

# INTRODUCTION AND FCC-ee COLLIDER BEAM PARAMETERS



Frank Zimmermann

“Other Science Opportunities at the FCC-ee”, 28 November 2024

# Other FCC(-ee) Science – a bit of history

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**14 May 2013 brainstorming meeting on LHC as a light source** organized by Herman Winick of SLAC. Followed by discussion on **HE-LHC, VHE-LHC (FCC-hh) & TLEP (FCC-ee) as light sources. (!)**

**Brainstorming in July 2020** on R1 outside terrasse (covid!): Michael Benedikt, Sara Casalbuoni (EU-XFEL, remote), Michael Doser, Frank Zimmermann; identified **7 exciting applications**. [10.5281/zenodo.7675664](https://zenodo.org/record/7675664)

... activity stopped ... but recently resumed ...

«Other FCC Science» Initiative (also in view of ESU), **kick off brainstorm 23 August 2024**. <https://indico.cern.ch/event/1442918/>

# Exploit unique features of FCC-ee to enable new science

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- **Extremely low emittance storage rings** – booster and collider
- **Highest-energy e- beams, 20 GeV -183 GeV**
- **World's highest intensity positron source**, combined with CERN PS/AD complex
- **Highest energy positron beams**
- **Highest energy  $\gamma$  beams**
- **High-power beamstrahlung (several MW)**

Prepare complementary submission(s) to ESPPU

# FCC-ee collider rings - main machine parameters

Parameter	Z	WW	H (ZH)	ttbar
beam energy [GeV]	45.6	80	120	182.5
beam current [mA]	1270	137	26.7	4.9
number bunches/beam	11200	1780	440	60
bunch intensity [ $10^{11}$ ]	2.14	1.45	1.15	1.55
SR energy loss / turn [GeV]	0.0394	0.374	1.89	10.4
total RF voltage 400/800 MHz [GV]	0.120/0	1.0/0	2.1/0	2.1/9.4
long. damping time [turns]	1158	215	64	18
horizontal beta* [m]	0.11	0.2	0.24	1.0
vertical beta* [mm]	0.7	1.0	1.0	1.6
horizontal geometric emittance [nm]	0.71	2.17	0.71	1.59
vertical geom. emittance [ $\mu\text{m}$ ]	1.9	2.2	1.4	1.6
vertical rms IP spot size [nm]	36	47	40	51
beam-beam parameter $\xi_x / \xi_y$	0.002/0.0973	0.013/0.128	0.010/0.088	0.073/0.134
rms bunch length with SR / BS [mm]	5.6 / 15.5	3.5 / 5.4	3.4 / 4.7	1.8 / 2.2
luminosity per IP [ $10^{34} \text{ cm}^{-2}\text{s}^{-1}$ ]	140	20	$\geq 5.0$	1.25
total integrated luminosity / IP / year [ $\text{ab}^{-1}/\text{yr}$ ]	17	2.4	0.6	0.15
beam lifetime rad Bhabha + BS [min]	15	12	12	11

4 years  
 $5 \times 10^{12} Z$   
 $\text{LEP} \times 10^5$

2 years  
 $> 10^8 WW$   
 $\text{LEP} \times 10^4$

3 years  
 $2 \times 10^6 H$

5 years  
 $2 \times 10^6 \text{ tt pairs}$

## Design and parameters to maximise luminosity at all working points:

- allow for 50 MW synchrotron radiation per beam.
- Independent vacuum systems for electrons and positrons
- full energy booster ring with top-up injection, collider permanent in collision mode

- x 10-50 improvements on all EW observables
- up to x 10 improvement on Higgs coupling (model-indep.) measurements over HL-LHC
- x10 Belle II statistics for b, c,  $\tau$
- indirect discovery potential up to  $\sim 70 \text{ TeV}$
- direct discovery potential for feebly-interacting particles over 5-100 GeV mass range

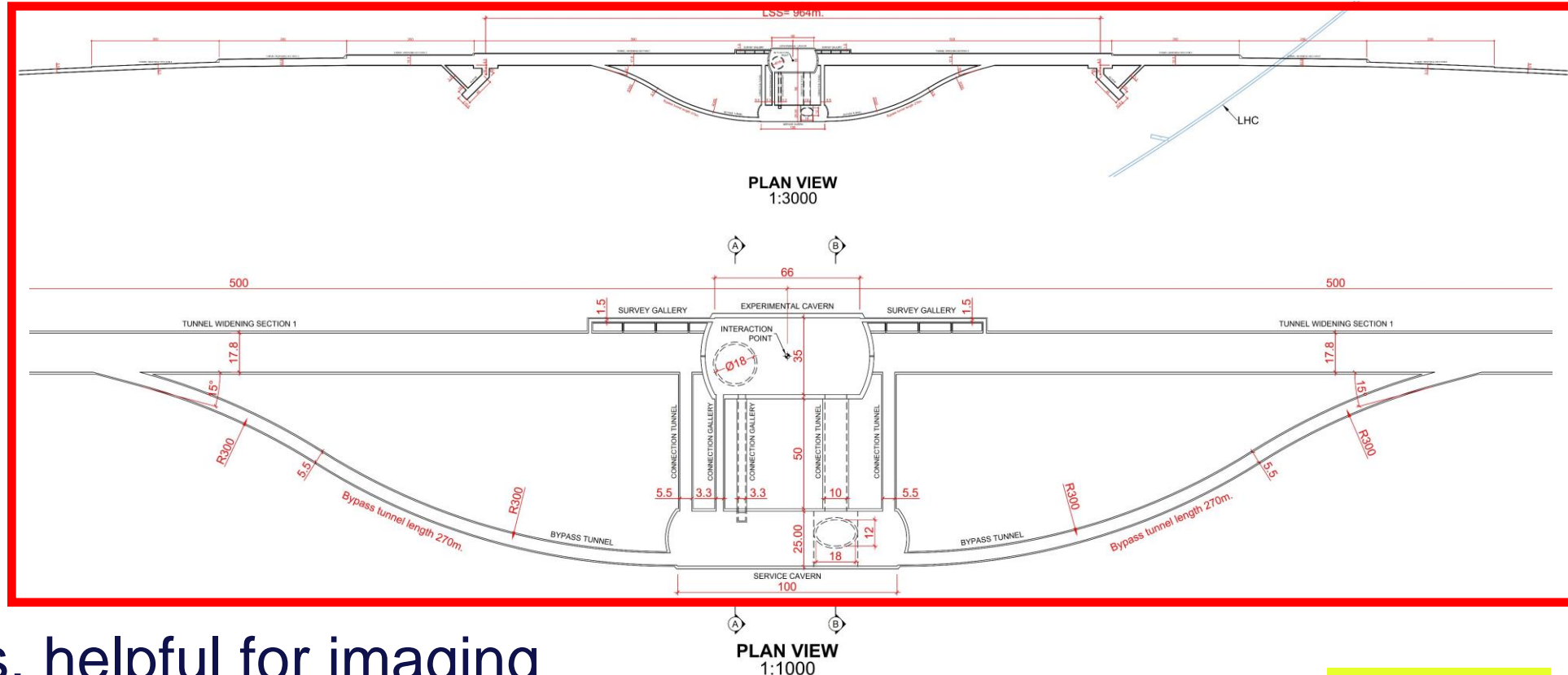
Up to 4 interaction points  $\rightarrow$  robustness, statistics, possibility of specialised detectors to maximise physics output

# How & where can we integrate the FCC photon beam lines ?

Option: around the four  $e^+e^-$  collision points

- booster is separated to bypass the experimental detector
- large underground infrastructure for FCC-hh
- wide tunnel

to be studied



- long tunnels, helpful for imaging

# 4 working groups

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## 1) photon science (light source, CBS)

- J. Byrd (), S. Casalbuoni (EuXFEL), F. Zimmermann (CERN)

## 2) HEP applications (QED, dark sector, )

- G. Arduini (CERN), J. Jaeckel (U Heidelberg), G. Schnell (Basque U., Bilbao)

## 3) $e^+$ applications (surface science, Ps BEC, 511 keV X-ray laser )

- B. Rienäcker (U Liverpool), M. Doser (CERN)

## 4) multipurpose applications of the $e^-/e^+$ beams and beamstrahlung photons (radionuclide production, neutron source);

- M. Calviani (CERN)

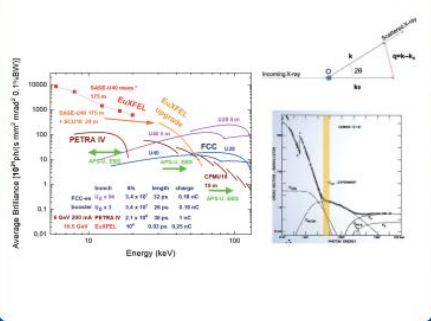
# OTHER SCIENCE OPPORTUNITIES AT THE FCC-ee

28-29 NOV 2024 | CERN | GENEVA, SWITZERLAND

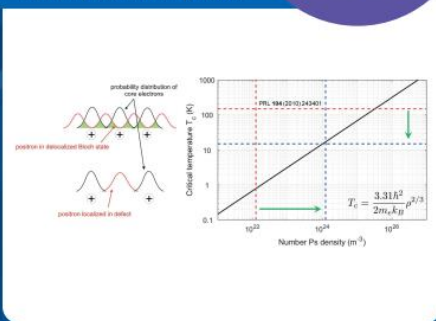


find more information

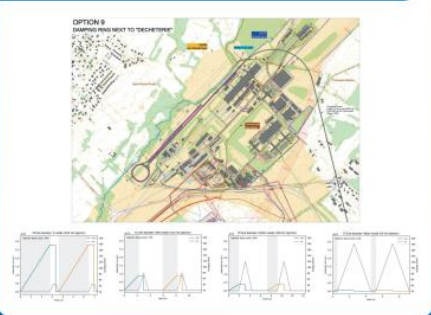
## 1 Diffraction-limited photon source down to 0.1 Å



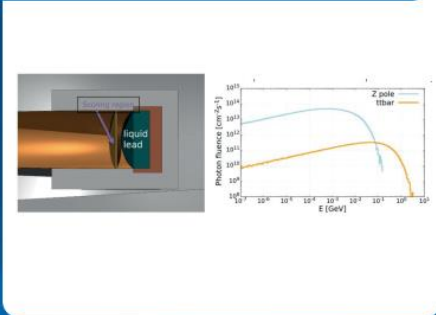
## 2 e<sup>+</sup> beams for surface/material science & pathway to positronium γ-ray laser



## 3 Intense energetic e<sup>+</sup>/e<sup>-</sup> and g beams for physics beyond colliders and neutron production



## 4 Harnessing beamstrahlung and e<sup>+</sup>/e<sup>-</sup> beams for radionuclide production and multipurpose applications.



**ORGANISERS:**  
 G. Arduini (CERN), M. Benedikt (CERN),  
 J. Byrd (ANL/LBNL), M. Calviani (CERN),  
 S. Casalbuoni (EU-XFEL), M. Doser (CERN),  
 B. Rieacker (U Liverpool), F. Zimmermann (CERN)



09:00 → 10:00

### FCC accelerator capabilities

Convener: Dr Sara Casalbuoni (European XFEL)

160/1-009

09:00

#### Introduction and FCC-ee collider beam parameters

Speaker: Frank Zimmermann (CERN)

15m

09:15

#### Pre-Injector capabilities

Speakers: Hannes Bartosik (CERN), Yannis Papaphilippou (CERN)

15m

09:30

#### Booster capabilities Including for light source applications

Speaker: Antoine Chance (CEA Irfu)

20m

09:50

#### Ultimate limit on beam brightness

Speaker: Sergey Antipov (DESY)

10m

10:00 → 11:00

### Photon science and extreme photon science | Part 1

Convener: Yannis Papaphilippou (CERN)

160/1-009

10:00

#### High-energy photons from the FCC-ee complex

Speaker: Dr Sara Casalbuoni (European XFEL)

20m

10:20

#### Imaging opportunities at 50-100 keV

Speaker: Marco Stampanoni

15m

10:35

#### Science with photons at 10s of GeV

Speaker: Frank Zimmermann (CERN)

10m

10:45

#### Laser Compton scattering in the collider

Speaker: Illya Drebot

15m

11:30 → 12:25

### Photon science and extreme photon science | Part 2

Convener: Stefano Redaelli (CERN)

160/1-009

11:30

#### Linac e<sup>+</sup> beam with crystalline undulator(s)

Speaker: Laura Bandiera (Universita e INFN, Ferrara (IT))

10m

11:40

#### Photons from coherent bremsstrahlung

Speaker: Armen Apyan

10m

11:50

#### Discussion

35m

14:00 → 15:20

## Physics Beyond Colliders, HEP applications

📍 160/1-009 

**Convener:** Gianluigi Arduini (CERN)

14:00

### Dark matter searches

**Speaker:** Paolo Crivelli (ETH Zurich (CH))

🕒 20m 

14:20

### Strong-Field QED with Electron-Laser Interactions and New Physics Searches with Photons

**Speaker:** IVO SchultHess (Deutsches Elektronen-Synchrotron DESY)

🕒 20m 

14:40

### Strong field QED In crystals

**Speaker:** Laura Bandiera (Universita e INFN, Ferrara (IT))

🕒 20m 

15:00

### Full Inverse Compton Scattering and Unruh photons

**Speaker:** Luca Serafini



Serafini-FICS-FCC-W...

🕒 20m 

15:20 → 15:50

Coffee

🕒 30m 📍 160/1-009

15:50 → 17:30

## Positron applications

📍 160/1-009 

**Convener:** Benjamin Rienacker (University of Liverpool (GB))

15:50

### Overview of slow positron beam facilities

**Speaker:** Benjamin Rienacker (University of Liverpool (GB))

🕒 20m 

16:10

### Material sciences with high-brightness, low energy positron beams

**Speaker:** Dr Marcel Dickmann (UniBW Germany)

🕒 20m 

16:30

### New experiments with dense positron clouds

muon-antimuon pair production by laser driven electron-positron recollision  
positron and positronium binding atoms (for example PsCl)

**Speaker:** Antoine Camper (University of Oslo (NO))

🕒 20m 



**09:00** → 10:30 **Multipurpose applications of the e-/e+beams and beamstrahlung photons**

📍 40/S2-D01 - Salle Dirac

**Convener:** Dr Marco Calviani (CERN)

09:00

**Introduction**

🕒 10m

**Speaker:** Dr Marco Calviani (CERN)

09:10

**Beamstrahlung radiation properties**

🕒 20m

**Speaker:** Alessandro Frasca (University of Liverpool (GB))

09:30

**Preliminary Assessment of the Radionuclide Production Possibilities at the FCCee**

🕒 30m

**Speaker:** Charlotte Duchemin (CERN SY/STI/RBS)

10:00

**A neutron source at FCC-ee?**

🕒 30m

**Speaker:** Frank Gunsing (Université Paris-Saclay (FR))**10:30** → 11:00**Coffee**

🕒 30m

📍 40/S2-D01 - Salle Dirac

**11:00** → 12:30**Discussion**

📍 40/S2-D01 - Salle Dirac

**Conveners:** Benjamin Rienacker (University of Liverpool (GB)), Frank Zimmermann (CERN), Gianluigi Arduini (CERN), Gunar Schnell, Joerg Jaeckel (ITP Heidelberg), Dr Marco Calviani (CERN), Mieczyslaw Witold Krasny (LPNHE, Sorbonne University, Paris, Centre National de la Recherche Scientifique (FR) and CERN), Dr Sara Casalbuoni (European XFEL)

# possible input to ESPP by end March 2025

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## 3 documents :

- PBC HEP applications
- non-HEP science (in particular photons and positrons)
- production applications

for in-person attendees

dinner at Luigia,  
today, 28 November  
at 19h30

148 Route du Nant-d'Avril  
Meyrin, Genève 1217  
+41227825586



# Enjoy this workshop !

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# References

1. M. Altarelli et al. (Eds.), XFEL: The European X-Ray Free-Electron Laser. Technical Design Report, Preprint DESY 2006-097, DESY, Hamburg, 2006 (see also <http://xfel.desy.de>).
2. E.A. Schneidmiller and M.V. Yurkov, "*Photon Beam Properties at the European XFEL*", DESY-11-152; TESLA-FEL 2011-01
3. C. G. Schroer et al., PETRA IV Conceptual Design Report, <https://bib-pubdb1.desy.de/record/426140/files/DESY-PETRAIV-Conceptual-Design-Report.pdf>
4. T. Tanaka and H. Kitamura, "*SPECTRA: a synchrotron radiation calculation code*", Journal of Synchrotron Radiation 8, 1221 (2001)
5. F. Burkart et al., "*LUXE — A QED Experiment at the European XFEL*," 10th Int. Particle Accelerator Conf. IPAC2019, Melbourne, Australia JACoW Publishing ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-TUPRB008
6. C. Hugenschmidt, *Positrons in Surface Physics* (2016), <https://arxiv.org/pdf/1611.04430>
7. M. Benedikt, S. Casalbuoni, M. Doser, F. Zimmermann, [First thoughts on the synergetic use of the FCC-ee collider and its injector complex for photon science and other applications](https://zenodo.org/record/7675663), 10.5281/zenodo.7675663.
8. S. Casalbuoni and F. Zimmermann, [FCC-ee booster as ultimate storage ring photon source](https://www.fcc-eu.org/2021/09/28/fcc-ee-booster-as-ultimate-storage-ring-photon-source/), FCC Week 2021
9. R. Aleksan, A. Apyan, Y. Papaphilippou, F. Zimmermann, *Scenarios for Circular Gamma-Gamma Higgs Factories*, Proc. IPAC2015, Richmond (2015) 2156