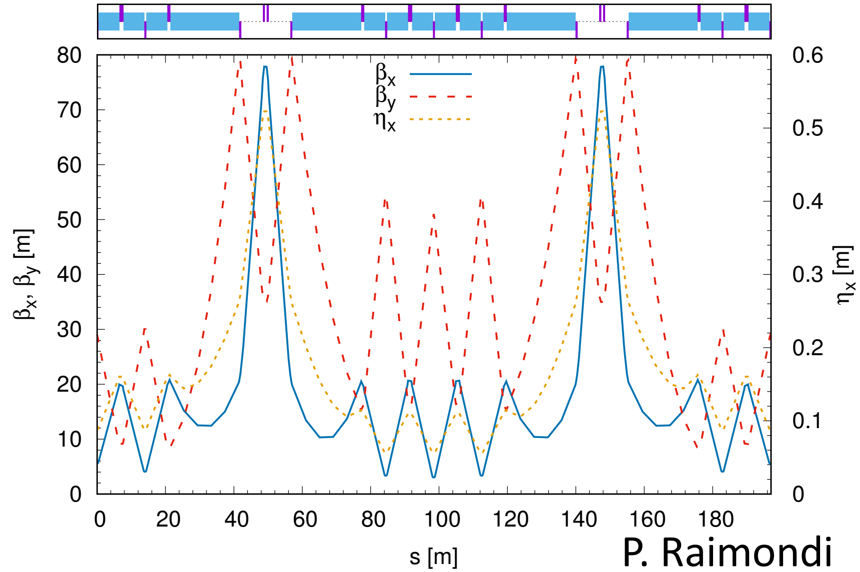
Optics design positron ring

More details in talk by S. Liuzzo

e+ ring parameter	unit	MAP option	LHC tunnel (NEW!)
Energy	**GeV**	**45**	**45**
Circumference	**km**	**6.3**	**27**
No.part./bunch	**#**	**$3 \cdot 10^{11}$**	
bunches	#	100	
e^+ bunch spacing = T_{rev} (AR)	ns	200	
Beam current	mA	240	
Emittance	nm	6	
U_0	GeV	0.51	
SR power	**MW**	**120**	**29**

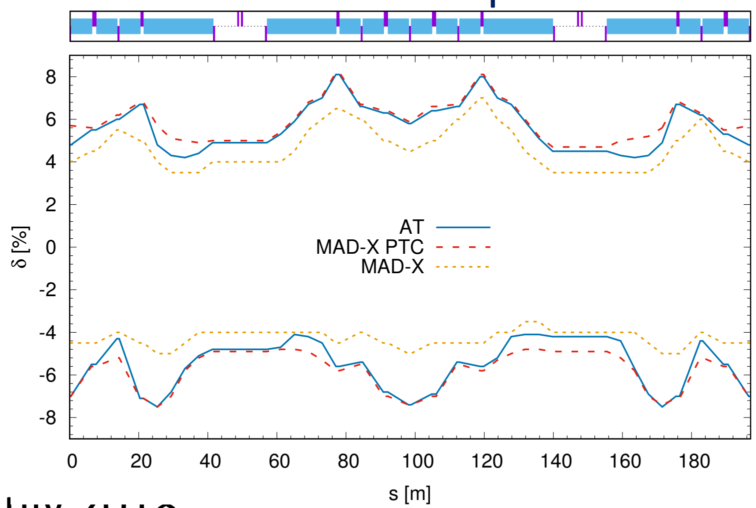
Details in specific talk on the Positron ring

Cell based on the Hybrid Multi Bend Achromat



P. Raimondi

momentum acceptance

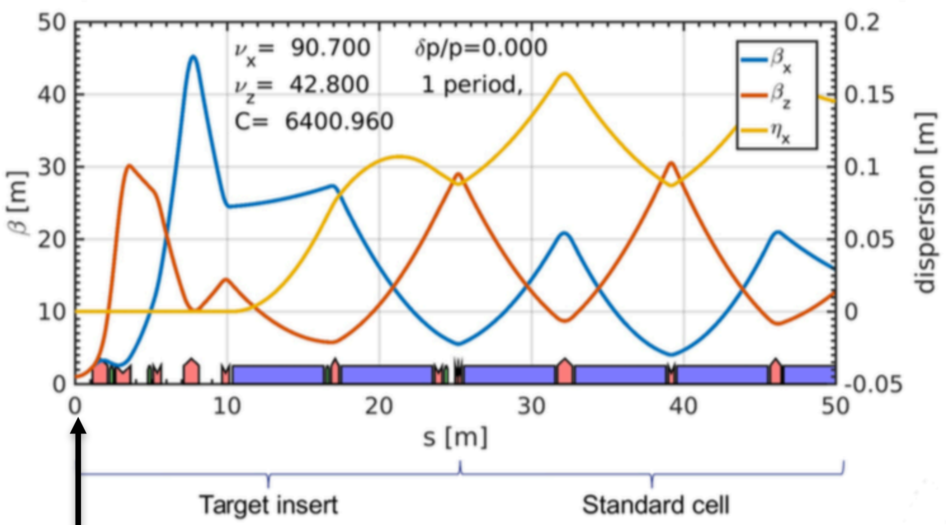


Optics design positron ring

More details in talk by S. Liuzzo

e+ ring parameter	unit	MAP option	NEW! LHC tunnel
Energy	**GeV**	**45**	**45**
Circumference	**km**	**6.3**	**27**
No.part./bunch	**#**	**$3 \cdot 10^{11}$**	Details in specific talk on the Positron ring
bunches	#	100	
e^+ bunch spacing $= T_{rev}$ (AR)	ns	200	
Beam current	mA	240	
Emittance	nm	6	
U_0	GeV	0.51	
SR power	**MW**	**120**	**29**

Target Insertion Region



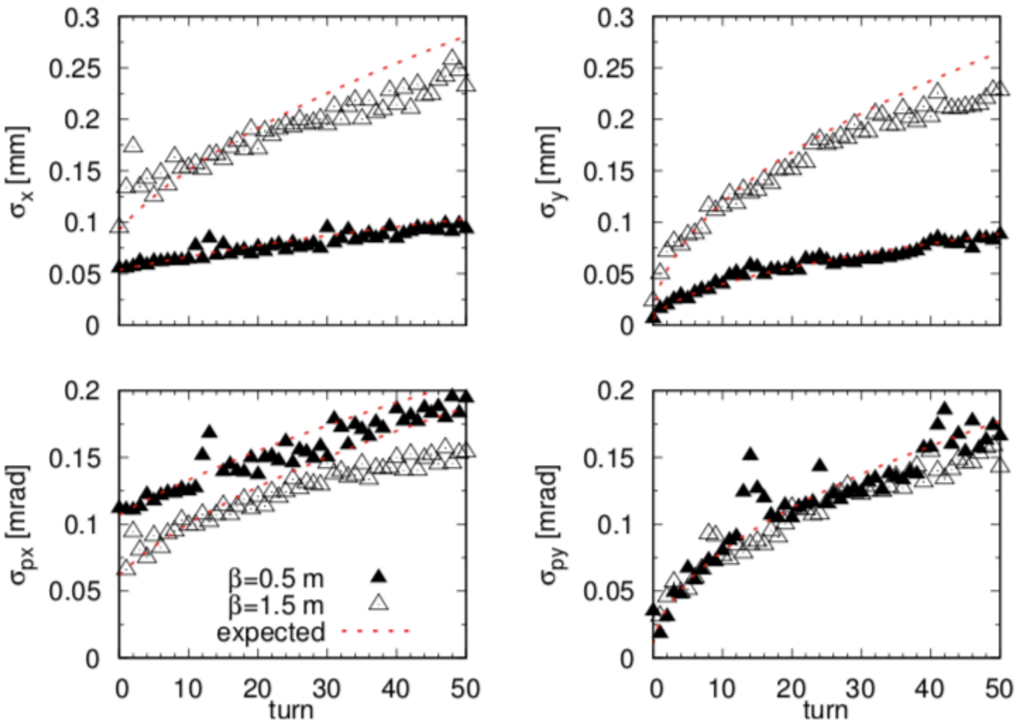
@target { $D_x \approx 0$; low-β ($\beta_{x,y}$ =0.5 m) }

Beam dynamics e^+ beam in ring-with-target

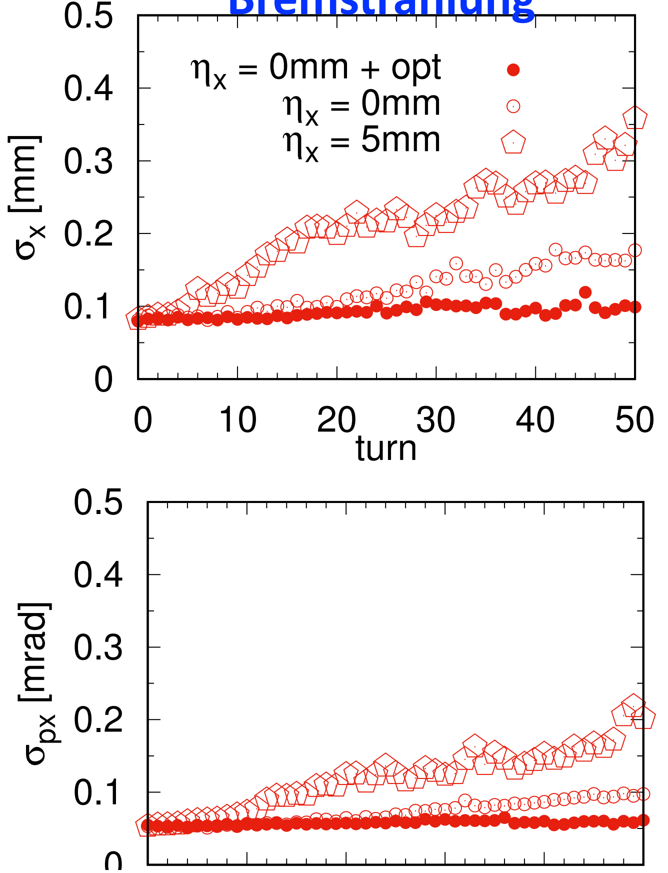
More details in: PR-AB 21, 061005 (2018)

e^+ emittance growth controlled with proper β and D values @ target

Multiple scattering



Bremstrahlung



multiple scattering contribution also explained analytically:

one pass contribution due to the target: $\sigma_{MS} = \frac{1}{2}\sqrt{n}\,\sigma'_{MS}\,\beta$

After 40 turns $\sigma'_{MS} = 25\ \mu\text{rad}$

n number of turns

@Target :

linear and non-linear terms of horizontal dispersion $\eta_x = 0$

M. Boscolo, Padova, 2 July 2018

LEMMA ring-plus-target Test at DAΦNE after SIDDHARTA-2 run

- **Beam dynamics study of the ring-plus-target scheme:**
  - transverse beam size / current / lifetime
- **Measurements on target:**
  - temperature (heat load) / thermo—mechanical stress

GOAL of the experiment:

- **Validation LEMMA studies**, benchmarking data/expectations
- **Target Tests**: various targets (materials and thicknesses)

Ref. M. Boscolo, M. Antonelli, O. Blanco, S. Guiducci, A. Stella, F. Collamati, S. Liuzzo, P. Raimondi, R. Li Voti "*Proposal of an experimental test at DAΦNE for the low emittance muon beam production from positrons on target*", in publication in **IOP Conf. Series: Journal of Physics: Conf. Series** (IPAC18) also LNF-18/02(IR).

DAFNE Layout for the LEMMA Test

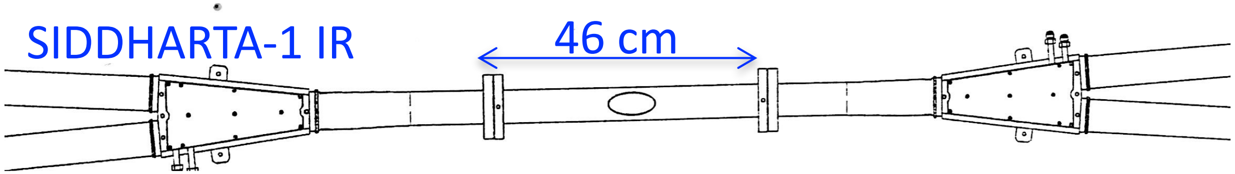
The target will be placed at the SIDDHARTA IP because:

- low-β and D_x=0 is needed (similarly to IP requirements)
- to minimize modifications of the existing configuration

Possible different locations for the target can be studied

For the preparation of this experiment we need:

1. **Full design of vacuum chamber IR and target insertion system**
2. **Target design**
3. **Diagnostics for target thermo-mechanical stress measurements**
4. **Beam diagnostics**
5. **Injection scheme (on axis)**
6. **Optics and beam dynamics**



Given the limited energy acceptance of the ring we plan to insert **light targets (Be, C)** with thickness in the range ≈ **100 μm**. Crystal targets can be foreseen too.

Diagnostics for the test at DAFNE

- **Beam characterization after interaction with target, additional beam diagnostic to be developed**:
  - **turn by turn charge measurement** (lifetime)
    - ✓ existing diagnostic already used for stored current measurement
    - ✓ need software and timing reconfiguration
  - **turn by turn beam size**
    - ✓ beam imaging with synchrotron radiation
    - ✓ DAFNE CCD gated camera provides gating capabilities required to measure average beam size at each turn.
    - ✓ software modification and dedicated optics installation required.
- **Target diagnostics:**
  - Passive Infrared Thermography
  - Infrared radiometry
  - Measurement of surface deformation

Year of the Strategy Input

Observation: Existing SPS and LHC rings give long-term perspective to pursuit of LEMMA scheme

Thinking strategy
L. Evans, S. Stapnes, D. Schulte

- LHC tunnel ideal to house 45 GeV positron ring
- SPS requires much more installed voltage and power
- SPS tunnel can house 3+3 TeV muon collider
- LHC tunnel can house 7+7 or 14+14 TeV muon collider
- LEP3 collider in LHC tunnel is consistent with doing muon production studies, spot on for Z production

Considered phased approach:

- Phase 1: eSPS would be entry point for all options
- Phase 2: LEP3 or CLIC (use to test and develop muon production)
- Phase 3: Muon collider in SPS or LHC tunnel
- Allows to develop all technologies and wait for physics input to define energy scales and choices

positron source

Positron sources parameters for future projects

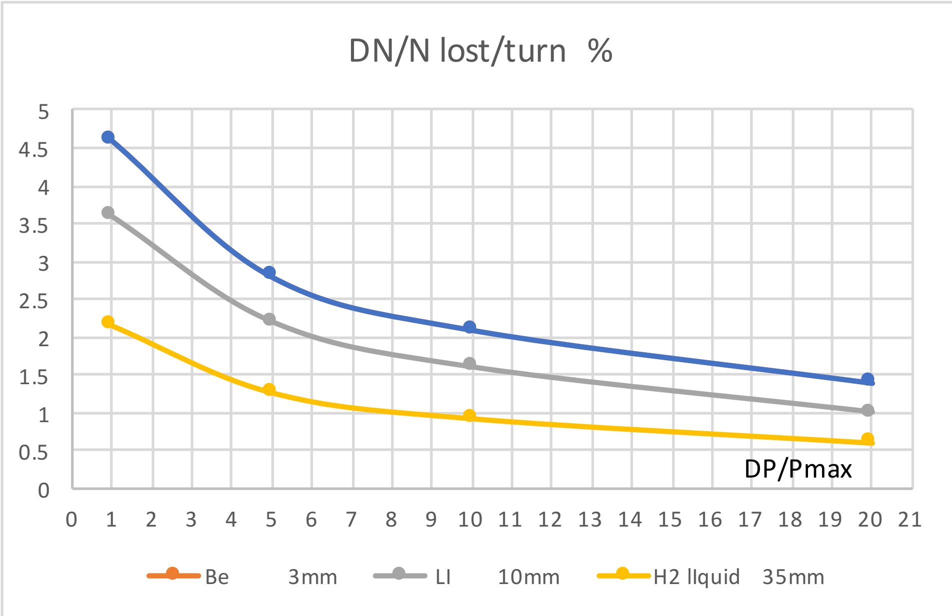
	SLC	CLIC	ILC	LHeC	LHeC	LEMMA
E [GeV]	45.6	3000	250	140	60	45
$\gamma\varepsilon_x$ [μm]	30	0.66	10	100	50	18
$\gamma\varepsilon_y$ [μm]	2	0.02	0.04	100	50	18
e^+ [10^{14} s^{-1}]	0.06	1.1	1.9	18	440	100

- The highest positron rate has been achieved at the SLAC Linear Collider more than 20 years ago
- The future Linear Colliders CLIC and ILC design foresee a positron rate higher than SLC by a factor 20 ÷ 30 and much smaller emittances
- The LHeC and LEMMA proposals aim at extremely high rates, about two order of magnitude higher than CLIC and ILC

Positron loss per turn due to target interaction

DN/N lost/turn %

Ring energy acceptance %	Be 3mm	LI 10mm	H2 lIquid 35mm
1	4.6	3.6	2.2
5	2.8	2.2	1.3
10	2.1	1.6	0.9
20	1.4	1.0	0.6



The percentage of particles DN/N with an energy loss larger than the ring acceptance (calculated from a FLUKA simulation) are listed in the table for different values of the ring acceptance and for 3 different targets

The target tickness has been chosen to have the same number of muon produced per incident positron

FLUKA simulation, F. Collamati

Positron source requirements for LEMMA

	Be 3mm			LI 10mm			H2 llquid 35mm		
Ring energy acceptance %	e^+ beam lifetime (turns)	ΔN/sec	P e^+ drive beam (MW)	e^+ beam lifetime (turns)	ΔN/sec	P e^+ drive beam (MW)	e^+ beam lifetime (turns)	ΔN/sec	P e^+ drive beam (MW)
5	35	2.69E+16	277	45	2.11E+16	217	78	1.21E+16	125
10	47	2.01E+16	207	62	1.53E+16	157	107	8.86E+15	91
20	71	1.34E+16	39	99	9.53E+15	98	163	5.80E+15	60

To evaluate the number of positrons per second required from the source we assume to have **100 bunches** with **3 10^{11} e^+/ bunch** stored in the ring for one beam lifetime

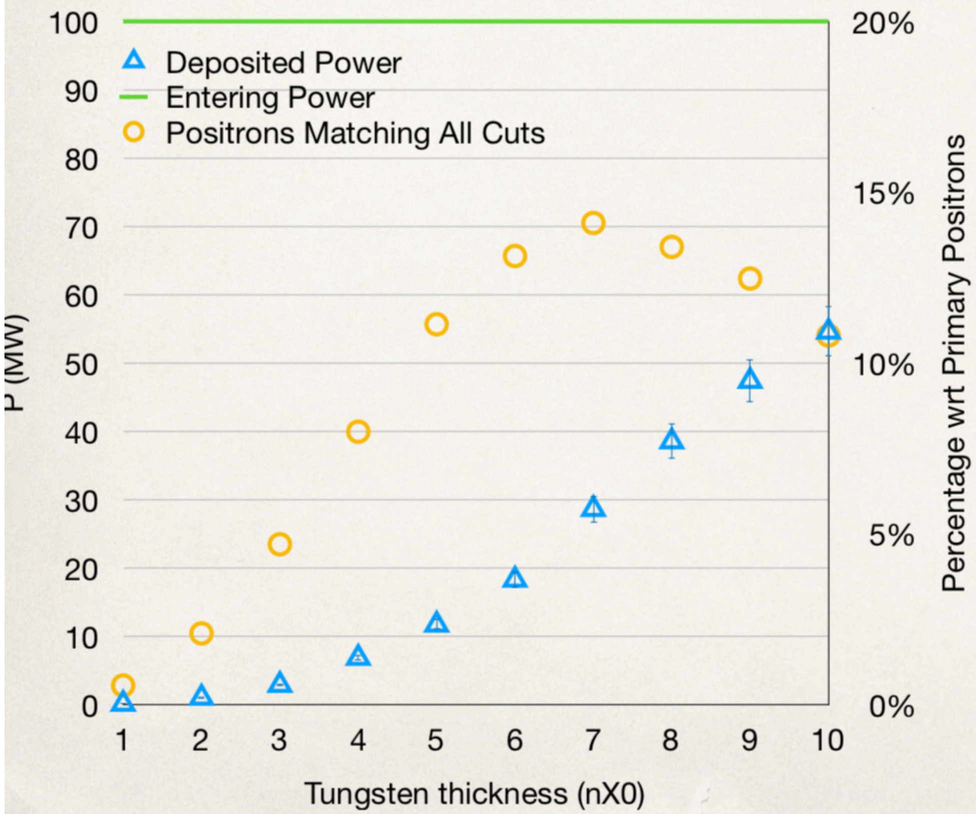
The drive beam power is given by the number of positrons accelerated per secound up to 45 GeV

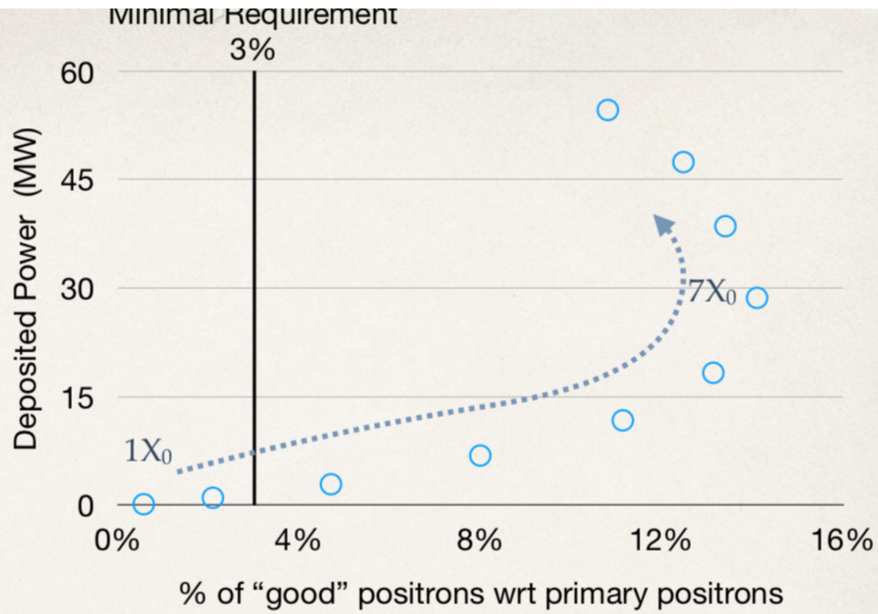
One of the objectives of the studies on the positron ring is to increase the ring energy acceptance in order to reduce the requirements on the positron source

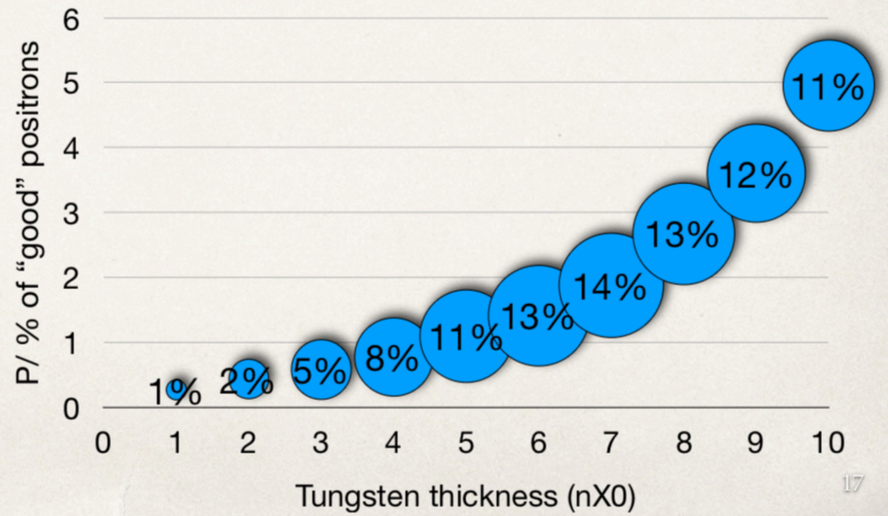
Present ring: Dp/p = 6%, tau = 40 turns, e^+/s = 2.4e16, P= 250 MW

Target: tau> 100 turns, e+/s < 1e16, P < 100 MW

Optimal configuration



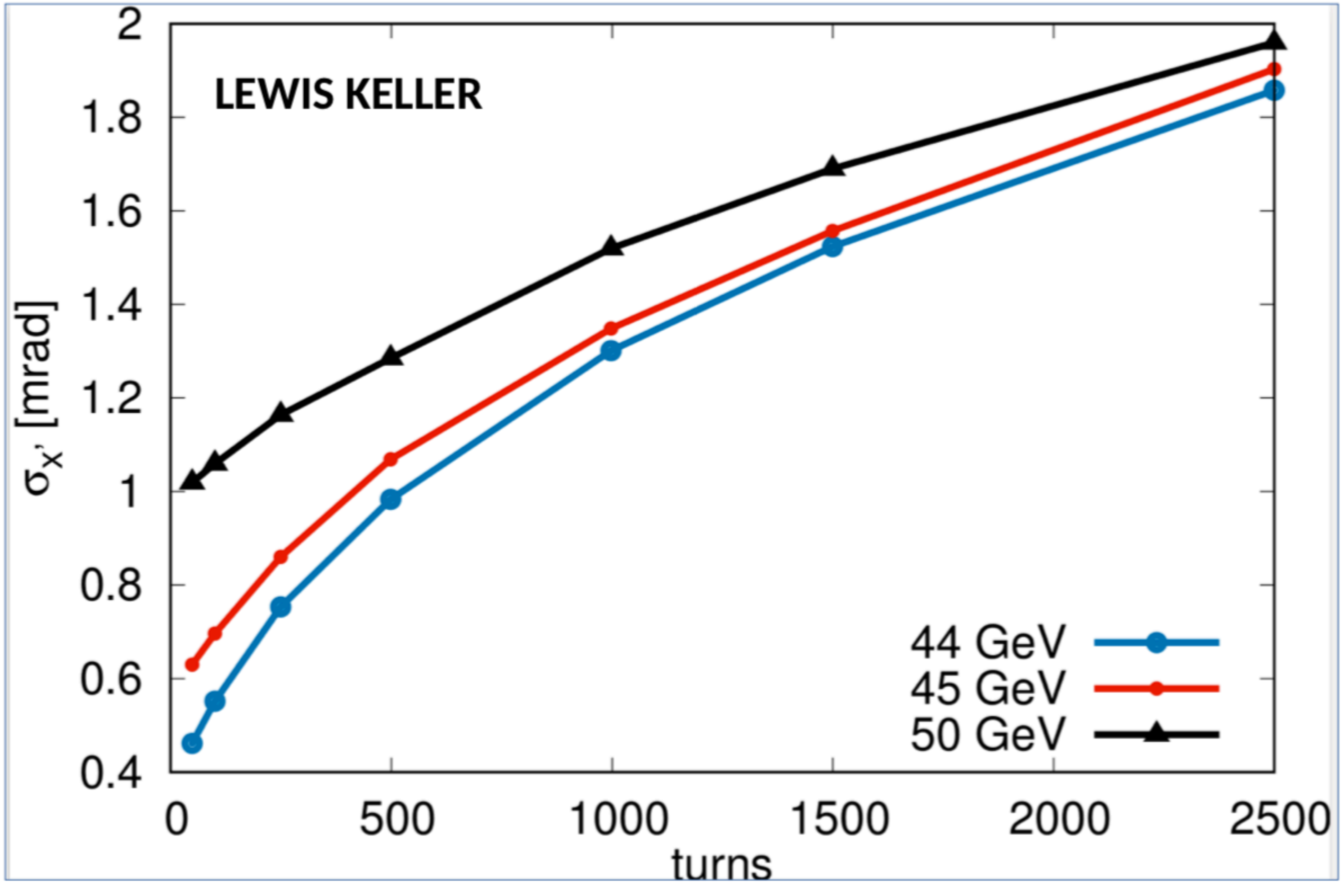




Muon accumulation

The muon accumulation

Muon beam divergence as a result of the interaction with the target over several turns in the AR.



Muons almost don’t loose energy when crossing the target.
The increase of the muon beam divergence comes from multiple scattering with the target, and therefore <u>muon emittance will increase</u>

Interaction point parameters on the e+ ring and the muon accumulator

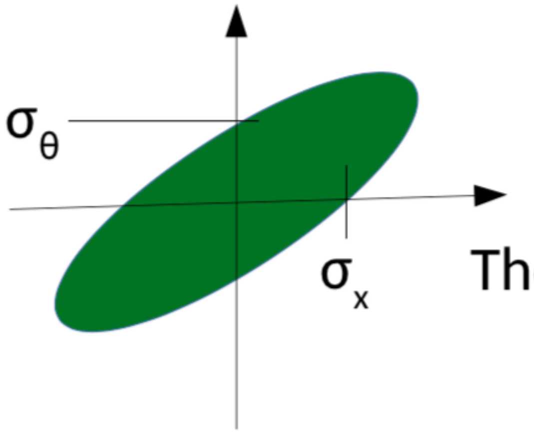
β to match the divergence of the produced muon beam → β_μ

	θ_μ mrad	ϵ_{e^+} nm	$\beta^*_{e^+}$ m	σ_{e^+} μm	σ'_{e^+} mrad	σ'_μ mrad	ϵ_{μ^+} nm	β_μ m
From e+ at 45GeV	1	10	0.01	10	1	1.41	14.1	0.01
	1	10	0.49	70	0.14	1.01	70.7	0.07
	1	10	1.00	100	0.10	1.0	100	0.10
From e+ at 44GeV	0.5	10	0.01	10	1	1.12	11.2	0.01
	0.5	10	1.00	100	0.1	0.51	51.4	0.20

We need beta* of the order of cm in the e+ ring AND in the accumulator

The muon emittance growth due to accumulation

Using the RMS divergence produced from one pass through the target, it is possible to analytically estimate the optics functions to match the beam at the target exit and the emittance growth.



$$\sigma_\theta \approx \frac{13.6\mathrm{MeV}\sqrt{L/\lambda}}{E} \qquad \sigma_x \approx \frac{L}{\sqrt{12}}\sigma_\theta$$

The optics functions to match the beam to the target :

$$\beta = \frac{4}{\sqrt{3}}L \qquad \alpha = -\sqrt{3}$$

Thus, the normalized emittance growth is :

$$\Delta\epsilon = \sigma_\theta^2 \frac{L}{\sqrt{12}} \times \frac{E}{m_\mu c^2}$$

For the 3 mm Be target the RMS divergence is ~60 urad, and the emittance growth AFTER ALL ACCUMULATION is

0.61 um (normalized) = 3 nm

Positron ring

HMBA like lattice varying number of cells and lattice length

	C	Cells	ε_x	Sext K_2	D.A.	M.A.	Dpp*Dx	Lifetime	α_c	damping	Bunch length	U0
	Km	#	nm	T/m^2	mm (hor.)	% (max)	mm (max)	Turns@37%	e-6	ms, (HV-S)	mm	MeV
	27	32	5.72	1.82	12.0	1.5	33	24	104	68-34	2.3	121
	27	64	0.7	29.2	12.0	7.3	40	40	29.0	68-34	1.2	119
	27	134	0.08	552	2.0	7.9	10	29	6.8	68-34	0.6	119
	27	268	0.01	1e4	0.0	7.8	2.3	19	1.7	68-34	0.3	119
	6.3	16	45.8	9.0	12.0	1.4	30	38	403	3.7-1.9	4.1	511
Current lattice	6.3	32	5.86	140	12.0	8.5	44	40	114	3.7-1.8	2.2	511
	6.3	64	0.71	2260	2.0	7.6	10	29	30	3.7-1.9	1.1	509

without target optics
3mm Be @ RF

Common parameters:
f_{rf} = 500MHz
$V_{rf} = 3U_0$
Q = [0.7 0.8]
ξ = [0 0]
$\Delta\phi/2\pi$ (sext) = 1.5/0.5
$\Theta = 2\pi$

27km lattice with 64 cells has, similar lifetime and smaller: emittance, sextupole's strengths, U_0, bunch length, α_c

Dynamic aperture (D.A.) and momentum aperture (M.A.) tracking for 256 turns, with circular apertures 50mm

Parameters for 6.3KM and 27km lattice

e^+ 45 GeV	Units	Parameters for positron ring different scenarios				
C	Km	6.3	6.3	**27**	27	27
N cells	#	32	32	32	**64**	64
n_e (bunches)	#	100	100	428	428	428
n_μ (bunches)	#	1	**2**	1	1	**2**
ε_x	nm	6	6	6	0.7	0.7
Current	A	0.24	0.24	0.24	0.24	**0.14**
$C_{m,acc}$	m	63	126	63	63	**126**
Turns for accumulation	#	25	12	6	6	3
N_{e+} / n_e	e+11	3	3	3	3	1.8
N_μ / n_μ	e+7	3.4	1.2	5.3	5.3	0.8
N_μ^2 * n_μ / ε_x	-	1 (ref)	x 0.25	x 2.5	x 20	x 1.0
U_0	GeV	0.51	0.51	0.12	0.12	0.12
Synch. power	MW	122	122	29	29	16.8

$\tau_{\mu,\ store}$ = 0.5ms

τ_{pos}= 37 turns

σ_μ =0. 74e-7 mu/e+

3mm Be @ 45GeV

- 27km gives potentially equivalent muons beams to the 6.3km lattice, with less positrons on target for a shorter time, and longer muon accumulator.

$$N_\mu = \sum_{it=0}^{t_e} \frac{C_e I_e}{c n_e q_e} \cdot \sigma_\mu \cdot \frac{n_e}{n_\mu} \cdot e^{-\frac{C_e it}{c\tau_e}} \cdot e^{-\frac{C_\mu n_e (t_e - it)}{c n_\mu \tau_\mu}}$$

Muon lifetime considered only every positron ring turn

Liquid target summary

Advantages:

- Power handling $\rightarrow \approx 1.5 \cdot 10^4 cm^3 s^{-1}$ $\rightarrow$ O(10) degrees bulk temperature rise
- long lifetime target
- no expected degradation/dpa damage
- self healing/renewable flow

Disadvantages:

- no standard
- more pieces $\rightarrow$ more complex
- lithium handling $\rightarrow$ safety system
- impact on vacuum has to be verified, maybe it needs differential vacuum box $\rightarrow$ complexity increase

Status of the art $\rightarrow$ IFMIF / LiLiT @ SARAF target

Solid target summary

Advantages:

- conventional, well known technology
- few components → easier
- minimize L → low target emittance contribution

Disadvantages:

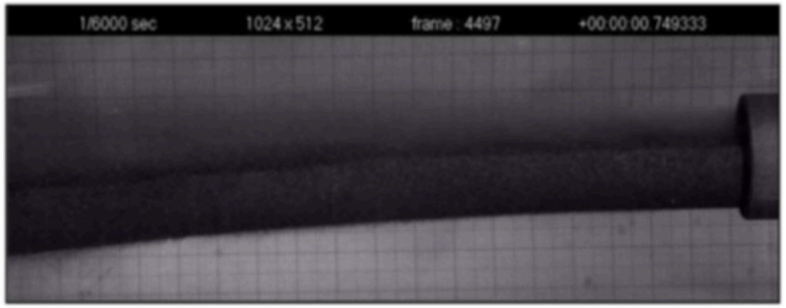
- something is moving at high speed in a very harsh environment
- dpa / material degradation / stresses
- limited lifetime
- power handling and cooling

Status of the art → Muon production target E @ PSI

Hybrid solution → powder flow

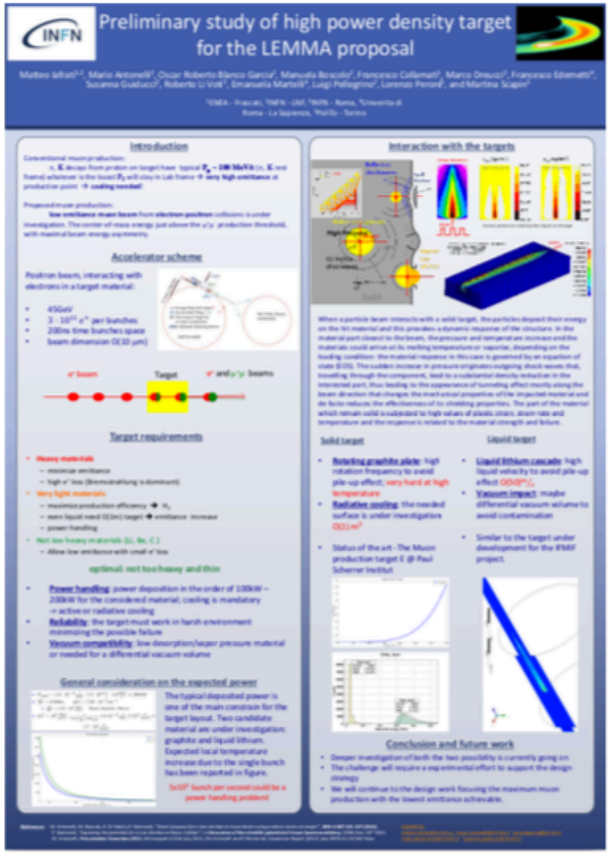
Powder continuous recirculating flow has been taken as a possible solution.

- no studies have been performed on this opportunity yet
- this concept is already in use, mainly with high Z materials (i.e. W)
- wear of parts and powder
- containment and main vacuum contamination



Status of the art → O. Caretta et al. @ RAL / CERN

Preliminary study for LEMMA target



A poster showing the preliminary study on LEMMA target has been presented @ HPTW 2018

- The community addressed it as an interesting and challenging topic
- We are in contact with the Israeli colleagues @ Soreq Nuclear Research Center, expert in liquid metals targets

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**

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**

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 ?)**

d) **Possibility of target test (LLi) at SARAF (weizmann)**

Finanziamenti

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

- 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

Name and Surname	**Institution**	**Position**	**INFN site**	**Person-months**	**WP**
Manuela Boscolo	INFN	Tecnologo	LNF	20.00	WP1
Susanna Guiducci	INFN	Dir. Ric.	LNF	3.00	WP1
Maria Enrica Biagini	INFN	Dir. Tecnologo	LNF	9.00	WP1
Mario Antonelli	INFN	Primo Ric.	LNF	7.00	WP1
Alberto Bacci	INFN	Ricercatore	Milano	6.00	WP1
Francesco Collamati	INFN	Ricercatore	Roma1	3.00	WP1
Mario Antonelli	INFN	Primo Ric.	LNF	7.00	WP2
Matteo Iafrati	INFN	Associato	LNF	6.00	WP2
Camilla Curatolo	INFN	Assegnista	Padova	18.00	WP2
Mauro Morandin	INFN	Dir. Ric.	Padova	4.00	WP2
Lorenzo Peroni	PoliTo	Prof. Ass.	Torino	8.00	WP2
Martina Scapin	PoliTo	RTD-A	Torino	8.00	WP2
Paolo Mereu	INFN	Tecnologo	Torino	2.00	WP2
Laura Bandiera	INFN	Ricercatore	Ferrara	4.00	WP2
Luca Tomassetti	Univ. Ferrara	Prof. Ass.	Ferrara	4.00	WP2
Roberto Li Voti	Univ. Roma Sapienza	Prof. Ass.	Roma1	7.00	WP2
Fabio Anulli	INFN	Ricercatore	Roma1	5.00	WP2
Francesco Collamati	INFN	Ricercatore	Roma1	3.00	WP2
Matteo Bauce	INFN	Ricercatore	Roma1	8.00	WP2
David Alesini	INFN	Primo Tecnologo	LNF	4.00	WP3
Maria Enrica Biagini	INFN	Dir. Tecnologo	LNF	6.00	WP3
Manuela Boscolo	INFN	Tecnologo	LNF	6.00	WP3
Andrea Ghigo	INFN	Dir. Tecnologo	LNF	4.00	WP3
Susanna Guiducci	INFN	Dir. Ric.	LNF	5.00	WP3
Luigi Pellegrino	INFN	Primo Tecnologo	LNF	4.00	WP3
Marcello Rotondo	INFN	Ricercatore	LNF	4.00	WP3
Angelo Stella	INFN	Tecnologo	LNF	4.00	WP3
Marco Zanetti	Univ. Padova	Prof. Ass.	Padova	5.00	WP3

Fabio Anulli	INFN	Ricercatore	Roma1	5.00	WP3
Francesco Collamati	INFN	Ricercatore	Roma1	3.00	WP3
Roberto Li Voti	Univ. Roma Sapienza	Prof. Ass.	Roma1	7.00	WP3
Mario Pelliccioni	INFN	Ricercatore	Torino	6.00	WP3
Nicola Amapane	Univ. Torino	Prof. Ass.	Torino	3.00	WP3
Silvia Maselli	INFN	Primo Ric.	Torino	3.00	WP3
Paola Sala	INFN Milano	Primo Ric	Milano	2.00	WP4
Donatella Lucchesi	Univ. Padova	Prof. Ass.	Padova	7.00	WP4
Lorenzo Sestini	Univ. Padova	Assegnista	Padova	10.00	WP4
Alessandro Bertolin	INFN	Ricercatore	Padova	10.00	WP4
Alessio Gianelle	INFN	Tecnologo	Padova	10.00	WP4
Cristina Biino	INFN	Primo Ric.	Torino	3.00	WP4
Ezio Menichetti	Univ. Torino	Prof. Ord.	Torino	3.00	WP4
Susanna Guiducci	INFN	Dir. Ric.	LNF	1.00	WP4
Maria Enrica Biagini	INFN	Dir. Tecnologo	LNF	1.00	WP5
Manuela Boscolo	INFN	Tecnologo	LNF	3.00	WP5
Camilla Curatolo	INFN	Assegnista	Padova	18.00	WP5
Donatella Lucchesi	Univ. Padova	Prof. Ass.	Padova	3.00	WP5
Mauro Morandin	INFN	Dir. Ric.	Padova	3.00	WP5
Marco Zanetti	Univ. Padova	Prof. Ass.	Padova	5.00	WP5
Nadia Pastrone	INFN	Dir. Ric.	Torino	6.00	WP5
Ezio Menichetti	Univ. Torino	Prof. Ord.	Torino	3.00	WP5