RD_FA (R&D per Futuri Acceleratori)

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RD_FA is a new activity initiated this year 2017 within the CSN1 for the study of potential future experiments. The new colliders considered by RD_FA are: ILC, CLIC, FCC-ee, CepC, FCC-hh, SppC, EIC and muon collider. The activity is organized in Working Packages as follows:

- WP1: Fisica e simulazione
- WP2: Machine Detector Interface (M. Boscolo, convener)
- WP3: Pixel detectors
- WP4: RICH e TPC con MPGD
- WP5: Ultralight drift chamber
- WP6: Silicon microstrip tracking
- WP7: MPGD per muon systems
- WP8: Muon Collider R&D (M. Antonelli, convener)

For the year 2017 the LNF group has been involved in WP1 , WP3 and WP8, as described in the following.

The activity on the Muon Collider (WP8) was started by an idea from M. Antonelli and P. Raimondi for muon production from positron beam on target, presented in Snowmass 2013 [1), 2)].

1 WP1: Fisica e simulazione

This WP aims at detector simulations for FCC-hh and FCC-ee, mainly physics studies EW (Z, W) and BSM together with theorists.

2 WP3: Machine Detector Interface for FCC-ee and FCC-hh

The interaction region is one of the key issues of a collider, it determines its success. For this reason it requires a careful design, balancing the requirements from the accelerator and detector sides. The interaction region design has to provide high luminosity that can be used for physics studies in the detectors with tolerable backgrounds and radiation. RD_FA is working on the design of the IR for FCC-hh and FCC-ee.

2.1 MDI FCC-hh

The LNF is involved in the Experimental Insertion Region (EIR) study group also supported by the project EuroCirCol (EU INFRADEV-H2020 project, coordinator for INFN: M. Boscolo).
The synchrotron radiation (SR) impact in the FCC-hh is evaluated. The SR rates hitting the FCC-hh detector are found to be low enough with safe values [3), 4), 5)].

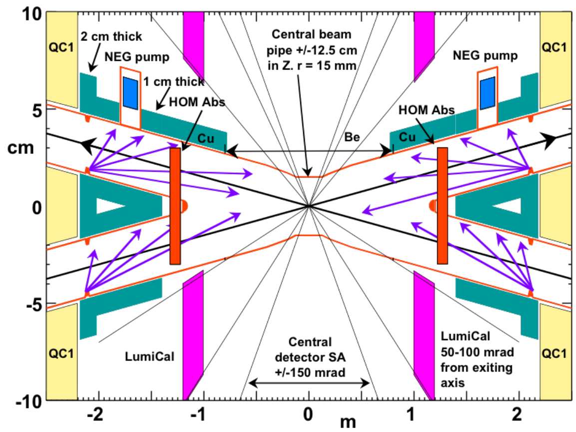

Figure 1: *FCC-ee IR layout.*

2.2 MDI FCC-ee

The whole MDI study of the FCC-ee design is coordinated by M. Boscolo (convener). The group is international with active participation not only from CERN, but from many labs such as SLAC, BINP, KEK, among others. Monthly meeting are held at CERN with remote connection as well to discuss the MDI design progress.

The FCC-ee collider is a very challenging machine with unprecedented high e^+e^- beam energy, luminosity and circumference. This machine will work at different beam energies, from 45.6 GeV up to 175 GeV, with a luminosity that goes from $2.1 \times 10^{36}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ for the lower energy to $1.3 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ for the highest one. The circumference is foreseen to be about 100 km. The plan is to have a flexible interaction region design that allows for this large beam energy range. The crab-waist collision scheme has been chosen to reach the highest possible luminosity, so the crossing angle is 30 mrad. The design has to include a luminosity monitor and masks to stop synchrotron radiation photons. The beam pipe dimensions have to be properly set according to the beam size and available space, with flexibility for possible future optics modifications. The large crossing angle together with the high beam energy may induce high synchrotron radiation (SR) in the interaction region and consequently into the detector. We can state that the SR in the interaction region drives the layout design. One of the most significant constraints is the requirement on the critical energy and power of the synchrotron radiation generated upstream of the IR that may shine into the detector. An additional constraint of the FCC-ee layout is the compatibility with the hadron collider FCC-hh, which drives the infrastructure design. In order to combine the two requests of a large crossing angle and the need to prevent high energy SR fans from going into the IP, the IR optics have been designed asymmetrically so that the incoming beam from both sides comes from the inner ring and the outgoing beam exits to the outer ring. In this way the outgoing beams are more strongly bent than the incoming beams thereby lowering the SR energy from the incoming beams. Some publications regarding the MDI FCC-ee study for this year 2017 are: [6], [7], [8], [9], [10], [11], [12]. The design is good progress and the goal is to have a feasible design ready for the CDR, in view of the European Strategy Update.

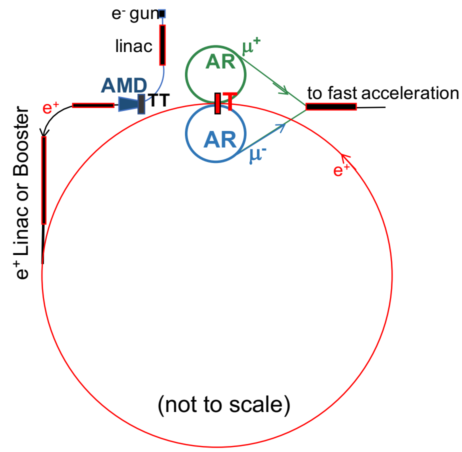

Figure 2: *First layout of the LEMMA accelerator complex.*

3 WP8: Muon Collider

We are studying a new scheme to produce very low emittance muon beams using a positron beam of about 45 GeV interacting on electrons on target. This is a challenging and innovative scheme that needs a full design study. One of the innovative topics to be investigated is the behaviour of the positron beam stored in a low emittance ring with a thin target, that is directly inserted in the ring chamber to produce muons. Muons can be immediately collected at the exit of the target and transported to two μ^+ and μ^- accumulator rings and then injected in muon collider rings. In 2017 we focused our study on the simulation of the e$^+$ beam interacting with the target, its degradation in the 6-D phase space and the optimization of the e$^+$ ring design to maximize the energy acceptance. We investigated the performances of this scheme, ring optics plus target system, comparing different multi-turn simulations. [13].

We started our study with a ring cell of 197 m based on the Hybrid Multi Bend Achromat, for large momentum and dynamic aperture, where we compared the results between tracking with Accelerator Toolbox (AT) in MATLAB, MAD-X and MAD-X PTC. They all show a relative good agreement.

The cell has been used to create a 45 GeV positron storage ring 6 km long to recirculate a beam strongly affected by the passage thorough the target. Then, we used a very creative method of particle tracking and interaction with target to separate the multiple scattering from bremsstrahlung, leading to a better understanding of the initial lattice design limitations. The beam phase space required the design of an Interaction Region to allocate the target. The beam has been matched to the target insertion location to minimize the emittance growth. It is matched to the divergence produced by the target multiple scattering, and horizontal dispersion is cancelled to avoid contributions from energy loss to the beam size. Our goal is a beam lifetime close to 100 turns with a ring plus target scheme, where the chosen target is 3 mm Beryllium. However, the beam lifetime resulting from simulations is about 40 turns due to the combined effect of energy loss in the target and the maximum momentum acceptance of the ring. Sextupole optimization has been performed to pursue a longer lifetime. We studied also the effect of several different materials and thicknesses concluding that beam lifetime and target thickness is inversally proportional, as expected. The effect of damping also showed to be slightly positive to reduce the total emittance growth. Further work on the lattice design is already foreseen when thermo-mechanical stress in the target are well understood.

An exploratory experiment to produce muon from positron on target has been performed at the CERN North Area H4 beamline with 45 GeV positrons. Data analysis is still on-going.

4 List of Conference Talks by LNF Authors in Year 2017

1. M. Boscolo, "Workshop Goals" and "Final Conclusions" of the First workshop on the FCC-ee MDI" CERN, 16-27 January 2017.
2. M. Antonelli, invited seminar, "Novel proposal for a low emittance muon collider", EPFL, Lausanne 2017.
3. M. Boscolo, "Studies of a scheme for low emittance muon beam production from positrons on target", IPAC17, Copenhagen, 14-19 May 2017.
4. M. Boscolo, "FCC-ee MDI staus and overview", FCC WEEK Conference, Berlin, 29 May-2 June 2017.
5. M. Boscolo, "Machine detector interface for the e^+e^- Future Circular Collider", EPS Conference on High Energy Physics, Venice, 5-12 July 2017.
6. F. Collamati, "Studies of a scheme for low emittance muon beam production from positrons on target", EPS Conference on High Energy Physics, Venice, 5-12 July 2017.
7. F. Collamati, "Low Emittance Muon Beams from Positrons", NuFact 2017, 25-30 September 2017.
8. M. Boscolo, "Novel Proposal of a Mow EMittance Muon Accelerator", INFN Machine Advisory Committee, 10 October 2017.
9. M. Antonelli, invited seminar, "Novel proposal for a low emittance muon collider", LAPP, Annecy, 2017.

5 Publications for the year 2017

References

1. J. M. Byrd *et al.*, "Working Group Report: High Intensity Electron and Photon Beams,"
2. M. Antonelli and P. Raimondi, "Snowmass Report: Ideas for Muon Production from Positron Beam Interaction on a Plasma Target", INFN-13-22/LNF, 21 November 2013.
3. F. Collamati, M. Boscolo, H. Burkhardt and R. Kersevan, "Synchrotron radiation backgrounds for the FCC-hh experiments," J. Phys. Conf. Ser. **874** (2017) no.1, 012004. doi:10.1088/1742-6596/874/1/012004, 10.18429/JACoW-IPAC2017-TUPVA004
4. A. Seryi *et al.*, "Overview of Design Development of FCC-hh Experimental Interaction Regions," doi:10.18429/JACoW-IPAC2017-TUPVA040
5. F. Zimmermann *et al.*, "Beam dynamics issues in the FCC," doi:10.18429/JACoW-HB2016-WEAM5X01
6. M. Boscolo and M. K. Sullivan, "Interaction Region for the FCC-ee Design," ICFA Beam Dyn. Newslett. **72** (2017) 70.

7. G. Voutsinas, N. Bacchetta, M. Boscolo, P. Janot, A. Kolano, E. Perez, M. Sullivan and N. Tehrani, "Luminosity- and Beam- Induced Backgrounds for the FCC-ee Interaction Region Design," doi:10.18429/JACoW-IPAC2017-WEPIK004

8. K. Oide *et al.*, "Progress in the Design of Beam Optics for FCC-ee Collider Ring*," doi:10.18429/JACoW-IPAC2017-TUOCB1

9. M. Koratzinos *et al.*, "Progress in the FCC-ee Interaction Region Magnet Design," doi:10.18429/JACoW-IPAC2017-WEPIK034

10. K. Oide *et al.*, "Beam Optics for FCC-ee Collider Ring," PoS ICHEP **2016** (2017) 040.

11. M. Boscolo, H. Burkhardt and M. Sullivan, "Machine detector interface studies: Layout and synchrotron radiation estimate in the future circular collider interaction region," Phys. Rev. Accel. Beams **20** (2017) no.1, 011008. doi:10.1103/PhysRevAccelBeams.20.011008

12. K. Oide *et al.*, "Design of beam optics for the Future Circular Collider e^+e^--collider rings," Phys. Rev. Accel. Beams **19** (2016) no.11, 111005 Addendum: [Phys. Rev. Accel. Beams **20** (2017) no.4, 049901] doi:10.1103/PhysRevAccelBeams.19.111005, 10.1103/PhysRevAccelBeams.20.049901 [arXiv:1610.07170 [physics.acc-ph]].

13. M. Boscolo *et al.*, "Studies of a Scheme for Low Emittance Muon Beam Production From Positrons on Target," doi:10.18429/JACoW-IPAC2017-WEOBA3