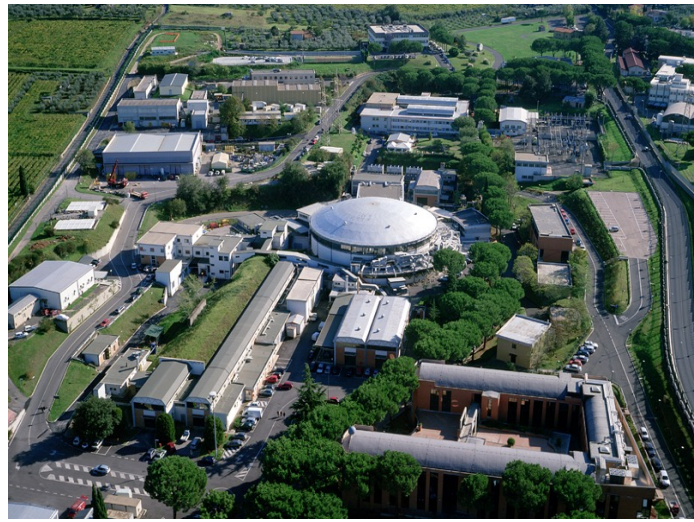


Particle Sources and Targets

Line of research

Manuela Boscolo (INFN-LNF) - manuela.boscolo@lnf.infn.it

manuela.boscolo@cern.ch

Tel. 06 – 9403 8228

Corso dottorato Fisica degli Acceleratori, Sapienza, Roma, 20 Novembre 2023

Particle Sources and targets

- **Accelerators need specific devices to produce particles**

  ***Sources* must be used to produce "beam" of particles**

  Can be source of charged or neutral particles

- **Particles need to be manipulated with *targets***

  Collimators, absorbers, septa,...

- **Particles are produced from interaction in matter** – i.e. photocathodes
- Strong interplay with condensed matter physics
- Secondary particles sources

Future Colliders: Future Circular Collider FCC

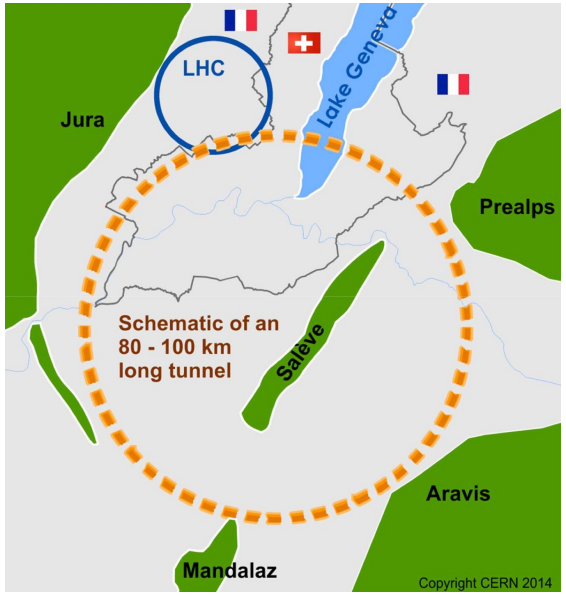
Summary documents CDR: http://fcc-cdr.web.cern.ch/

International collaboration to study:

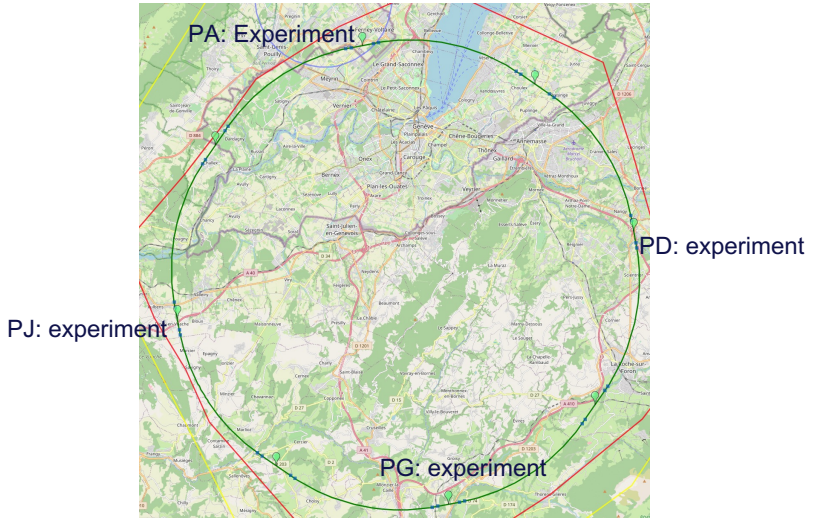
- Stage 1: **FCC-ee** (Z, W, H, $t\bar{t}$) as Higgs factory, electroweak & and top factory at highest luminosities
  High Luminosity electron-positron collider
  Beam energy ranging from 45.6 GeV to 182.5 GeV

- Stage 2: **FCC-hh** (~100 TeV) as natural continuation at energy frontier

- FCC integrated project allows seamless continuation of HEP after HL-LHC

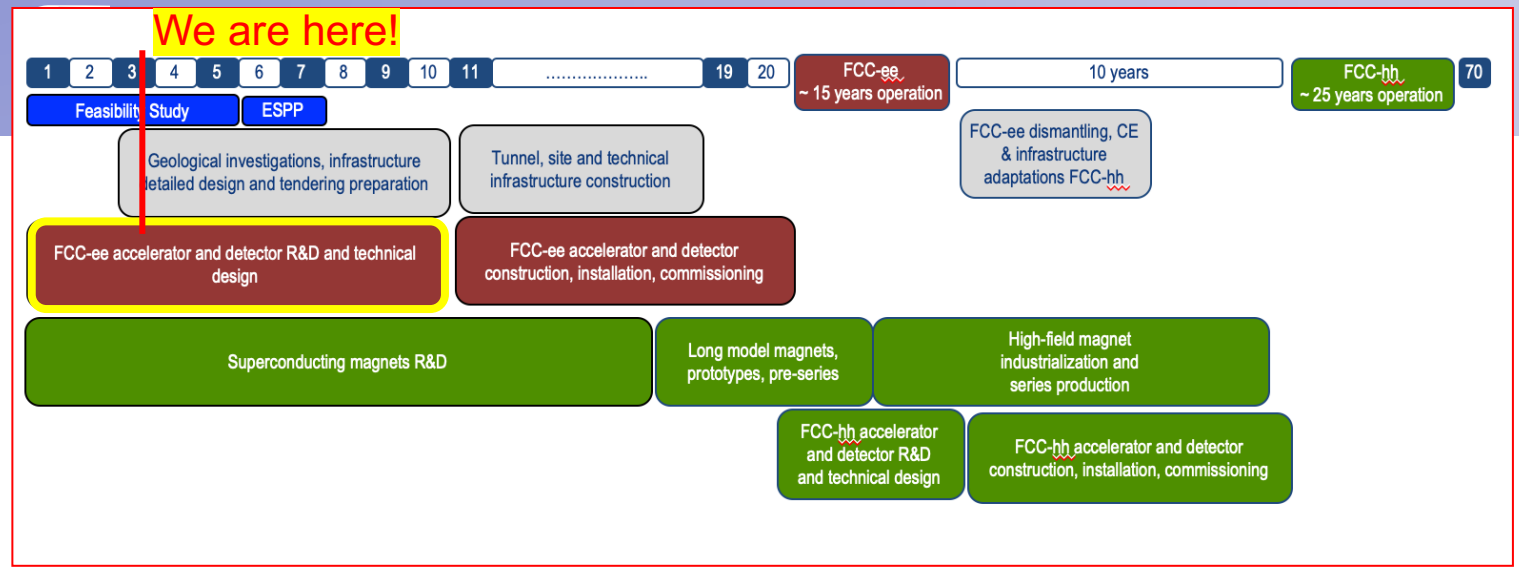


Infrastructure **100 km**:
16 T dipoles for 50 TeV protons require 100 km circumference

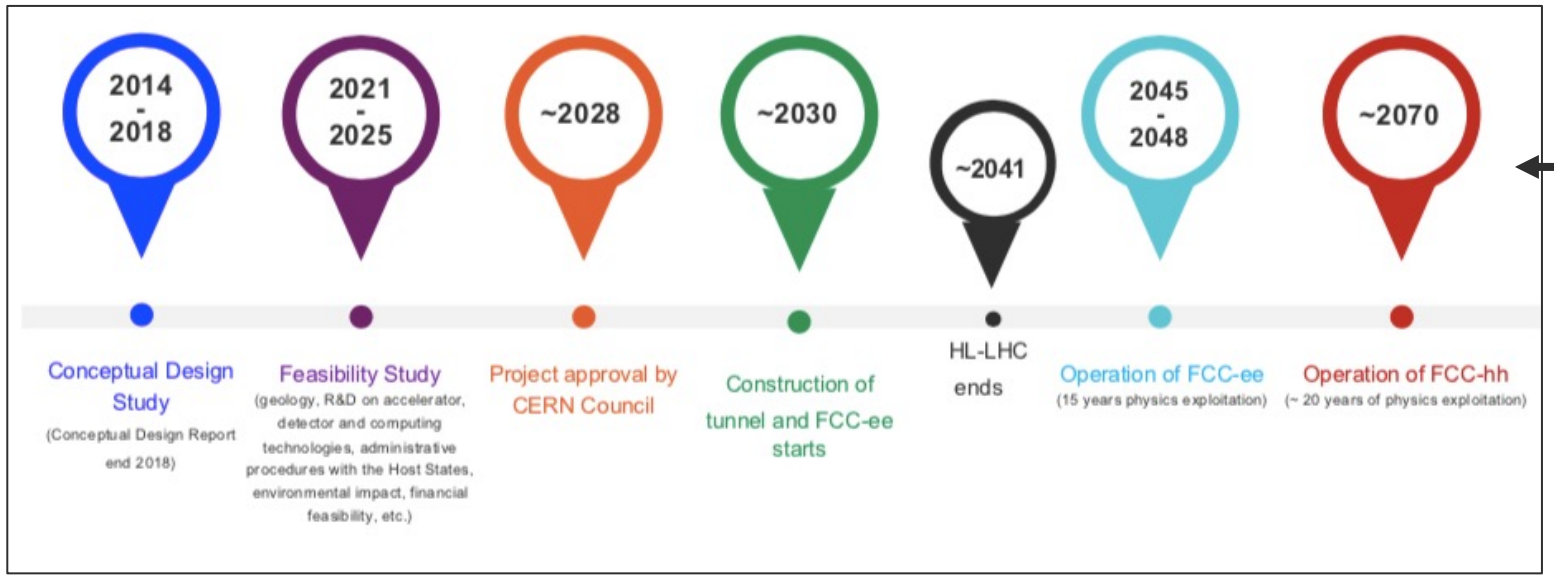


- Collaboration to FCC funded by INFN, strong Italian team contributing to many key areas
- LNF (solely in INFN) in FCCIS EU-H2020 project, Task Leader in MDI design, 2020-24
- R&D project to build a prototype of the FCC-Interaction Region has just started in Frascati

FCC estimated timeline



Technical schedule:
FCC-ee could start physics operation **in 2040 or earlier**



"Realistic" schedule takes into account:
- ❑ past experience in building colliders at CERN
- ❑ approval timeline: ESPP, Council decision
- ❑ that HL-LHC will run until ~ 2041
- → **ANY future collider at CERN cannot start physics operation before ~ 2045** (but construction will proceed in parallel to HL-LHC operation)

	√s	L /IP ($cm^{-2}\,s^{-1}$)	Int. L /IP(ab^{-1})	Comments
e^+e^- FCC-ee	~90 GeV Z 160 WW 240 H ~365 top	230 x10^{34} 28 8.5 1.5	75 5 2.5 0.8	2-4 experiments Total ~ 15 years of operation
pp FCC-hh	100 TeV	5 x 10^{34} 30	20-30	2+2 experiments Total ~ 25 years of operation
PbPb FCC-hh	$\sqrt{s_{NN}}$ = 39TeV	3 x 10^{29}	100 nb^{-1}/run	1 run = 1 month operation
ep Fcc-eh	3.5 TeV	1.5 10^{34}	2 ab^{-1}	60 GeV e- from ERL Concurrent operation with pp for ~ 20 years
e-Pb Fcc-eh	$\sqrt{s_{eN}}$ = 2.2 TeV	0.5 10^{34}	1 fb^{-1}	60 GeV e- from ERL Concurrent operation with PbPb

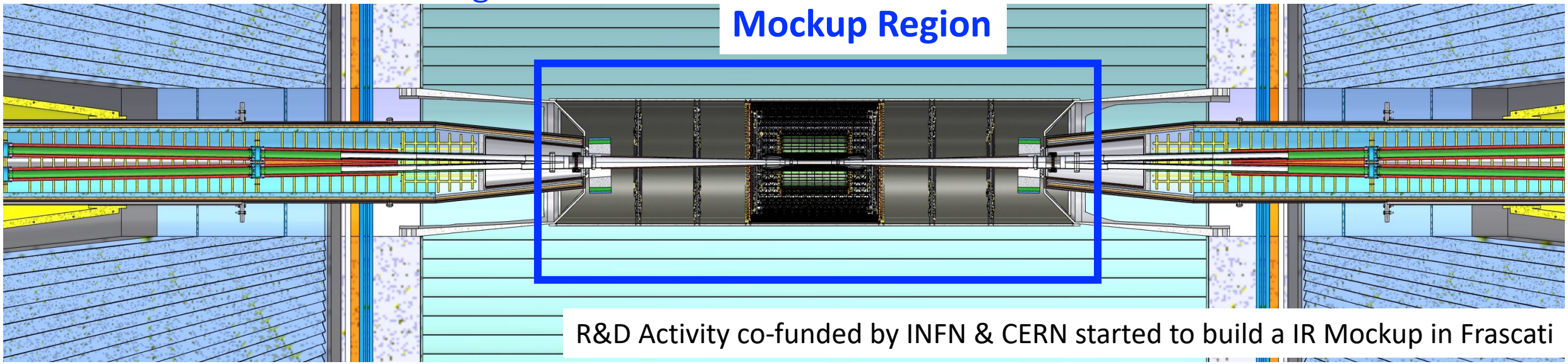
1st stage collider, FCC-ee: electron-positron collisions 90-360 GeV
Construction: 2033-2045 → Physics operation: 2048-2063

2nd stage collider, FCC-hh: proton-proton collisions at ≥ 100 TeV
Construction: 2058-2070 → Physics operation: ~ 2070-2095

Care should be taken when comparing to other proposed facilities, for which in some cases only the (optimistic) technical schedule is shown

Activity: collaborations with CERN on the design of the Interaction Region for FCC-ee

FCC-ee Central Interaction Region



R&D Activity co-funded by INFN & CERN started to build a IR Mockup in Frascati

zoom at the central region about ± 1.2 m

View including the rigid support tube, vertex detector and outer trackers

Some Refs:

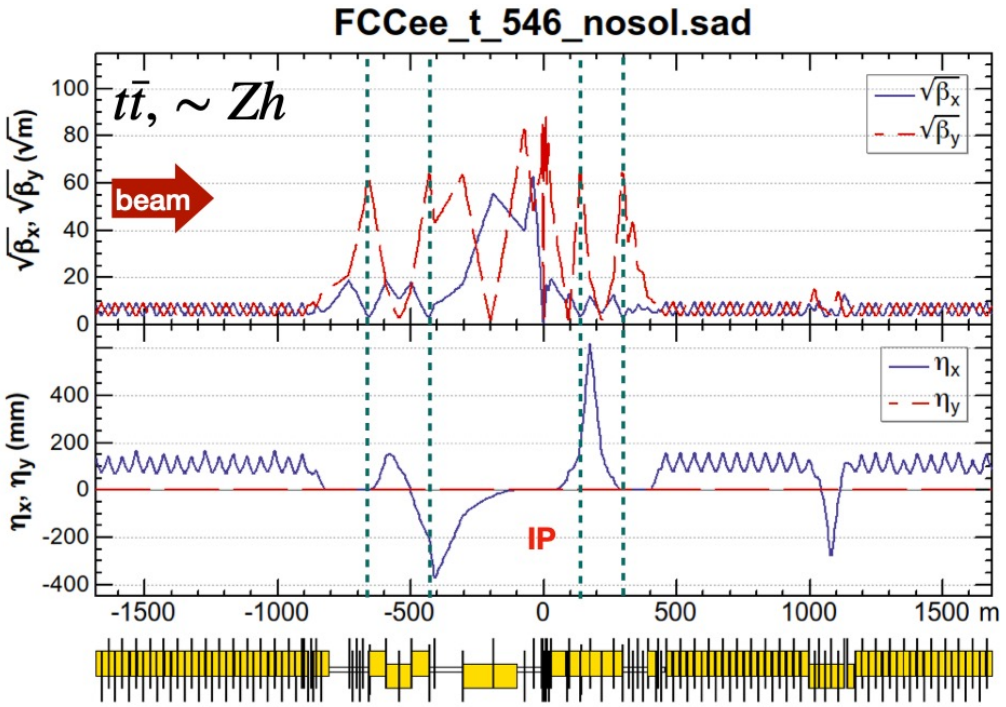
M. Boscolo, F. Palla, et al., *Mechanical model for the FCC-ee MDI,* EPJ+ Techn. and Instr., https://doi.org/10.1140/epjti/s40485-023-00103-7

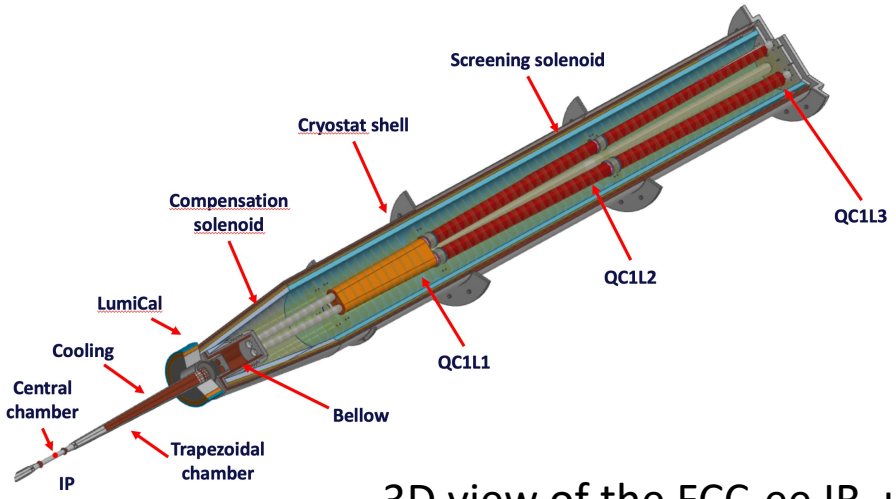
M. Boscolo and A. Ciarma, PRAB 26, 111002 (2023), link

M. Boscolo et al., Status of the *IR and MDI of the FCC-ee*, IPAC23, 7-12May 2023 https://www.ipac23.org/preproc/pdf/MOPA091.pdf

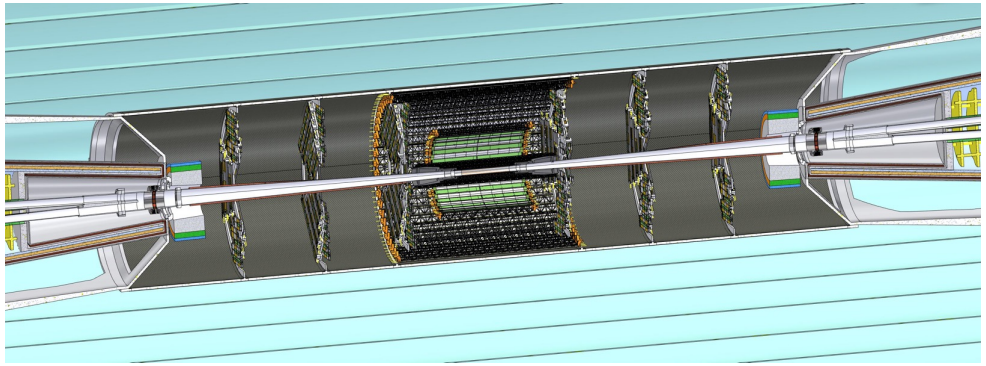
M. Boscolo, H. Burkhardt, K. Oide, M.K. Sullivan, EPJ+ (2021) https://link.springer.com/article/10.1140/epjp/s13360-021-02031-5

IR optics and mechanical design





3D view of the FCC-ee IR until the end of the first final focus quadrupole (~5.5 m)



- Crab waist/vertical chromaticity correction sextupoles are located at the dashed lines, they are superconducting.

- **The beam optics are asymmetric between upstream/downstream due to crossing angle & suppression of the SR upstream to the IP**

Possible PhD Theses: Machine-Detector Interface at FCC-ee

1. The proposed activity for this PhD thesis is to study the **FCC-ee machine backgrounds processes, their impact on the luminosity and the solutions to control and minimize this effect on detectors.**

Goals of the research program include:

- study and optimization of the FCC-ee interaction region including basic constraints from the detector
- study of the shiedings and absorbers for the experimental environment
- Simulations to assess detector backgrounds levels and tolerability
- Particle tracking and beam optic simulation tools (e.g. MAD-X, X-suite), and simulation of background generation processes
- benchmark with existing machines like SuperKEKB (Tsukuba, Japan)

Activity based at the INFN Frascati National Laboratories, in collaboration with CERN, CERN (CH), SLAC (US), BNL (US), KEK (Japan)

Contact: Manuela Boscolo
Manuela.boscolo@lnf.infn.it

Possible PhD Theses: Machine-Detector Interface at FCC-ee

1. Measurement and control of the luminosity at FCC-ee

The future circular electron-positron collider at CERN (FCC-ee) aims at unprecedented luminosities obtained with the crab-waist collision scheme.

The thesis will deal with the parameters that determine the **luminosity, its lifetime and control**, as well as the different ways to measure it, both **at the level of the accelerator as well as for the detectors**, where a precision of 100 ppm is needed to be achieved.

A similar crab-waist scheme has been adopted at the **SuperKEKB** collider at Tsukuba (Japan), where the candidate is expected to be seconded for some short periods to learn "in situ". The detector luminosity determination will use Bhabha scattering process, in which the two emerging leptons will be detector by a calorimeter. The candidate will study the mechanical tolerances and the interaction region layout that are needed to achieve the desired precision.

2. Study of the compensating scheme and machine related backgrounds at FCC-ee

The future circular electron-positron collider at CERN (FCC-ee) aims at unprecedented luminosities obtained with the crab-waist collision scheme.

Several effects are at the origin of the beam-induced backgrounds at the interaction region, such as the beam-beam effect, the radiative Bhabha scattering, beam losses from the collimators, synchrotron radiation and beam-gas interactions. Different machine **optics** will have different impacts on some of these backgrounds. The student will take confidence on the beam transport simulations and evaluate the backgrounds in the machine elements as well as in the detectors of the experiments, such as the **vertex detectors** or the **drift chambers**, in particular. A similar crab-waist scheme has been adopted at the SuperKEKB collider at Tsukuba (Japan), where the candidate is expected to be seconded for some **short periods to learn "in situ" the reduction of the beam-related backgrounds in a running machine.**

Contact: Manuela Boscolo
Manuela.boscolo@lnf.infn.it

FCC – INFN and Italian involvement

LNF organized and hosted the annual FCCIS workshop with 2 important events:

13-15 Nov. 23 Annual FCCIS Workshop, Rome:
https://indico.cern.ch/event/1326738/

16-17 Nov. 23: IR & MDI Mockup Workshop, LNF Frascati:
https://agenda.infn.it/event/37720/

First FCC-Italy workshop 21-22 March22

https://agenda.infn.it/event/29752/

FCC Accelerator activities: Italian involvement (M.Boscolo)

FIELD NOTES

momentum allowed the ALICE collaboration to extract the total charm cross-section in pp collisions. Interestingly, the fraction of Λ_c is significantly above the e+e- baseline. Jet substructure measurements presented by ALICE and CMS allow a detailed comparison to Monte Carlo event generators. Furthermore, the first direct observation of the dead-cone effect, a suppression of forward gluon radiation in case of a massive emitter, was presented by the ALICE collaboration using charm-tagged jets (see p9).

An element of non-perturbative QCD that keeps theorists on their toes is hadronic spectroscopy. This trend continued at Moriond where the discoveries of several new states were presented, including the same-sign doubly charmed T_{cc}^+ $(c-c-\bar{u}-\bar{d})$ (LHCb) and the $Z_{cs}(c-\bar{c}-s-\bar{u})$ (BES III). The exploration of the χ_{c1} earlier known as X(3872), with the hope of revealing its molecular or tetraquark nature, continues in pp as well as in PbPb collisions.

The best constraint of the charm diffusion coefficient in the quark–gluon plasma (ALICE), jet quenching studies with Z-hadron correlations (CMS) and surprising results on ridge structures in γp and γPb collisions (ATLAS) were presented during a dedicated heavy-ion session. Interestingly, by studying the abundant nuclei produced in heavy-ion collisions, the ALICE collaboration ruled out simple coalescence models for antideuteron production in PbPb collisions (see p15).

Finally, the current status of the muon anomalous magnetic moment was reviewed. The experimental value presented last year by the Fermilab g-2 collaboration shows a 1.5–4.2σ discrepancy with the SM prediction, depending on the theoretical baseline. An interesting comparison between continuum and lattice computations of the hadronic vacuum polarisation contributions was presented, and a new lattice result on hadronic light-by-light scattering was described, indicating that this "trouble-making" contribution is being brought under theoretical control.

Exciting experimental results and developments in the theory of QCD and high-energy interactions that, perhaps, remained somewhat hidden during the pandemic years, were on full display at Moriond, making the 56th edition of this conference a resounding success.

An element of non-perturbative QCD that keeps theorists on their toes is hadronic spectroscopy

Jan Fiete Grosse-Oetringhaus *CERN* and **Kirill Melnikov** *KIT Karlsruhe.*

FIRST FCC-ITALY WORKSHOP

Future Circular Collider workshop debuts in Italy

The first Italian workshop on the Future Circular Collider (FCC) took place in Rome from 21 to 22 March and was attended by around 120 researchers.

The FCC study is exploring the technical and financial feasibility of a 91 km-circumference collider situated under French and Swiss territory near CERN, thus exploiting existing infrastructures. In a first phase (FCC-ee) the tunnel would host an electron–positron collider at energies from 90 to 365 GeV, which would be replaced by a proton–proton collider (FCC-hh) with a centre-of-mass energy of at least 100 TeV, almost an order of magnitude higher than that of the LHC. The proposed roadmap foresees the R&D for the 16 T superconducting dipole magnets needed to keep the FCC-hh proton beams on track to take place in parallel with FCC-ee construction and operation

"The FCC is a large infrastructure that would allow Europe to maintain its worldwide leadership in high-energy physics research. This project is therefore of strategic importance in the international science scenario of the coming years," remarked INFN president Antonio Zoccoli in introduction. "INFN has great potential and could make a significant contribution to its implementation. In this perspective, it is important to clearly identify the main activities in which to invest, assemble the necessary human resources and identify possible industrial partners."

The workshop was opened by FCC study leader Michael Benedikt, who gave an overview of the FCC feasibility study, while deputy study leader Frank Zimmermann covered the technological challenges, design features and machine studies for FCC-ee. Opportunities for technological development related to the FCC-ee were then presented, along with machine studies, in which INFN are already involved. Scientific and technological R&D areas where collaborations could be strengthened or initiated were also identified, prompting an interesting discussion with CERN colleagues.

INFN is already well integrated both in the FCC coordination structure and several ongoing studies, having participated in the project since its beginning, and provides important contributions on all aspects of the FCC study. These range from accelerator and detector R&D, such as the development of superconducting magnets, to experimental and theoretical physics studies. This is made evident by the strong Italian involvement in FCC-related European programmes, such as EuroCirCol for FCC-hh and FCC-IS for FCC-ee, and AIDAinnova on innovative detector technologies for future accelerators. INFN is committed to the development of superconducting magnets for FCC-hh, for which substantial additional funding could come from a project in the context of the next-generation funding programme Horizon Europe.

The second day of the workshop focused on the work that experimental and theoretical physicists have been carrying out to deeply understand and the scientific potential of the visionary FCC project, the specific requests for the detectors and the associated R&D activities.

This workshop was the first in a series organised by INFN to promote and support the FCC project and pursue the key technological R&D needed to demonstrate its feasibility by the next update of the European strategy for particle physics.

Franco Bedeschi *INFN Pisa*, **Manuela Boscolo** *INFN Frascati and* **Marina Cobal** *University of Udine.*

Visionary *Participants at the FCC's Rome workshop discussed the proposed project's scientific potential.*

18 CERN COURIER JULY/AUGUST 2022

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FIELD NOTES

SECOND AFRICAN CONFERENCE ON FUNDAMENTAL AND APPLIED PHYSICS

Accelerating knowledge transfer with physics

Science and technology are key instruments for a society's economic growth and development. Yet Africa's science, innovation and education have been chronically under-funded. Transferring knowledge, building research capacity and developing competencies through training and education are major priorities for Africa in the 21st century. Physics combines these priorities by extending the frontiers of knowledge and inspiring young people. It is therefore essential to make basic knowledge of emerging technologies available and accessible to all African citizens to build a steady supply of trained and competent researchers.

In this spirit, the African School of Fundamental Physics and Applications was initiated in 2010 as a three-week biennial event. To increase networking opportunities among participants, the African Conference on Fundamental and Applied Physics (ACP) was included as a one-week extension of the school. The first edition was held in Namibia in 2018 and the second, co-organised jointly by Mohammed V University and Cadi Ayyad University in Morocco, was rebranded ACP2021, originally scheduled to take place in December but postponed due to COVID-19. The virtual event held from 7 to 11 March attracted more than 600 registrants, an order of magnitude higher than its first edition.

The ACP2021 scientific programme covered the three major physics areas of interest in Africa defined by the African Physical Society: particles and related applications; light sources and their applications; and cross-cutting fields covering accelerator physics, computing, instrumentation and detectors. The programme also included topics in quantum computing and quantum information, as well as machine learning and artificial intelligence. Furthermore, ACP2021 focused on topics related to physics education, community engagement, women in physics and early-career physicists. The agenda was stretched to accommodate different time zones and 15 parallel sessions took place.

Welcome speeches by Hassan Hbid (Cad. Ayyad University) and by Mohammed Rhachi (Mohammed V University) were followed by a plenary talk by former CERN Director-General Rolf Heuer, "Science bridging Cultures and Nations" and an overview of the African Strategy for Fundamental and Applied Physics (ASFAP). Launched in 2021, the ASFAP aims to increase African education and research capabilities, build the foundations and frameworks to attract the participation of African physicists, and establish a culture of awareness of grass-roots physics activities contrary to the top-down strategies initiated by governments (*CERN Courier* November/December 2021 p22). Shamila Nair-Bedouelle (UNESCO) conveyed a deep appreciation of and support for the ASFAP initiative, which is aligned with the agenda of the United Nations Sustainable Development Goals. A rich panel discussion followed, raising different views on physics education and research roadmaps in Africa.

A central element of the ACP2021 physics programme is the ASFAP community planning meeting, where physics and community-engagement groups discussed progress in soliciting the community input that is critical for the ASFAP report. The report will outline the direction for the next decade to encourage and strengthen higher education, capacity building and scientific research in Africa.

The motivation and enthusiasm of the ACP2021 participants was notable, and the efforts in support of research and education across Africa were encouraged. The next ACP in 2023 will be hosted by South Africa.

Farida Fassi *Mohammed V University, Morocco.*

Science for society *Map showing the countries in Africa with home institutes participating in ACP2021 (green).*

SESAME CULTURAL HERITAGE DAY

SESAME revives the ancient Near East

The Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME) is a 2.5 GeV third-generation synchrotron radiation (SR) source developed under the auspices of UNESCO and modelled after CERN. Located in Allan, Jordan, it aims to foster scientific and technological excellence as well as international cooperation amongst its members, which are currently Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, Palestine and Turkey. As a user facility, SESAME hosts visiting scientists from a wide range of disciplines, allowing them to access advanced SR techniques that link the functions and properties of samples and materials to their micro, nano and atomic structure.

The location of SESAME is known for its richness in archaeological and cultural heritage. Many important museums, collections, research institutions and universities host departments dedicated to the study of materials and tools that are inextricably linked to prehistory and human history, demanding interdisciplinary research agendas and teams. As materials science and condensed-matter physics play an increasing role in understanding and reconstructing the properties of artefacts, SESAME offers a highly versatile tool for the researchers, conservators and cultural-heritage specialists in the region.

The high photon flux, small source size and low divergence available at SR sources allow for advanced spectroscopy and imaging techniques that are well suited for studying ancient and historical materials, and which often present very complex and heterogeneous structures. SR techniques are non-destructive, and

SESAME offers a versatile tool for researchers, conservators and cultural-heritage specialists in the region

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CERN COURIER
VOLUME 62 NUMBER 4 JULY/AUGUST 2022

IOP Publishing

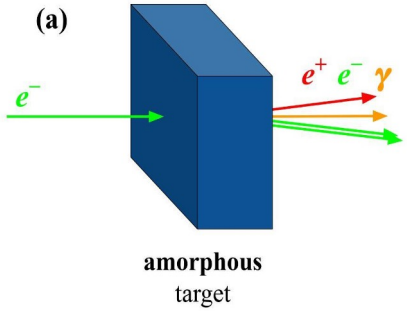
link CERN courier Jul/Aug ed.

Hybrid crystal-based positron source for the FCC-ee

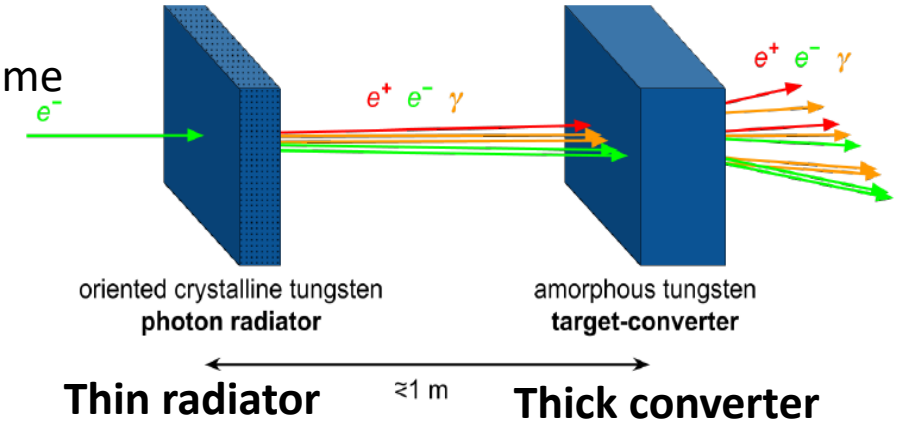
Contact: **L. Bandiera** - INFN Ferrara
bandiera@fe.infn.it

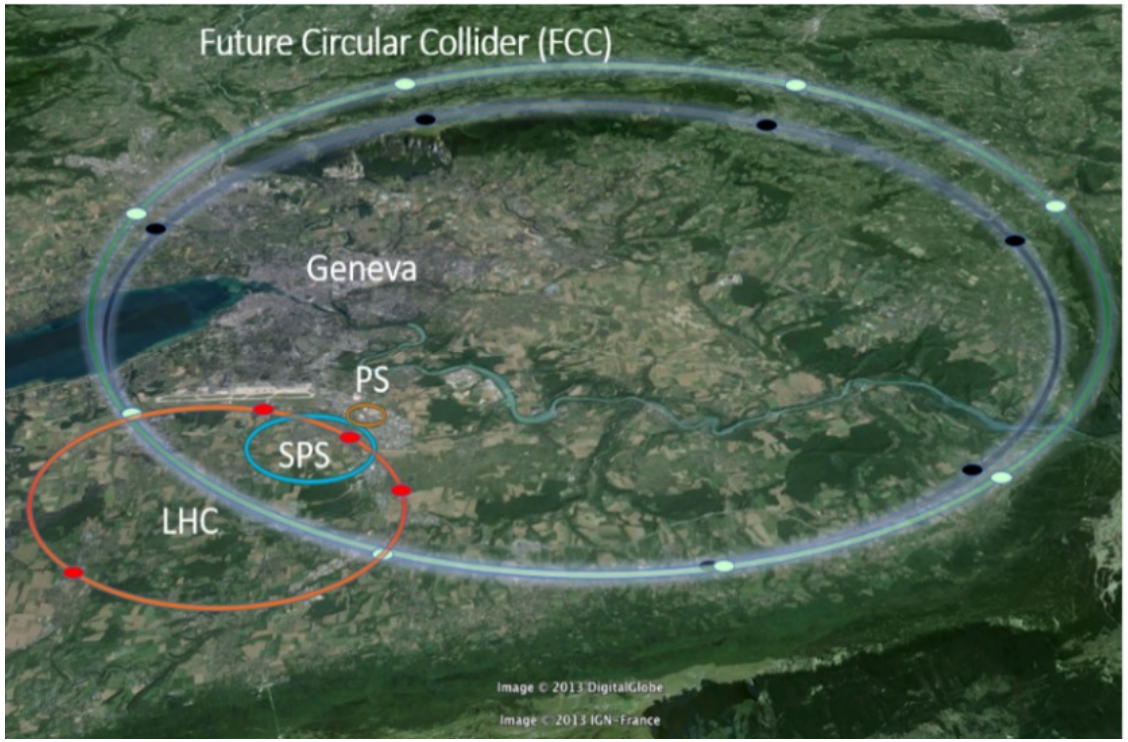
- The **FCC-ee Compact Design Report** of the **injector complex** foresees **a 6 GeV linac**.
- Currently **the conventional and hybrid scheme are under study!**

Conventional



Hybrid scheme





I. Chaikovska *et al.*, **JINST 17 (2022) P05015.**

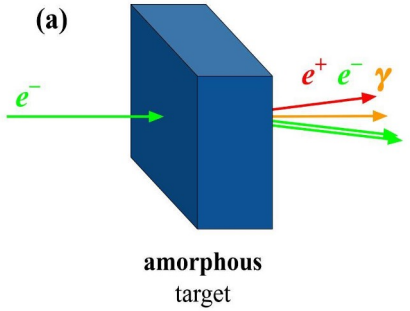
An hybrid source can be advantageous to future colliders (FCC-ee, CLIC, ILC or CEPC) as well as for current ones (SuperKEK B).

Hybrid crystal-based positron source for the FCC-ee

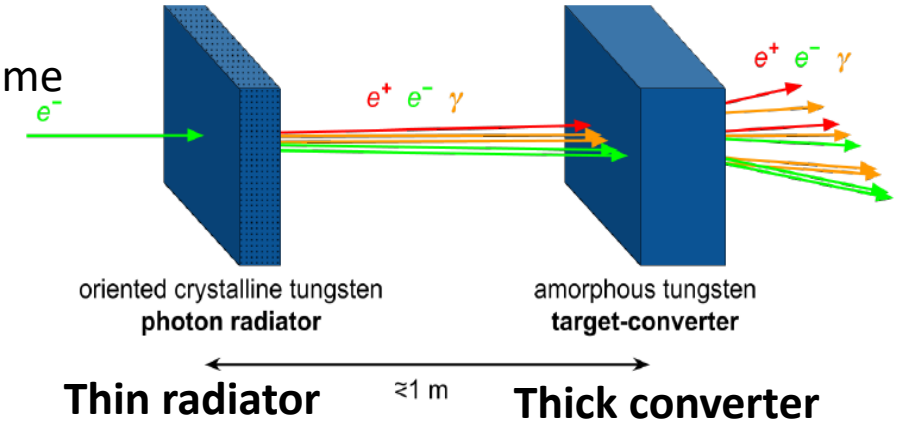
Main advantages of the hybrid source:

- **Enhancement of photon generation** in **crystals in channeling conditions** ➔ **enhancement of pair production in the converter target!**
- **High rate of soft photons** ➔ creation of **soft e^+ easily captured** in matching systems
- **Decrease of the deposited energy and Peak Energy Deposition Density (PEDD) in the converter target!**

Conventional



Hybrid scheme



Idea of R. Chehab, V. Strakhovenko and A. Variola, NIM B 266 (2008) 3868

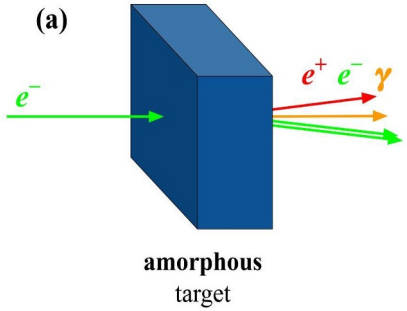
Collaboration between INFN-Ferrara and IJCLab Paris Orsay to develop hybrid crystal-based positron sources for future colliders. Possibilities of spending period at Paris Orsay.

Hybrid crystal-based positron source for the FCC-ee

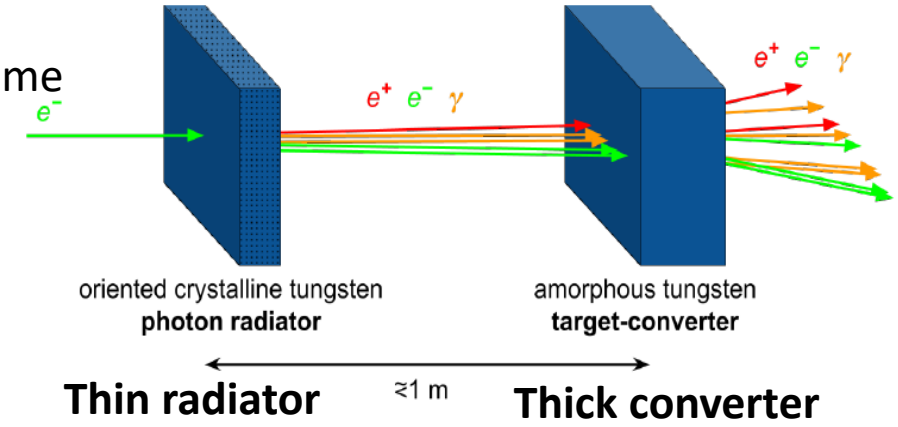
CHART project at PAUL SCHERRER INSTITUT PSI

CHART project on the FCCee Injection System: Collaboration between PSI and CERN with external partners: CNRS-IJCLab (Orsay), INFN-LNF, **INFN-Ferrara**, KEK (Japan)

Conventional

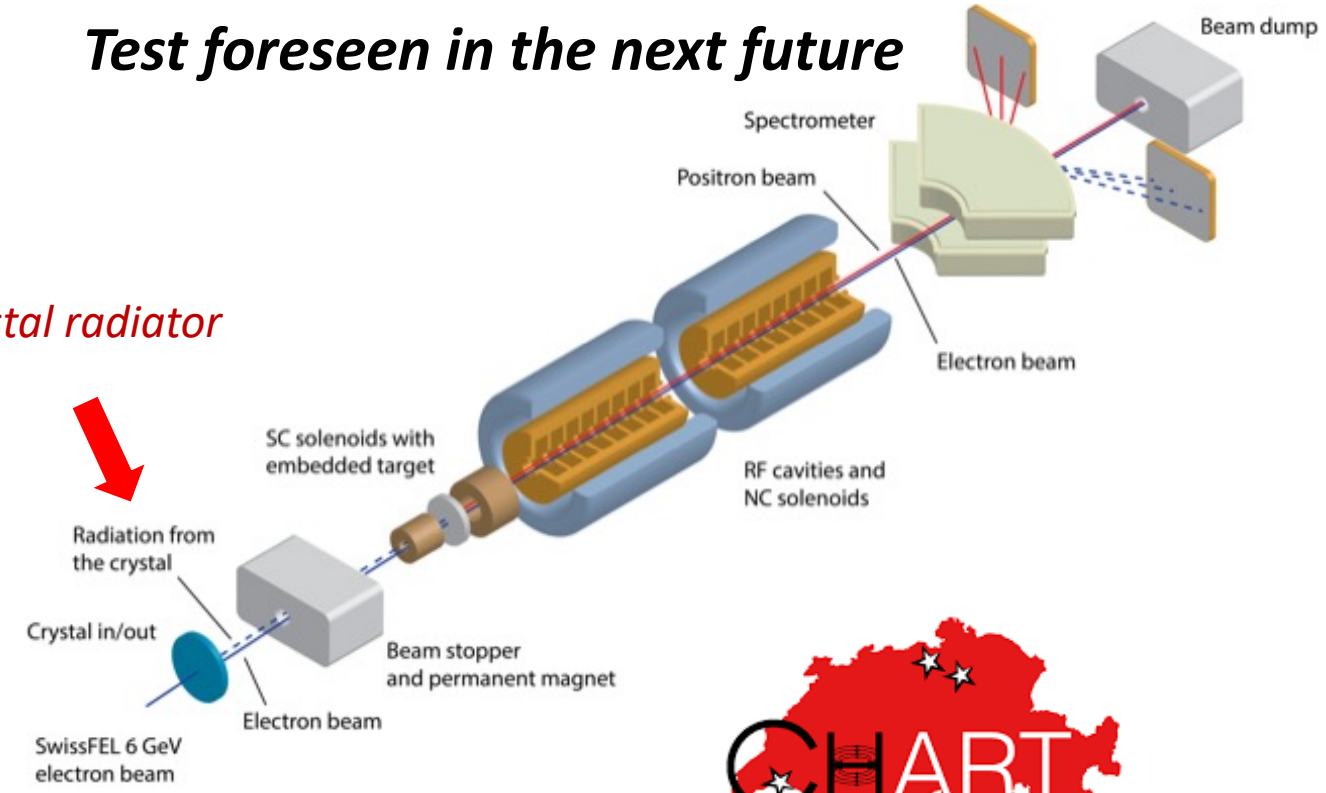


Hybrid scheme



Test foreseen in the next future

Crystal radiator

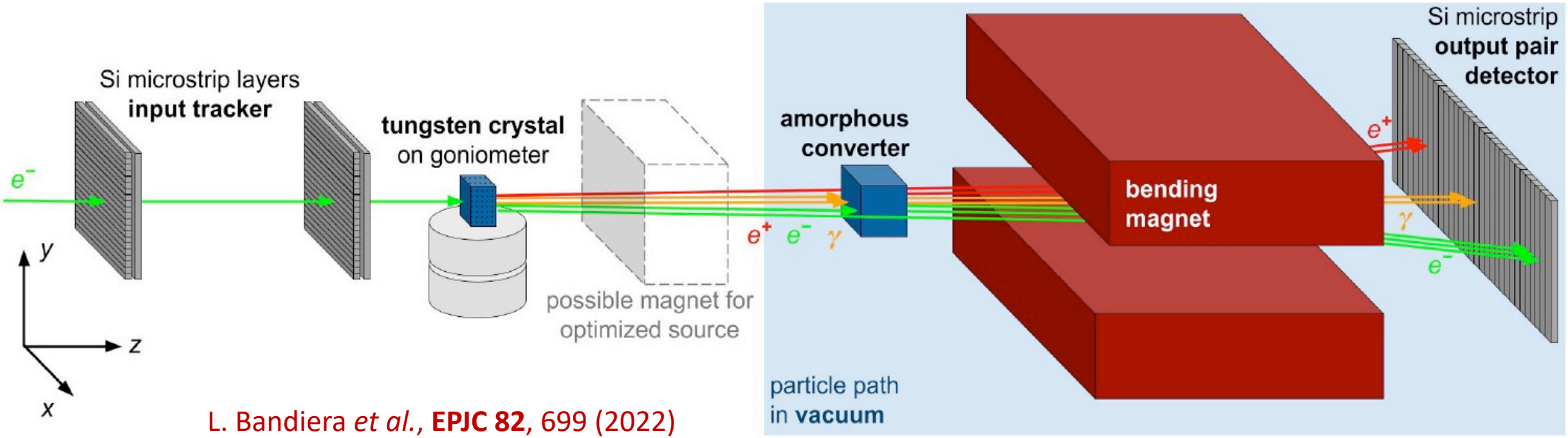


CHART

Swiss Accelerator Research and Technology

Activities: experimental tests on the targets

Possible PhD thesis



L. Bandiera *et al.*, **EPJC 82**, 699 (2022)

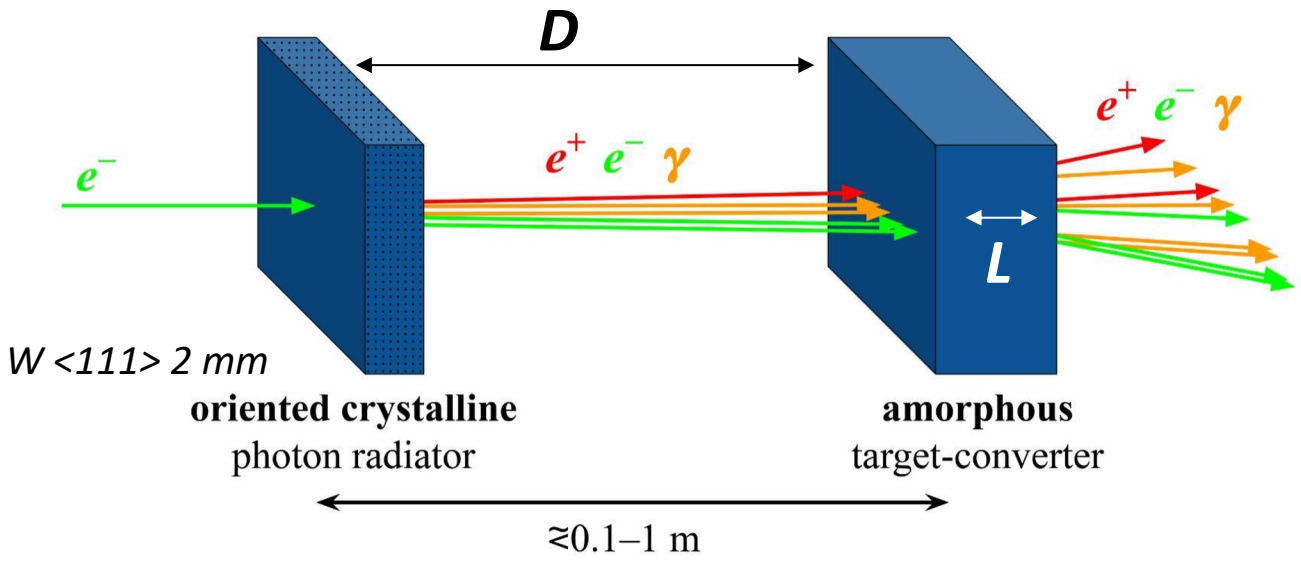
Ministero dell'Università e della Ricerca
Bando PRIN 2022
UNIVERSITÀ RICERCA

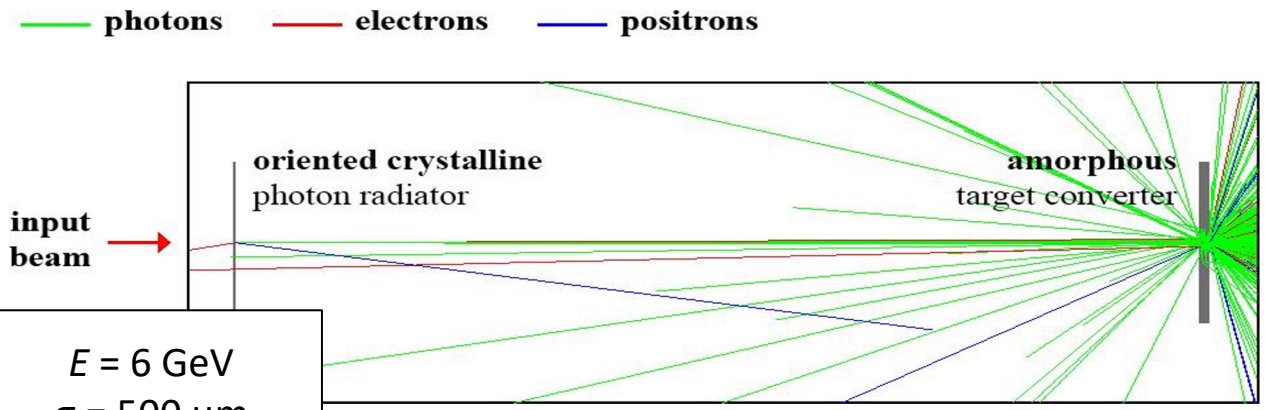
***Intense positron source Based On Oriented crySTals* - e+BOOST (PI L. Bandiera)**
Financed by Italian Ministry of University and Research - PRIN project

Setup at CERN PS extracted lines

Electron energy of 6 GeV

Activities: MC with Geant4 for the source optimization





E = 6 GeV
σ = 500 µm
σ' = 100 µrad

Possible PhD thesis

energy deposit and PEDD in amorphous converter can be reduced by tuning ***L*** (while keeping the radiator thickness fixed to maximise EM enhancement) and ***D***

Geant4 simulation of the radiator + converter system

M. Soldani et al., **NIM A**, 1058, 168828 (2024)

Collaboration with IJCLab (leader I. Chaikovska)

Activity currently on RD-MUCOL

Plasma wake-field acceleration in nanostructures

$$E[\mathrm{GV/m}] = m_e \omega_p c/e \approx 100\sqrt{n_0[10^{18}\mathrm{cm}^{-3}]}$$

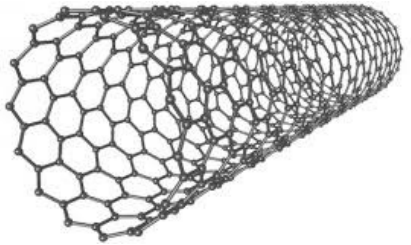
Acceleration gradient: 1-10 TeV/m

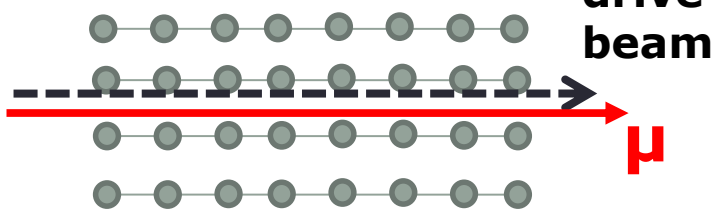
Considerably **higher electron density** in a **solid state** than in a gaseous plasma

Channeling makes **crystal** almost **transparent** both to accelerated and to drive beam

Possible drive beam:

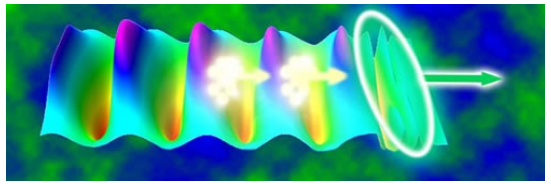
- **X-rays**
- **electrons**
- **heavy high-Z beams**





Possible accelerated beam:

- **muons**
- **e+/e-**
- **protons**

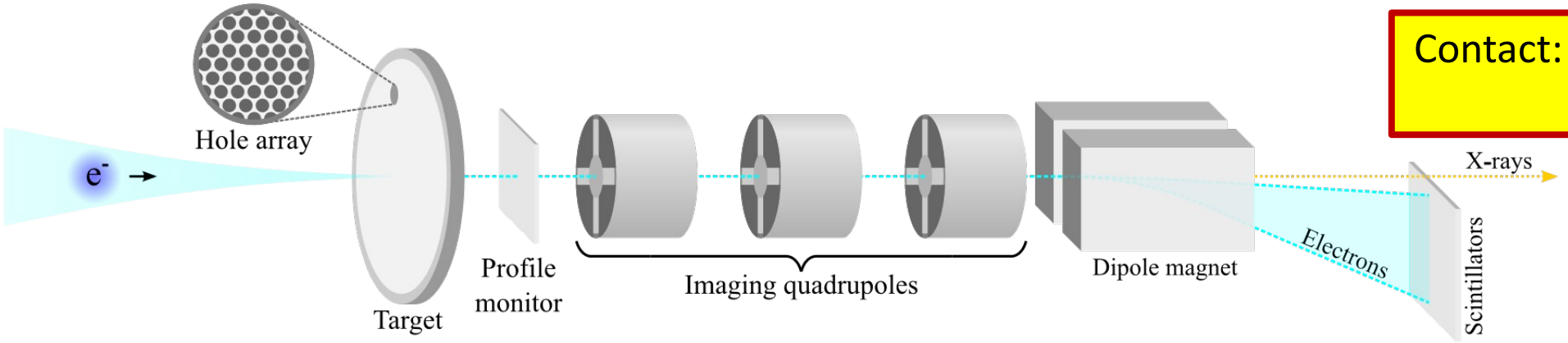


Compact muon collider?

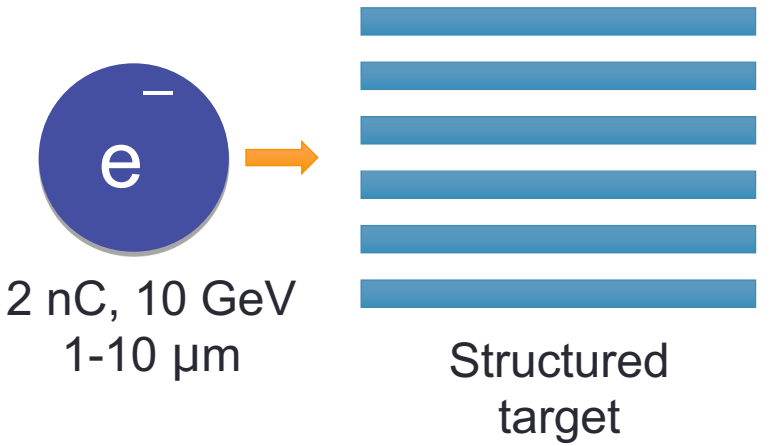
* R. Ariniello, …, and T. Tajima, Snowmass'2021 AF6: Advanced Acceleration Concepts, arXiv: 2203.07459

E336 SLAC FACET-II experimental setup

Contact: **L. Bandiera,** INFN Ferrara
bandiera@fe.infn.it



To measure:



Transverse momentum distribution & other beam parameters

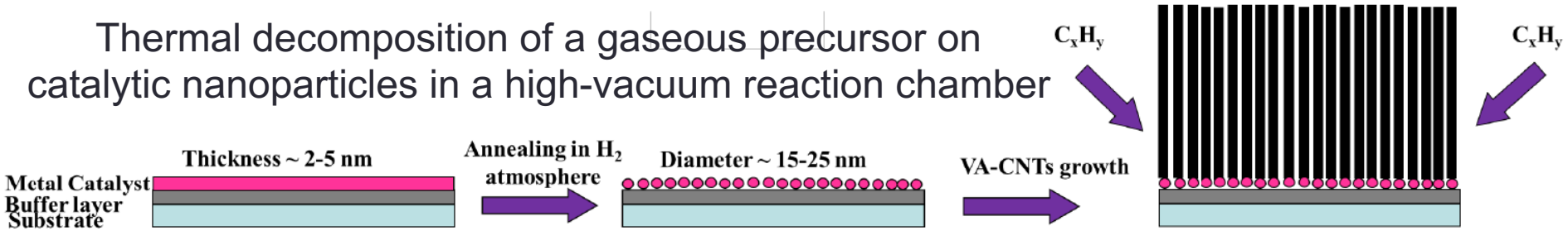
X-rays
Gamma-rays

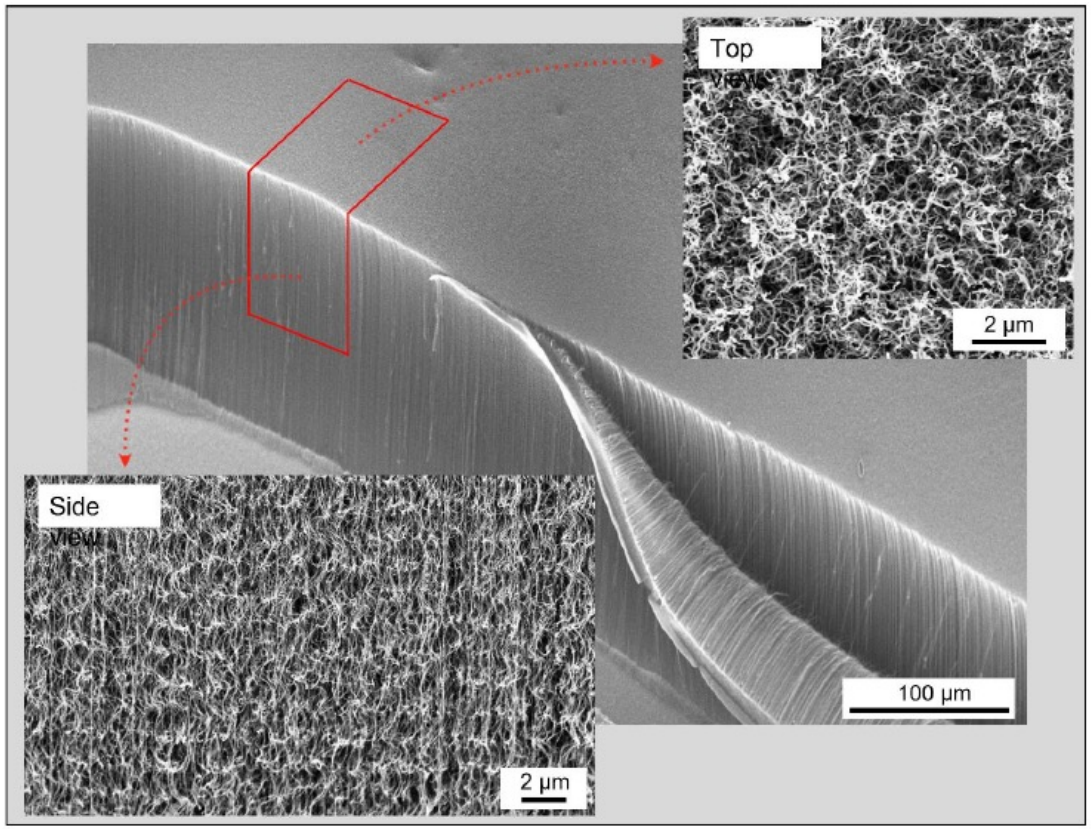
Observation of transverse plasma waves

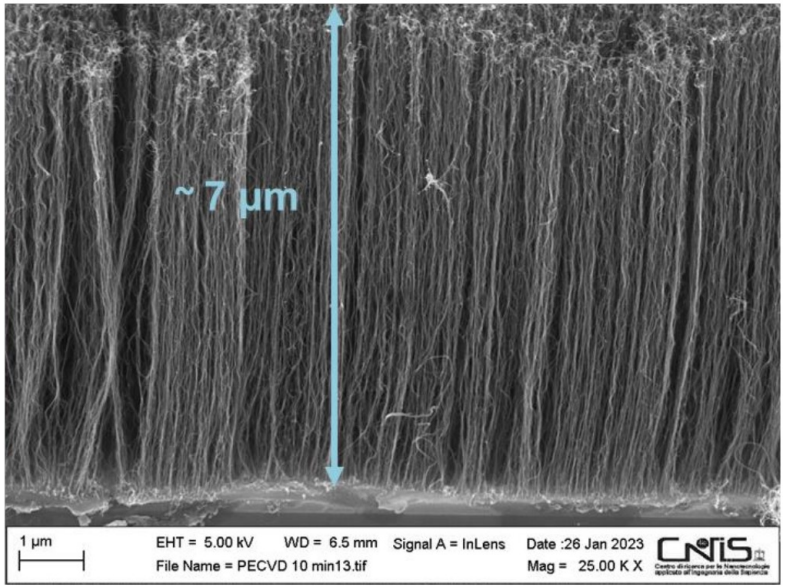
*Max F. Gilljohann et al (E336 collaboration) 2023 JINST 18 P11008 **DOI** 10.1088/1748-0221/18/11/P11008

Future Target: carbon nanotubes

Thermal decomposition of a gaseous precursor on catalytic nanoparticles in a high-vacuum reaction chamber







Contact: **G. Cavoto, La Sapienza**
gianluca.cavoto@uniroma1.it

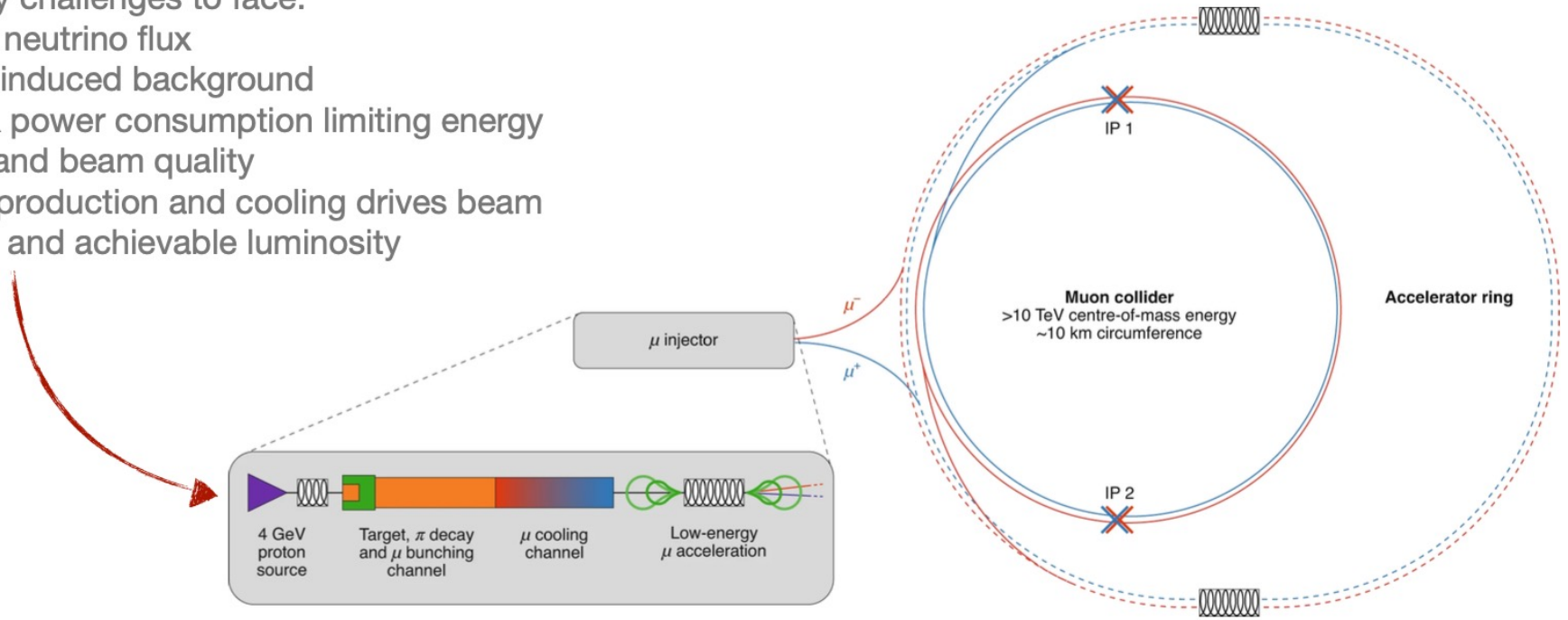
* F. Sarasini et al. Composites Part B 243 (2022) 110136

Studies on Material for the Muon Collider

MUON COLLIDER AT A GLANCE

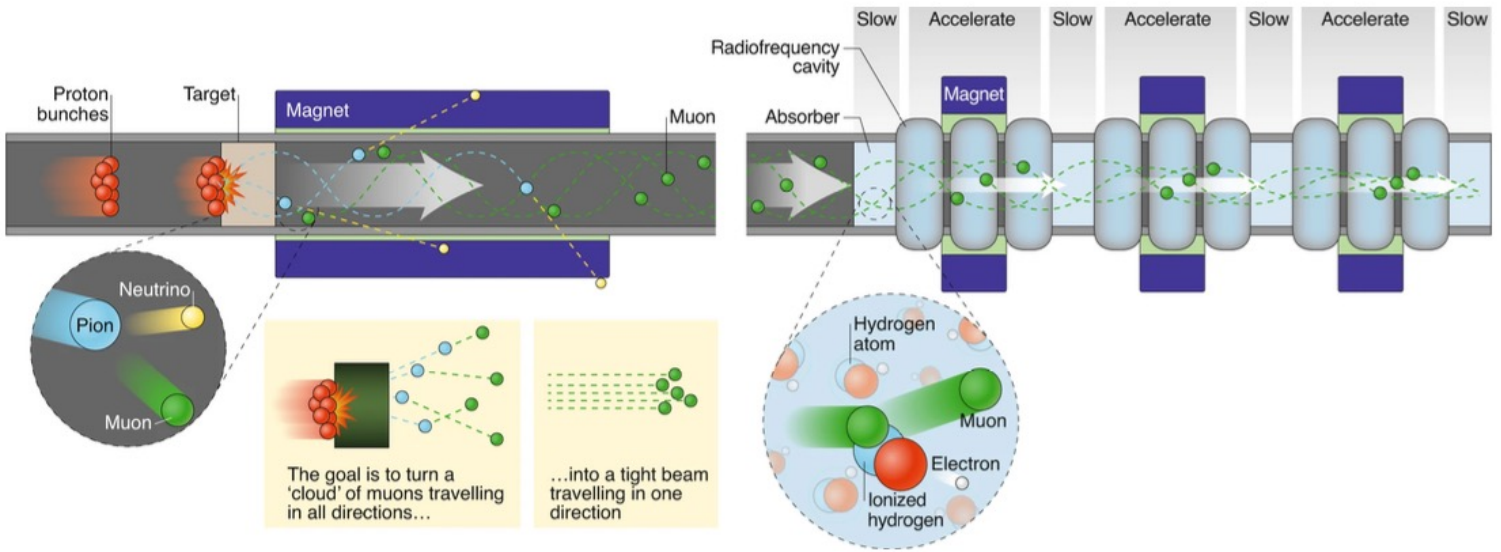
Many key challenges to face:

- Dense neutrino flux
- Beam-induced background
- Cost & power consumption limiting energy reach and beam quality
- Muon production and cooling drives beam quality and achievable luminosity



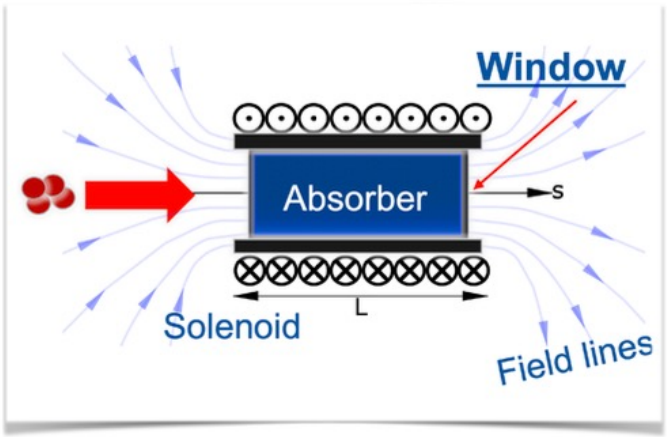
Contact: Matteo Bauce et al.

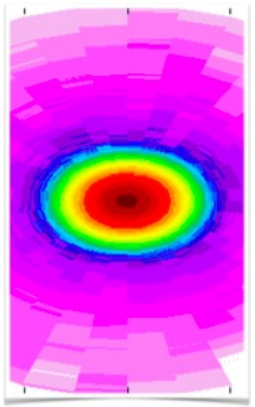
LIGHT-MATERIAL ABSORBERS FOR MUON COOLING



Parameters:
- 20 to 5 MeV cooling
- 4e12 muons/pulse
- 5 Hz repetition rate
- σ_{RMS}=0.6 mm

- *Low-Z* and *thin* absorbers (LiH, H_2,…) to minimize beam Multiple Scattering
- Thin windows to contain liquid absorbers (Be, Si_3N_4, SiC, C



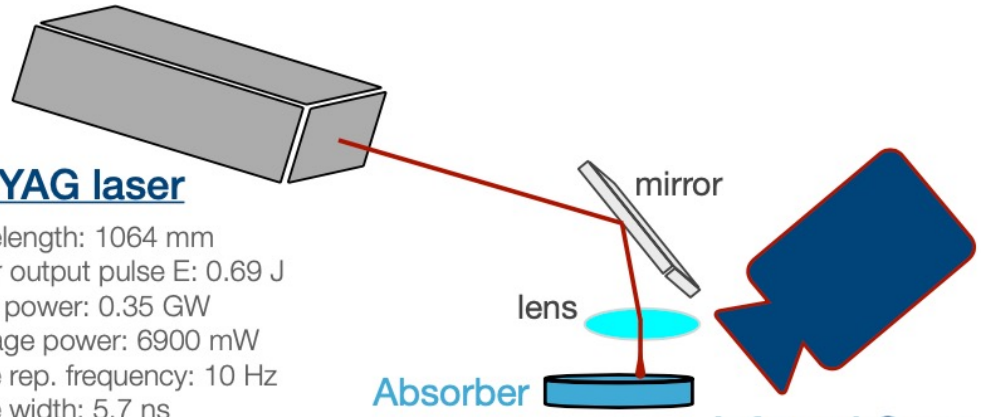


3

ABSORBER MATERIAL CHARACTERISATION

Target crash test with photons

Ex ante ex post characterisation

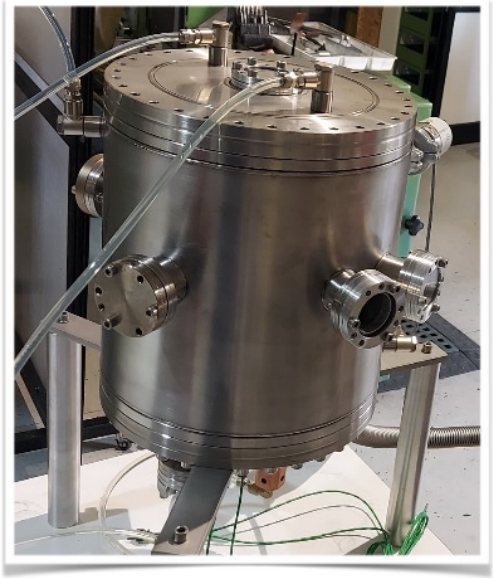


Nd:YAG laser

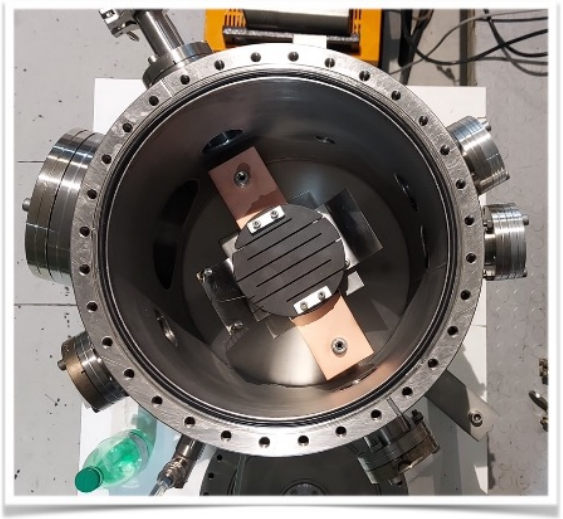
Wavelength: 1064 mm
Laser output pulse E: 0.69 J
Peak power: 0.35 GW
Average power: 6900 mW
Pulse rep. frequency: 10 Hz
Pulse width: 5.7 ns

Infrared Camera
FLIR X6901sc SLS

Optic: 17 mm, calibrated in the range [-80 °C, +300 °C]



vacuum chambers for thermal measurements



SAPIENZA
UNIVERSITÀ DI ROMA

Dipartimento di Scienze di Base e Applicate per l'Ingegneria

4

Particle production, Particle interaction, Particle monitoring

- Many and diverse opportunities for PhD projects
- Interplay between condensed matter physics, material science and accelerator physics – extremely interesting
- International collaborations with activities mainly at CERN

Contacts in the slides: Manuela Boscolo, Laura Bandiera, Gianluca Cavoto, Matteo Bauce

Summary List of PhD Thesis proposals

Contact	Topic	Area of research
Manuela Boscolo	**Measurement and control of the luminosity at FCC-ee**	Future e+e- Colliders FCC
Manuela Boscolo	**Interaction Region Design of the FCC-ee**	Future e+e- Colliders FCC
Laura Bandiera	**Setup at CERN PS extracted lines Electron energy of 6 GeV**	Future e+e- Colliders FCC
Laura Bandiera	**Geant4 simulation of the radiator + converter system**	Future e+e- Colliders FCC
Gianluca Cavoto	**Carbon nanotubes for plasma wake field acceleration**	Plasma wakefield acceleration
Matteo Bauce	**Study of thermal stress for absorber materials in the Muon Collider ionisation cooling cells**	Proton-based Muon Collider R&D

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