BACKGROUNDS AT FCC-ee

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Background assesment at FCC-ee

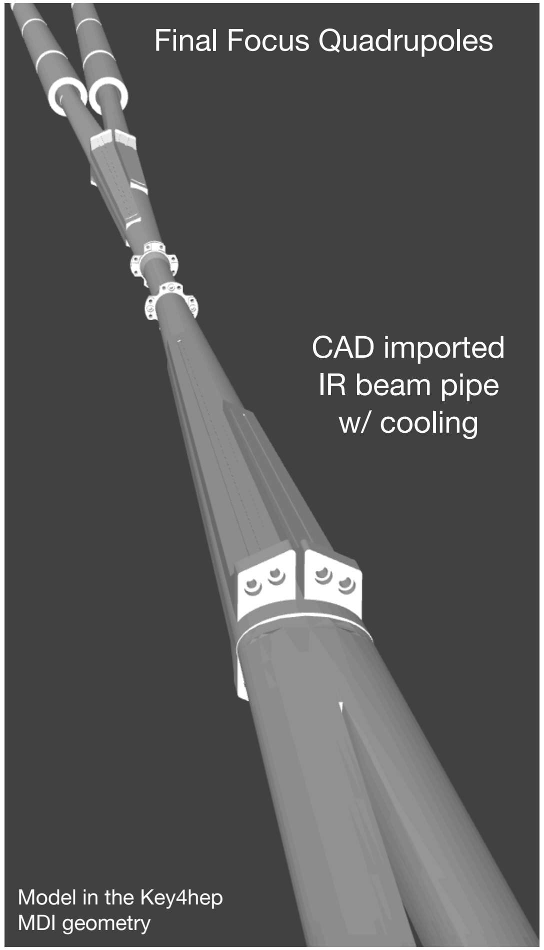
Estimation of beam induced backgrounds is a **driver element** for the design of detectors and MDI region.

A **streamlined procedure** for occupancy calculation in each subdetector is a key feature under development in the FCCSW framework:

- **repository** with primary particles for each **background source** at the 4 FCCee energies
- **detector description** for the (currently) 3 experiments and common **MDI elements**
- particle tracking in the detectors performed using **key4hep/ddsim**

Key aspects:
- MDI modelization (pipe, cooling, supports, fields, etc)
- identification of appropriate event generators

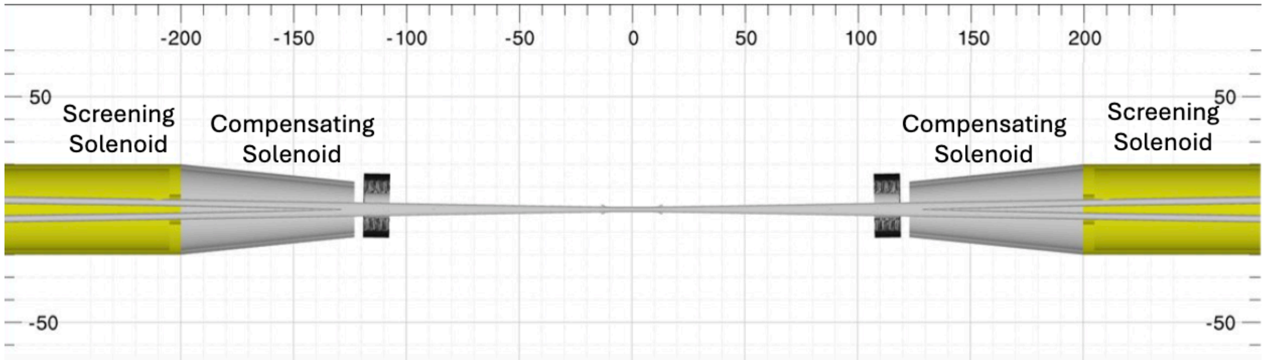
Key4hep MDI modelization



Engineered CAD model of AlBeMet162 beam pipe imported in **Key4hep**.
- Double-layered central section for paraffine cooling
- **Cooling manifolds** for ellipto-conical chambers implemented
- Beam pipe **separation region** profile congruent to impedance studies

Compensating and Screening solenoid cryostats
Final Focus Quadrupoles simple equivalent material model
Magnetic **field map** for anti-solenoids and FF magnets

Future upgrades:
- realistic **bellows** to be placed before beam pipe separation, currently under development
- IR carbon fiber **support tube**



Sources of Background in the MDI area

Luminosity backgrounds

- **Incoherent Pairs Creation (IPC)**: Secondary e^-e^+ pairs produced via the interaction of the beamstrahlung photons with real or virtual photons during bunch crossing.
- **Radiative Bhabha:** beam particles which lose energy at bunch crossing and exit the dynamic aperture

Single beam induced backgrounds:

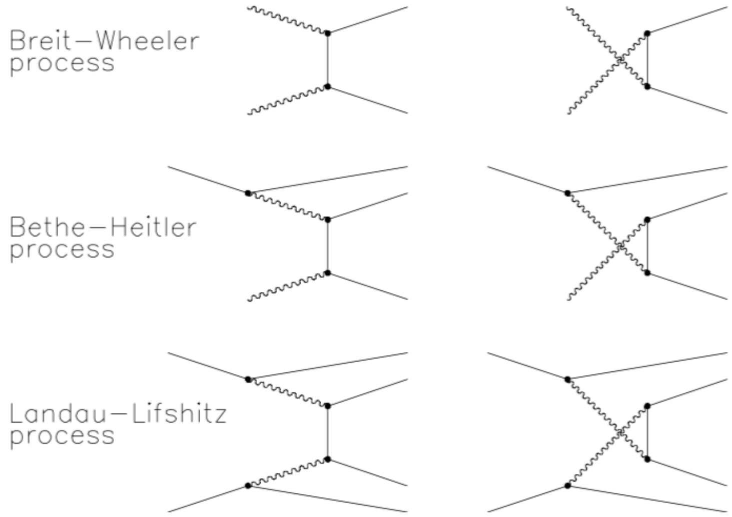
- **Generic Halo Losses:** high rate of beam losses in the IR coming from halo (transverse or longitudinal) being diffused by the collimators after lifetime drop
- **Synchrotron Radiation** from upstream magnets
- **Beam-gas** (elastic and inelastic scattering)
- Compton scattering on **thermal photons**

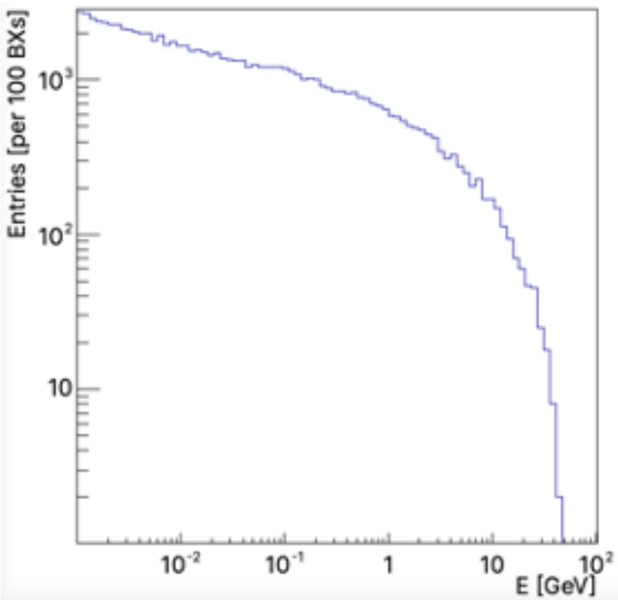
Incoherent Pairs Creation (IPC)

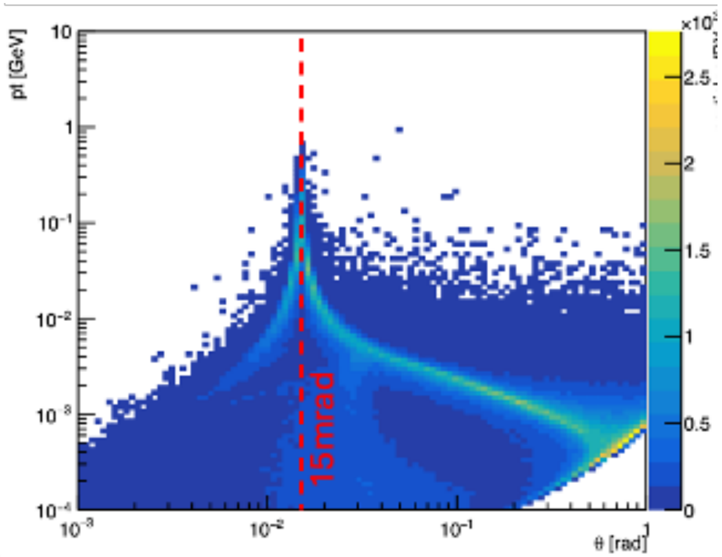
This process has been simulated using the generator **GuineaPig++.**

Well understood background source, process for first occupancy calculation in the sub-detectors:

- IDEA Vertex Detector
- IDEA Drift Chamber
- ALLEGRO Liquid Argon ECal







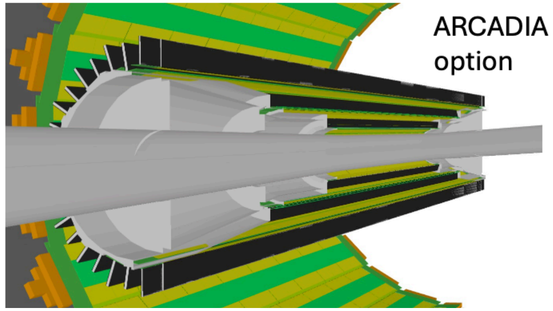
Beam parameters for V23 (06/05/2023)

β_x, β_y [mm]	110/0.7
σ_x, σ_y [μm]	8.837/0.031
σ_z [μm]	12700
N_e [10^{11}]	15.1
N_{IPC} per BX	~900

Number and kinematics of IPCs change with the evolution of the beam parameters!

IPC: IDEA Vertex Detector

A. Ilg

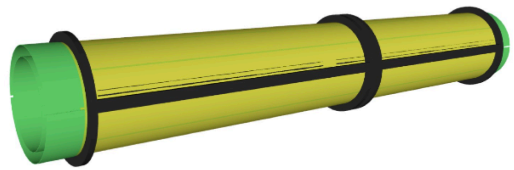


ARCADIA option

Two sensor technology options under investigation:

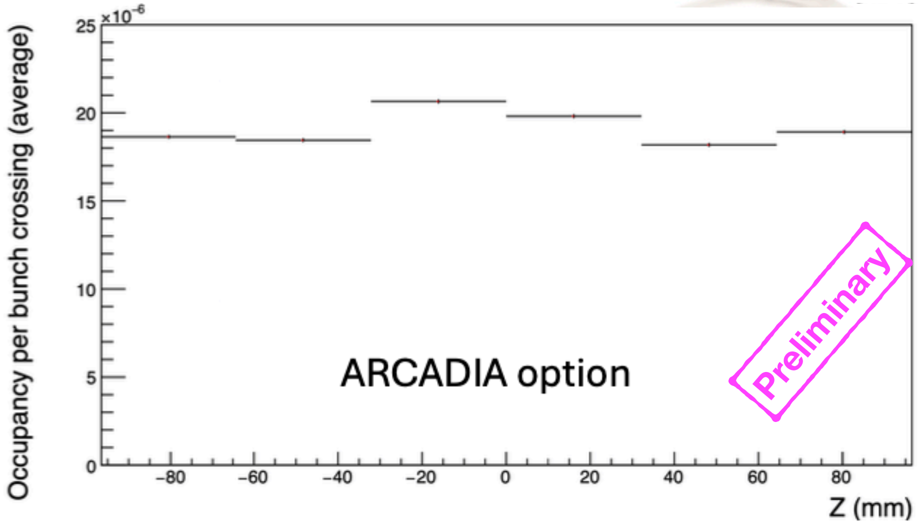
- ARCADIA sensor staves
- ultralight ALICE ITS3 bent sensors

ALICE ITS3 option



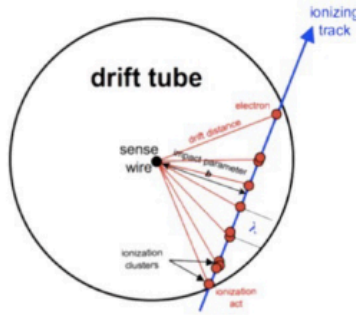
Occupancy calculated for the **innermost layer** of the vertex (r=13.7mm), assuming cluster size of 5, safety factor of 3 and 25µm pixel size.

	ARCADIA	ALICE ITS3
Occupancy	$\sim 20\times10^{-6}$	$\sim 30\times10^{-6}$
Hit rate	$170\ MHz/cm^2$	$250\ MHz/cm^2$



IPC: IDEA Drift Chamber

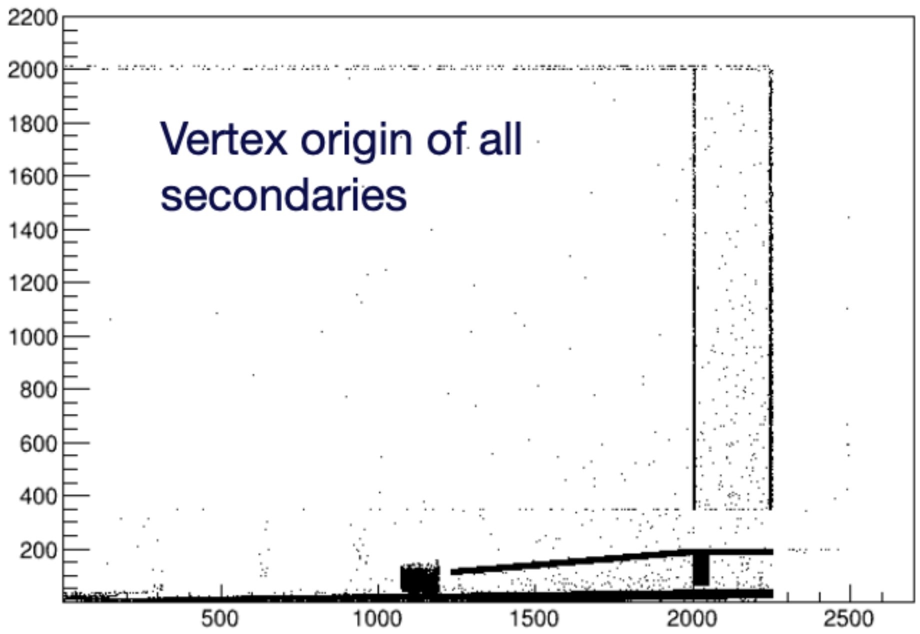
B. Francois

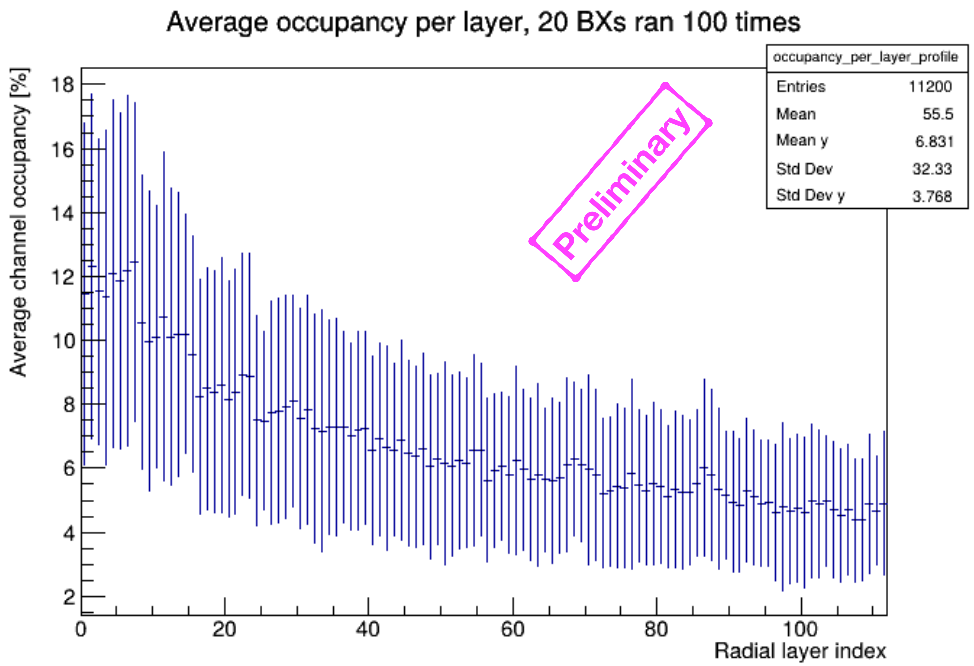


Investigated drift chamber (DCH) occupancy at **SIM hit level** from IPC.

Assuming a conservative 400ns maximum drift time:

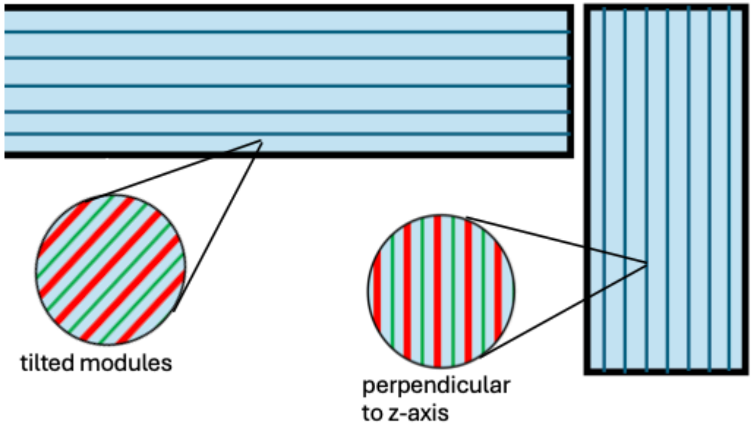
- **Integrate** IPC background contributions **20BXs** (Z-pole, 20ns bunch spacing)
- Keeping all Geant4 energy deposits (no filters): **overall SIM hit occupancy ~7%**





IPC: ALLEGRO Noble Liquid ECAL

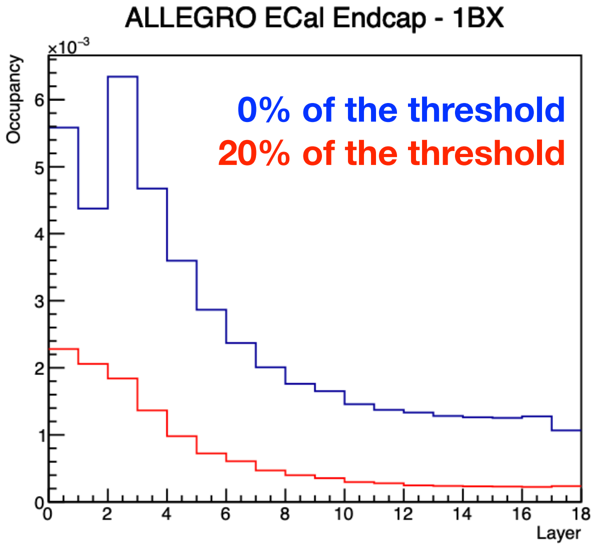
Sampling calorimeter: **lead absorbers**, **LAr gaps**, **high granularity readout**

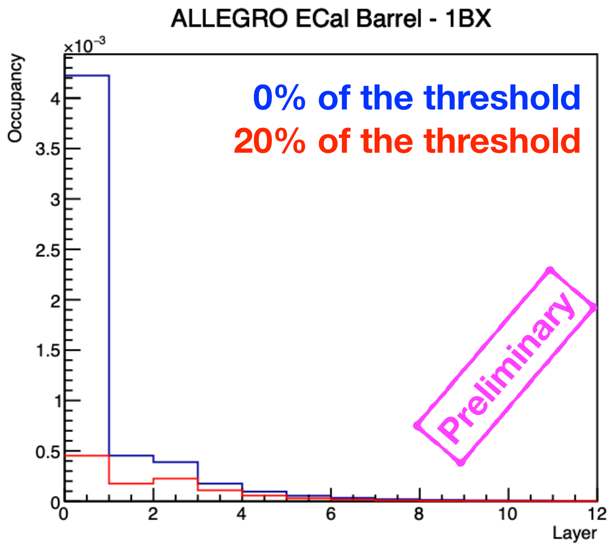


Cut on the energy deposited in each layer is a fraction of the most probable value for energy deposit per cell from a MIP (20GeV muon)

Average occupancy per BX (4000BXs):

	No cuts	20% MPV cut
Endcap	0.1% ~ 0.6%	0.02% ~ 0.2%
Barrel	<0.45%	<0.05%



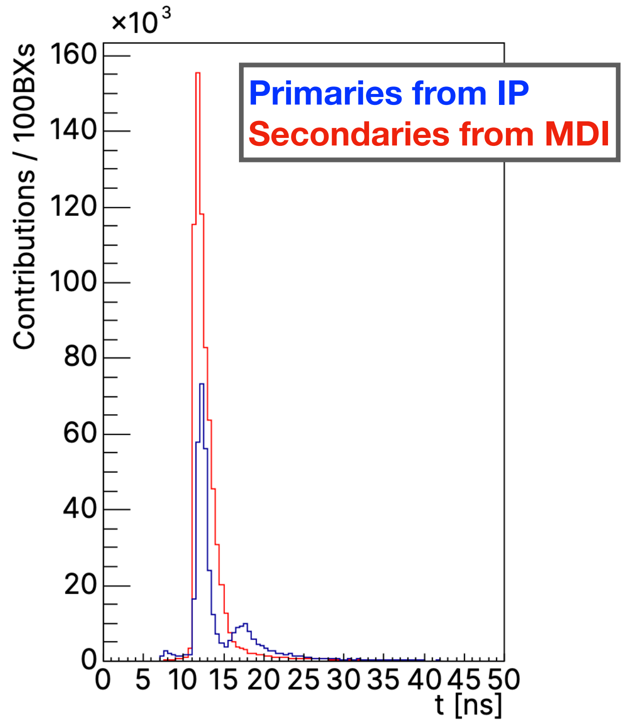


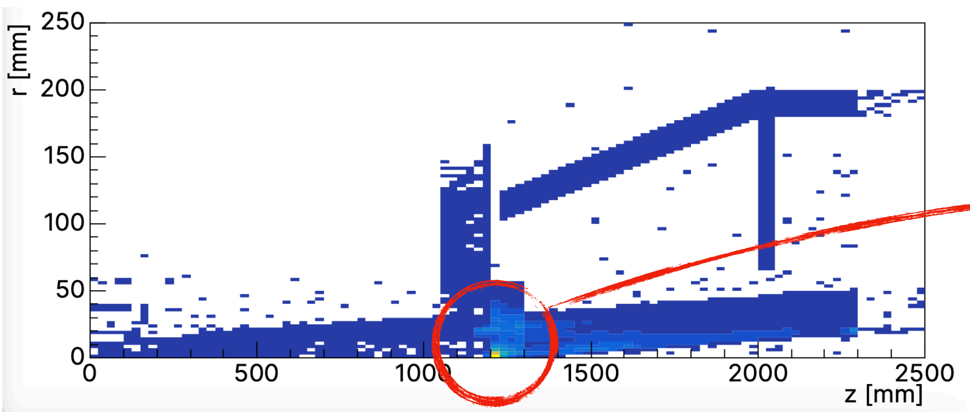
O(0.1%) occupancy/BX may grow quickly if the **readout integration time** is larger than a few BXs ($\Delta t \sim 20ns$ at Z-pole)

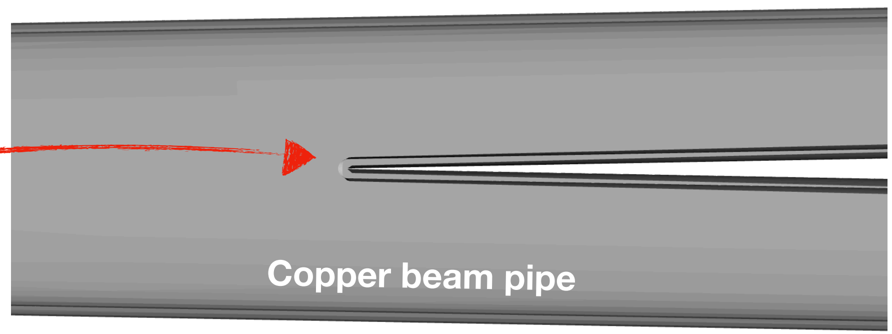
Backscattering from MDI

Thanks to the use of CAD model for the IR beam pipe in simulations, a contribution coming from **backscattering** of low angle particles on the **beam pipe separation region** was noticed from the tracking of IPCs in the sub-detectors.

- **optimization** of the region and design of dedicated **shieldings**
- study of possible offline **background mitigation** (e.g. time signature)



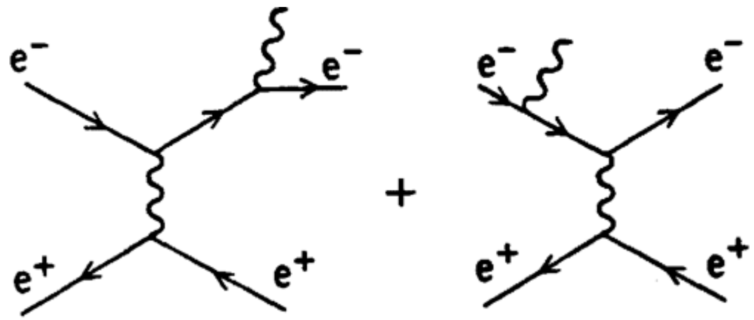




Radiative Bhabha

During bunch crossing beam particles can **lose energy** via photon emission, and exit the lattice **energy acceptance**.

Particles produced using **BBBrem**[1] for the events generation in the c.o.m. and **GuineaPig++** to include beam beam effects according to lattice parameters.



Radiative Bhabha Total Cross Section [mbarn]				MINIMUM PHOTON ENERGY			LUMINOSITY PER IP
ENERGY	LATTICE	CUTOFF		0.01%	3%	50%	$cm^{-2}s^{-1}$
Z	v572 (V23)	1 sigmaY	36.5 nm	—	**112.7**	**18.3**	1.41E+36
T	v572 (V23)	1 sigmaY	49.0 nm	—	**115.4**	**18.7**	1.38E+34
Z	v605 (V24.3)	1 sigmaY	36.5 nm	**332.6**	**112.7**	**18.3**	1.43E+36
T	v605 (V24.3)	1 sigmaY	43.6 nm	**337.1**	**114.3**	**18.6**	1.38E+34

Due to bunch dimensions and density effects, the **interaction range** is not infinite.

We apply a **cutoff** on momentum transfer t assuming as a critical distance:

$$t = \left(\frac{\hbar c}{d}\right)^2 \qquad d_0 = \sigma_y$$

$$t > t_0 = d < d_0$$

[1] BBBREM – Monte Carlo simulation of radiative Bhabha scattering in the very forward direction, R. Kleiss, H. Burkhardt

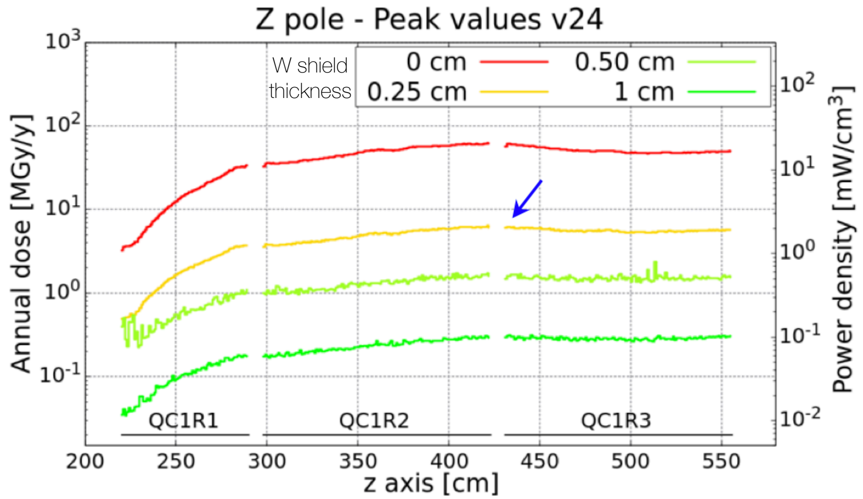
Radiative Bhabha: beam losses in IR

A. Frasca

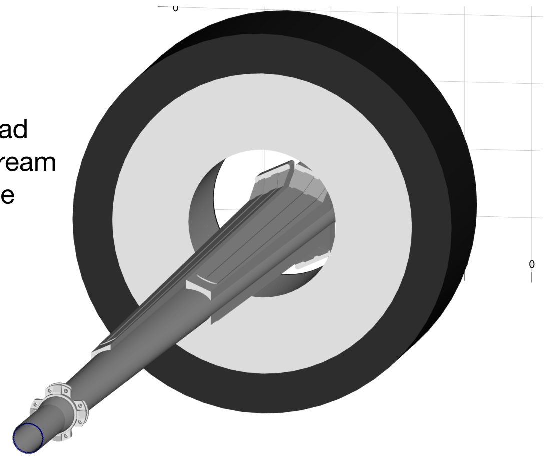
Off-energy particles are tracked downstream to estimate the **power deposited** on the SC final focus quadrupoles.

FLUKA simulations show that a **thin tungsten shielding** between the magnets and the pipe efficiently reduces the total dose below O(10MGy/y).

Integration of this shielding is an important part of the magnets final design.



50-110 mrad from downstream beam pipe



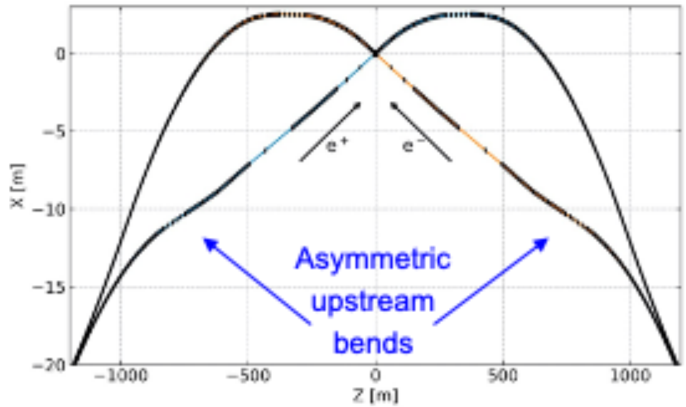
Radiative Bhabha may constitute a background source for the **LumiCal**.

- radiative correction of the signal process
- off-energy particles feel stronger beam-beam kick
- no left-right coincidence, but potential large energy deposition

Dedicated studies ongoing to assess the contribution in the detector acceptance

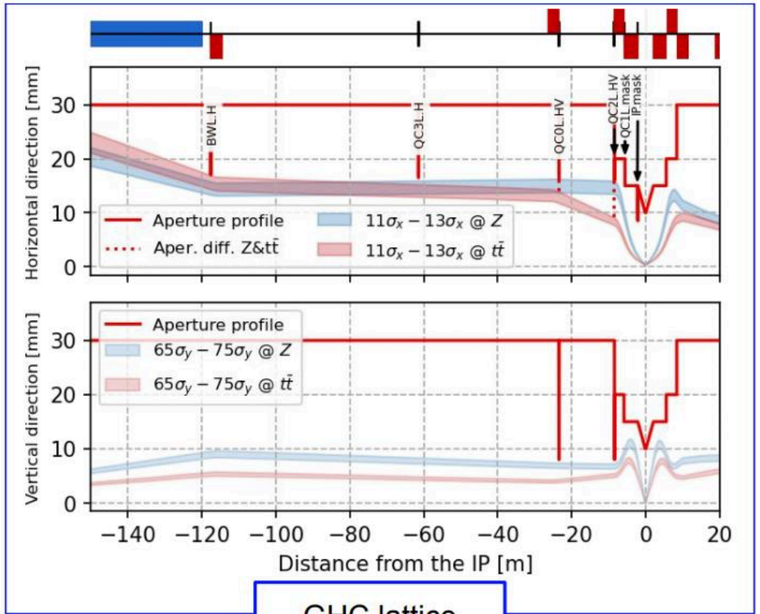
Synchrotron Radiation

K. André



SR is the **main driver** for FCC-ee MDI and lattice design

- **Asymmetric bend** to mitigate SR coming from upstream magnets
- Characterization of the radiation using **G4 based tool BDSim**
- Tungsten **SR collimators and masks** to protect the IR



GHC lattice

SR Background coming from the **beam core** particles is **completely shielded** thanks to the **tungsten masks.**

Other contributions currently under study are:

- **beam halo** particles
- non zero closed orbits
- top-up **injection**

Characterization of this background is essential for **dedicated shielding** design.
First tracking in key4hep ongoing for **occupancy calculation**.

Generic Halo Losses in the IR

G. Broggi

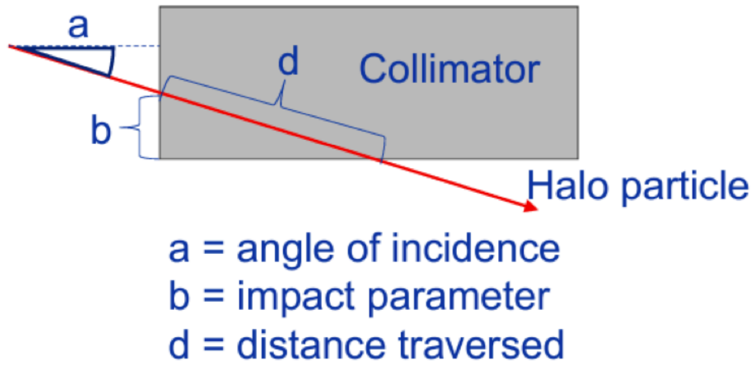
Following **beam lifetime reduction** due to a slow process, beam halo particles can be **lost in the MDI region** following the interaction with the **main collimators**.

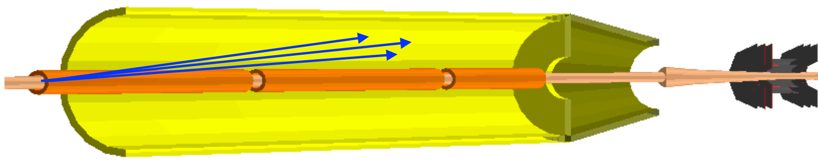
This study is independent on the loss process, particles are generated hitting the collimator with a given **impact parameter range** and tracked for 500 turns into the full lattice.

Tracking performed using **X-Suite**, interfacing with **BDSIM** for the collimator interaction.

Particles hitting the beam pipe in the MDI region need to be tracked using **FLUKA / key4hep** to study the production of secondaries and the **induced backgrounds** in the detector.

➡ optimization of collimation scheme and shielding design





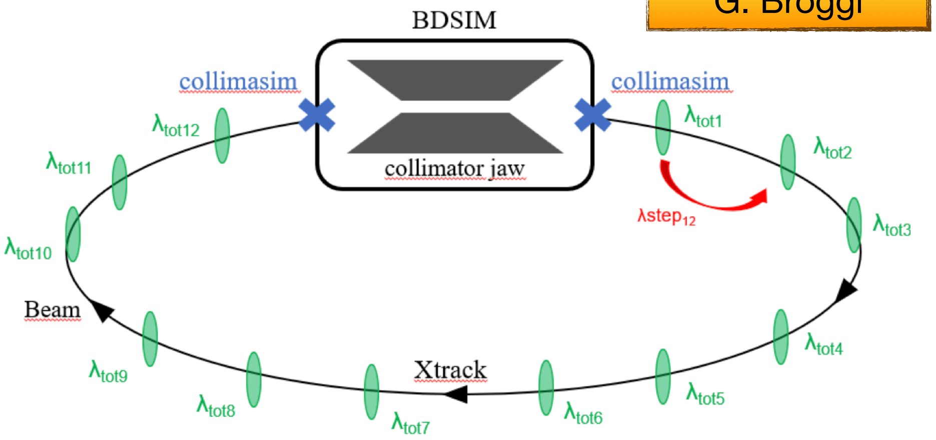
Beam-gas Losses from multi-turn

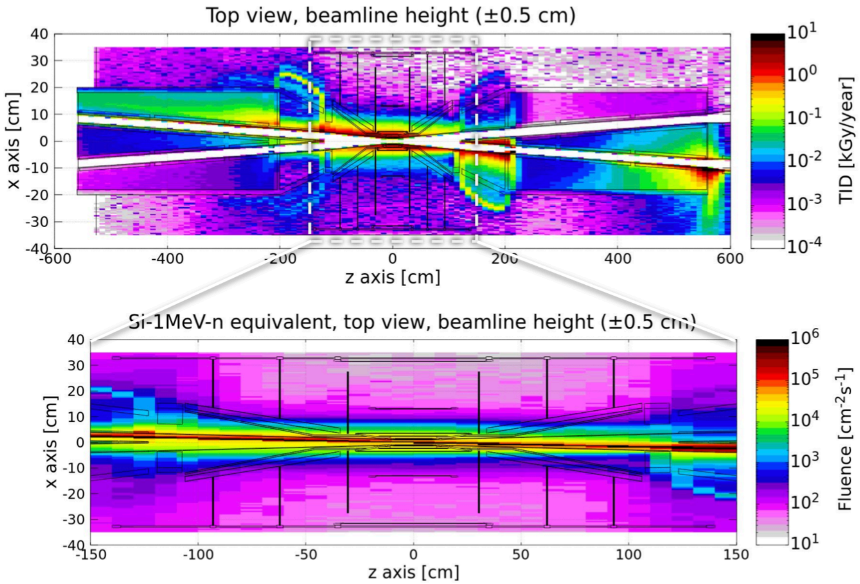
G. Broggi

First multi-turn tracking in **X-Suite** using **beam-gas elements** based on lattice pressure profile.

Dominant contribution: **inelastic beam-gas** (Bremsstrahlung)

➡ Next step: tracking in Key4hep for occupancy estimates





A. Frasca

Beam-gas Losses in IR

Local beam-gas losses in the IR studied also with FLUKA.

- Geometry includes both beam lines, SR masks and collimators, MDI elements, IDEA detector.
- particles generated from 500m upstream the IP
- first loss maps for e^- and photons
- Total Ionizing Dose below kGy/year

Summary

Realistic description of MDI elements in simulations

- CAD description for IR beam pipe and magnetic fields for experiments and machine elements

Occupancy calculations for IPCs

- Test and establish workflow in Key4hep, first results and mitigation strategies

Radiative Bhabha

- Annual dose in magnets and detectors, effect on LumiCal under study

Synchrotron Radiation

- Masks efficiently shield photons from beam core, other effects currently under study

Halo losses and single-beam background sources

- Optimization of collimators scheme