FCC-ee BACKGROUNDS

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Thanks to M. Boscolo

A brief introduction

- Master Degree in Physics (2018)
- Ph.D. in Accelerator Physics (02/2022)
- Fellowship @CERN on Beam Induced Backgrounds for FCCee MDI group (02/2021-02/2023)
- Tecnologo @INFN-LNF on Beam Induced Backgrounds (now - 2y)

My work is focused on the study of **particles created in the MDI region** that may cause **background** in the detector or other **issues for the machine**, and to help devise **mitigation strategies** where needed.

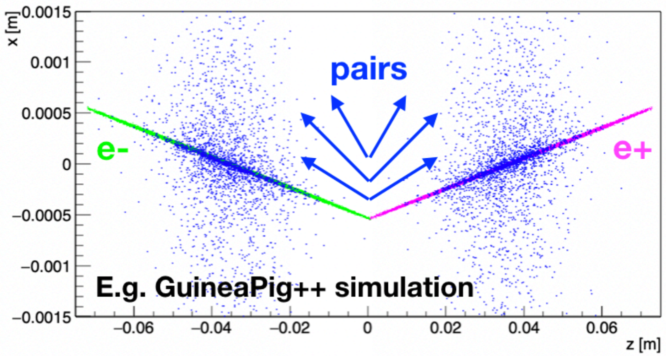
Future and ongoing works include:

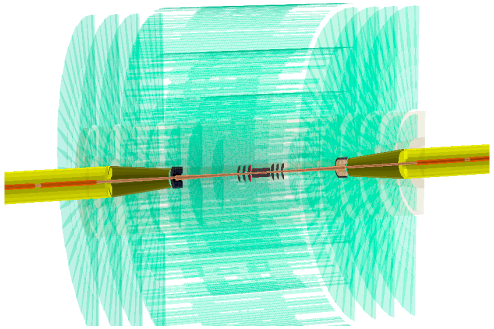
- **Incoherent Pairs Creation** —> background determination
- **Beam losses due to failure scenarios** —> background, collimators and power on FFQs
- **Synchrotron Radiation** —> masks and shieldings efficiency
- **Beamstrahlung radiation characterization** —> beamstrahlung photon dump
- **Radiative Bhabhas** (spent beam & photons) —> RB monitor and power on FFQs

All these studies are in strong **synergy and collaboration** with many groups (optics, magnets, detector design, collimation, software, civil engineering, …)

Background assessment: workflow with Key4hep

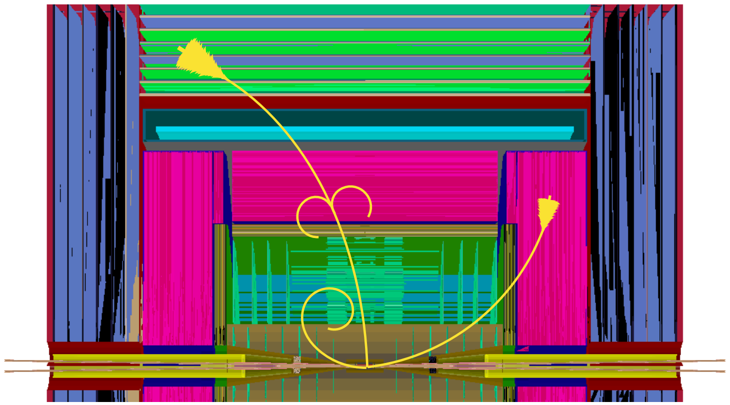
Primaries produced by **external generators** (GuineaPig++, BDSim, Xtrack, …)



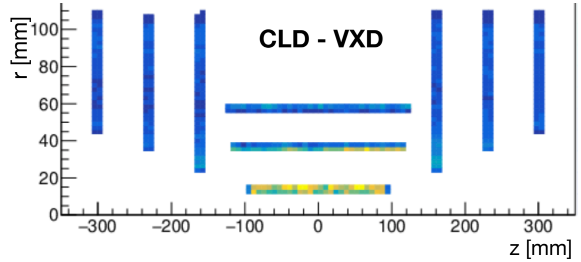


Detector and MDI geometry description in **DD4hep:** public common git repo, CLD fully implemented, IDEA ongoing

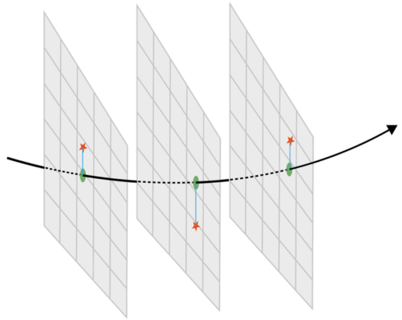
Tracking particles in the detector performed by **turnkey software Key4hep** - Geant4 physics libraries, DD4hep implementation, magnetic field map, …



Hits collected for analysis and occupancy determination (no truth)



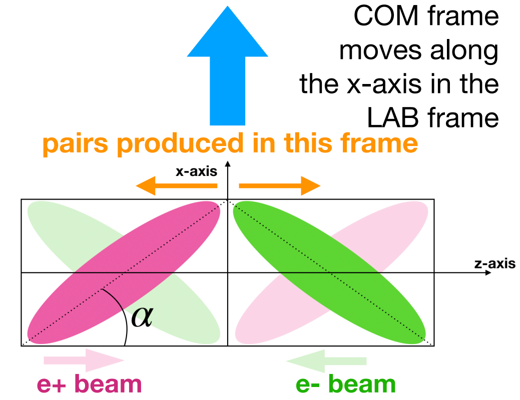
$$occupancy = hits/mm^2/BX \cdot size_{sensor} \cdot size_{cluster} \cdot safety$$



Signal **reconstruction:**
W.I.P. - only available on ILCSoft

Incoherent Pairs Creation (IPC)

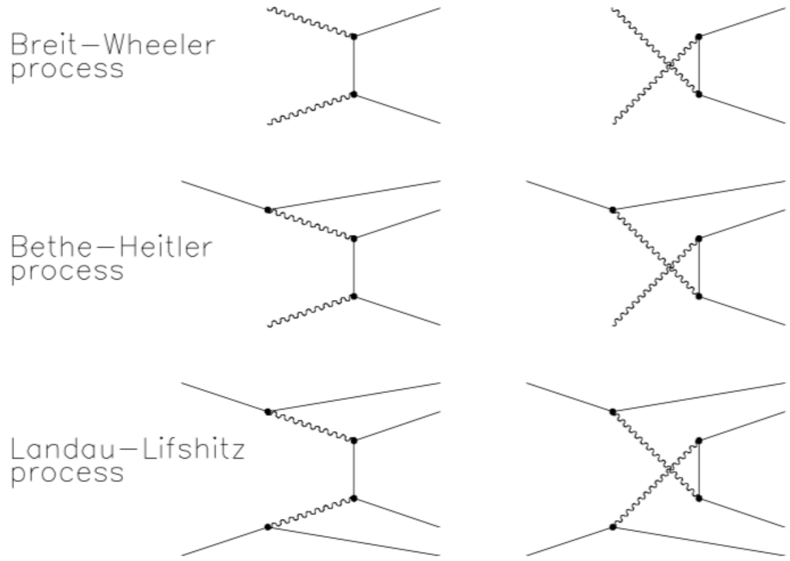
Secondary e^-e^+ pairs can be produced via the interaction of the beamstrahlung photons with real or virtual photons emitted by each particle of the beam during bunch crossing.



Center of Mass frame (GuineaPig)

This process has been simulated using the generator **GuineaPig++,** which simulates the bunch crossing using a **step-by-step** approach to calculate the **EM-field** produced by the bunches for beam-beam effect.

GuineaPig++ is also used to generate the **beamstrahlung photons**.



While for the **CLD** detector the induced **occupancy is low (<<1%)**, it is important ti repeat this study for **other experiments** which may use different technologies - drift chambers, MWPC, etc. - with lower segmentation

Beam Losses in the IR due to Failure Scenarios

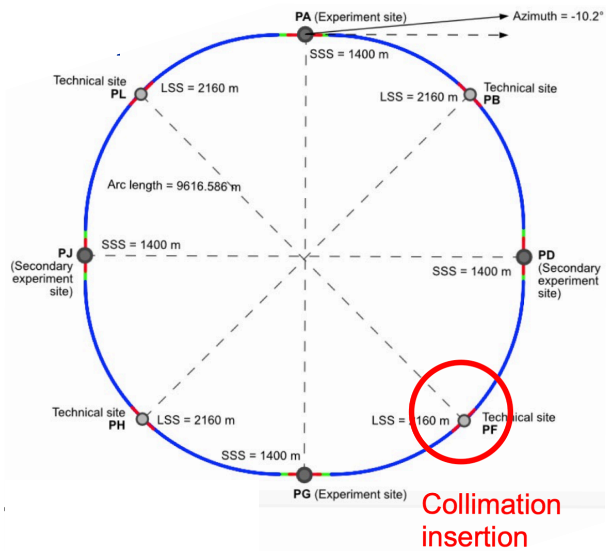
Thanks to A. Abramov for the primary particles.

The induced background in the event of a **drop of the beam lifetime to 5 minutes** showed very high occupancies from halo losses on the **Horizontal Primary Collimator** and the **off-momentum collimators.**

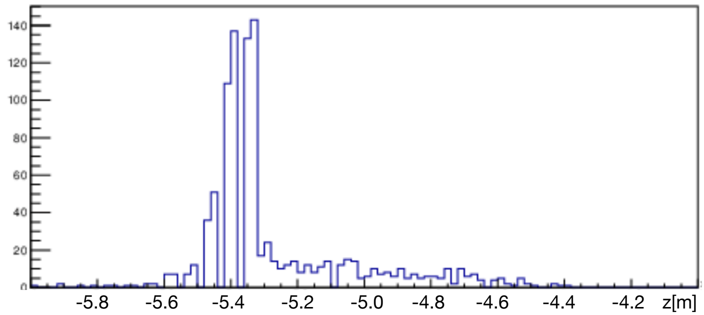
- Collaboration with the CERN collimation group to assess the efficiency of possible **mitigation strategies.**
- Estimate of the **deposited power** on the superconductive Final Focus magnets

A. Abramov, M. Hofer - FCCWeek2022

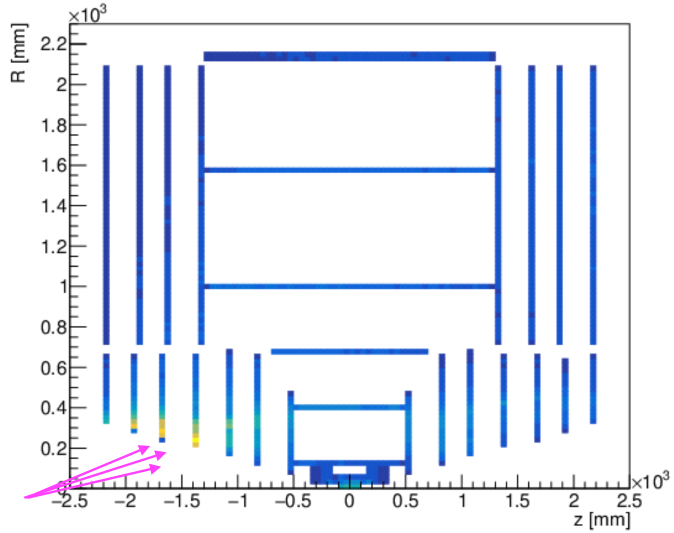
4IP lattice v529

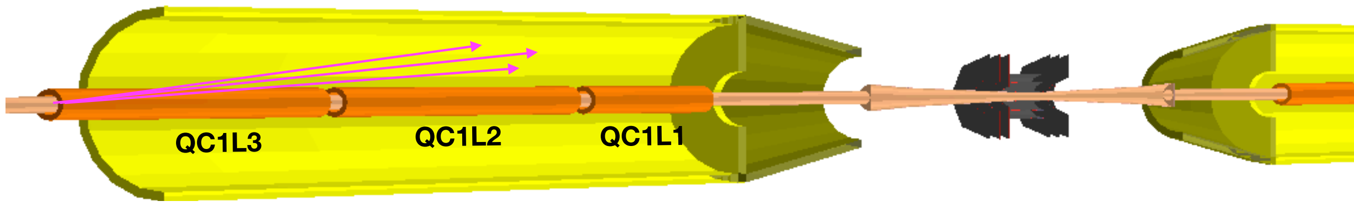


Losses location



Hits in subdetectors [a.u.]

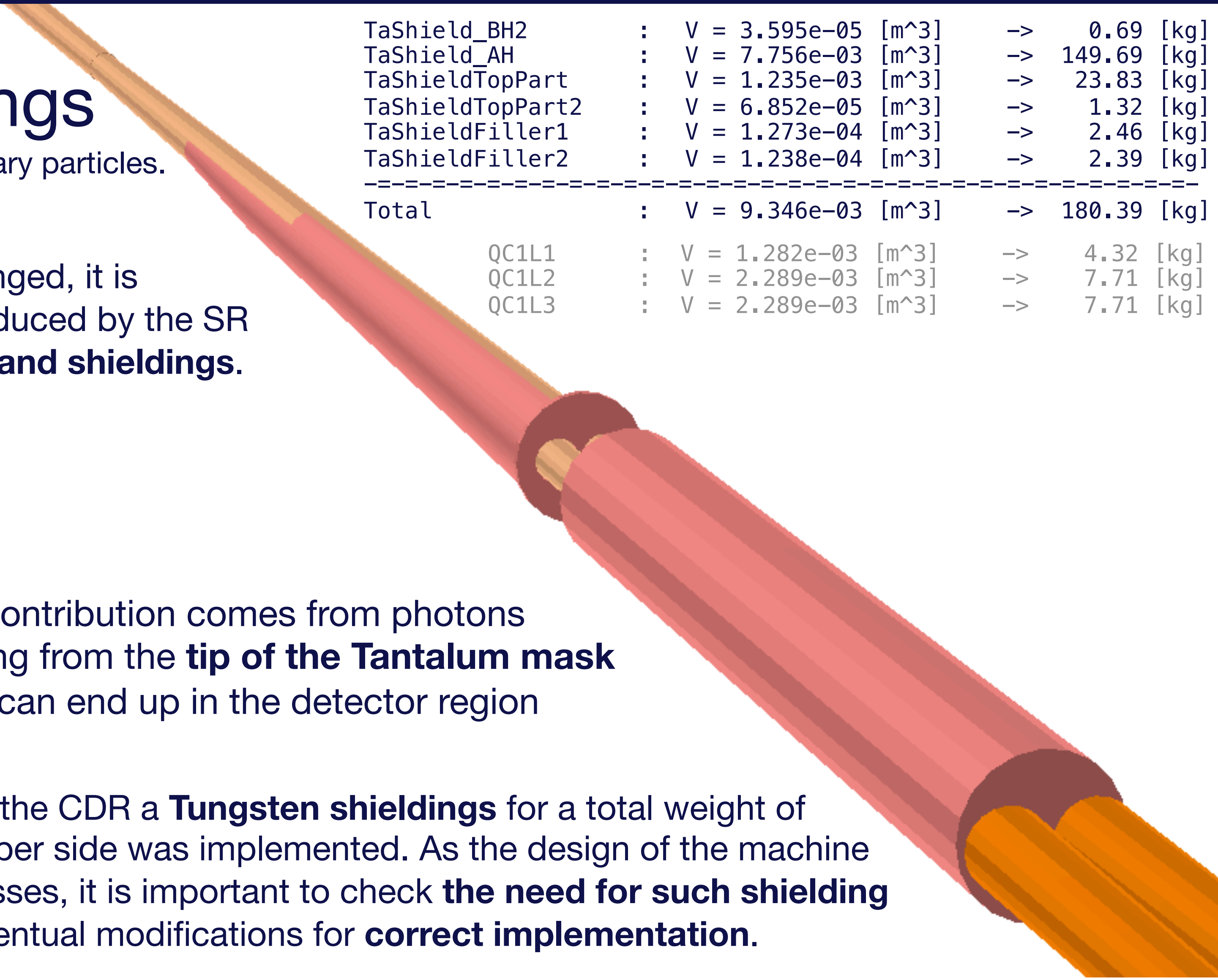




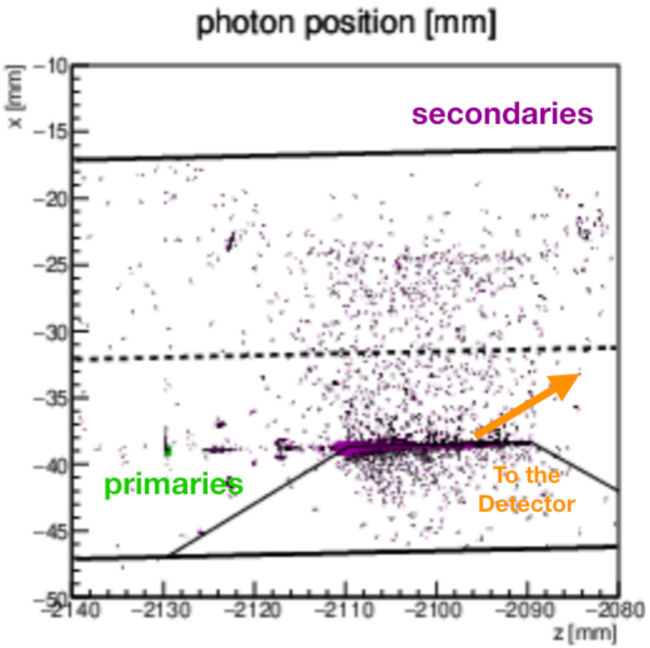
SR Mask and Shieldings

Thanks to K. André and M. Sullivan for the primary particles.

TaShield_BH2	: V = 3.595e-05 [m^3]	-> 0.69 [kg]
TaShield_AH	: V = 7.756e-03 [m^3]	-> 149.69 [kg]
TaShieldTopPart	: V = 1.235e-03 [m^3]	-> 23.83 [kg]
TaShieldTopPart2	: V = 6.852e-05 [m^3]	-> 1.32 [kg]
TaShieldFiller1	: V = 1.273e-04 [m^3]	-> 2.46 [kg]
TaShieldFiller2	: V = 1.238e-04 [m^3]	-> 2.39 [kg]
Total	: V = 9.346e-03 [m^3]	-> 180.39 [kg]
QC1L1	: V = 1.282e-03 [m^3]	-> 4.32 [kg]
QC1L2	: V = 2.289e-03 [m^3]	-> 7.71 [kg]
QC1L3	: V = 2.289e-03 [m^3]	-> 7.71 [kg]



As the lattice and the beam pipe has changed, it is necessary to redefine the **background** induced by the SR and the features of the dedicated **masks and shieldings**.



Main contribution comes from photons diffusing from the **tip of the Tantalum mask** which can end up in the detector region

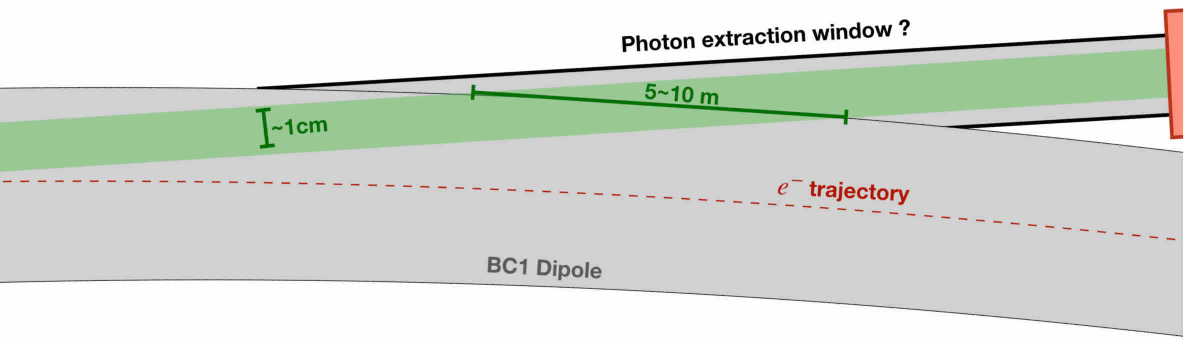
During the CDR a **Tungsten shieldings** for a total weight of 180kg per side was implemented. As the design of the machine progresses, it is important to check **the need for such shielding** and eventual modifications for **correct implementation**.

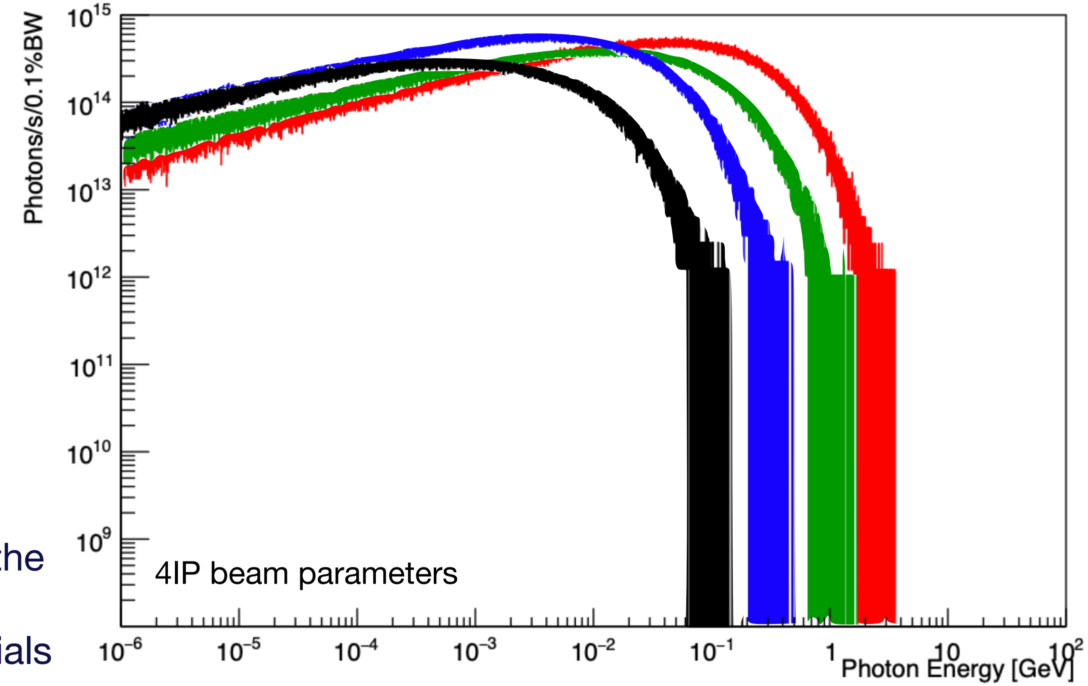
Beamstrahlung radiation Characterisation

The photons are emitted **collinear to the beam** with an angle proportional to the beam-beam kick. This radiation is extremely intense **O(100kW)** and **hits the beam pipe** at the end of the first downstream dipole.

The generator for the beamstrahlung radiation is **GuineaPig++**

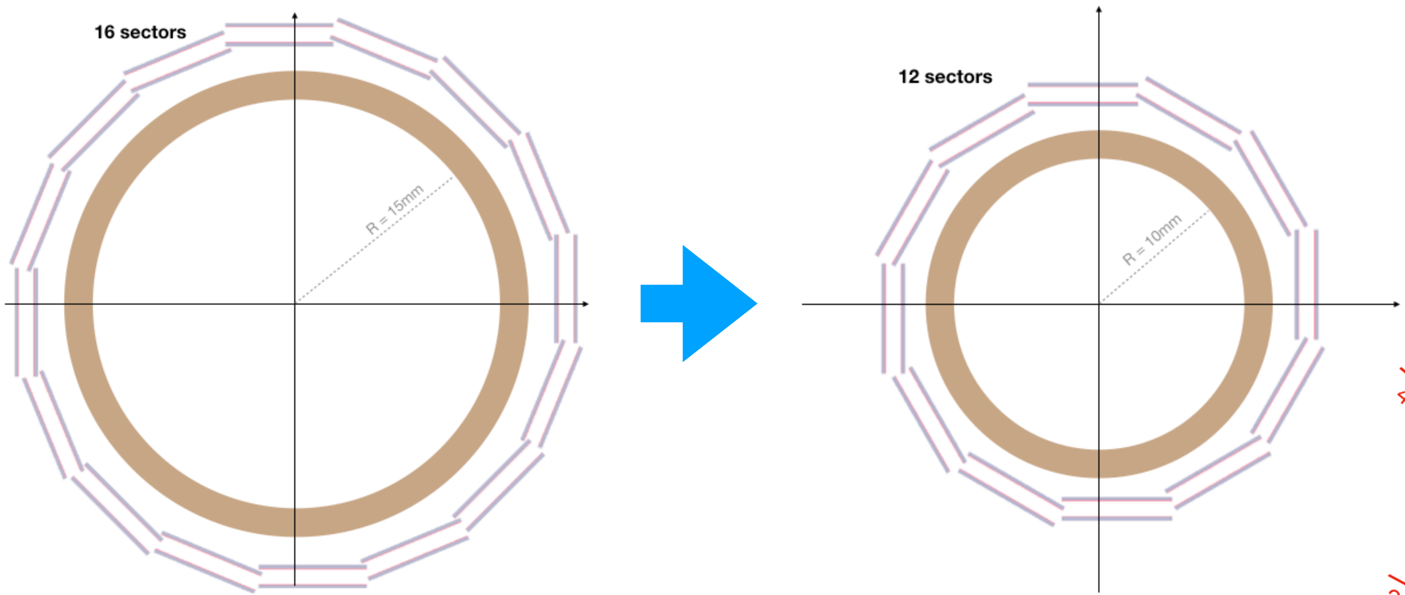
The design of a **dedicated extraction line** and **beam dump** for the beamstrahlung photons is currently in progress, exploring tunnel integration, magnets design, cooling system, and different materials for the beam dump.





	Total Power [kW]	Mean Energy [MeV]
Z	370	1.7
WW	236	7.2
ZH	147	22.9
Top	77	62.3

Updated CLD VXD for Small Beam Pipe

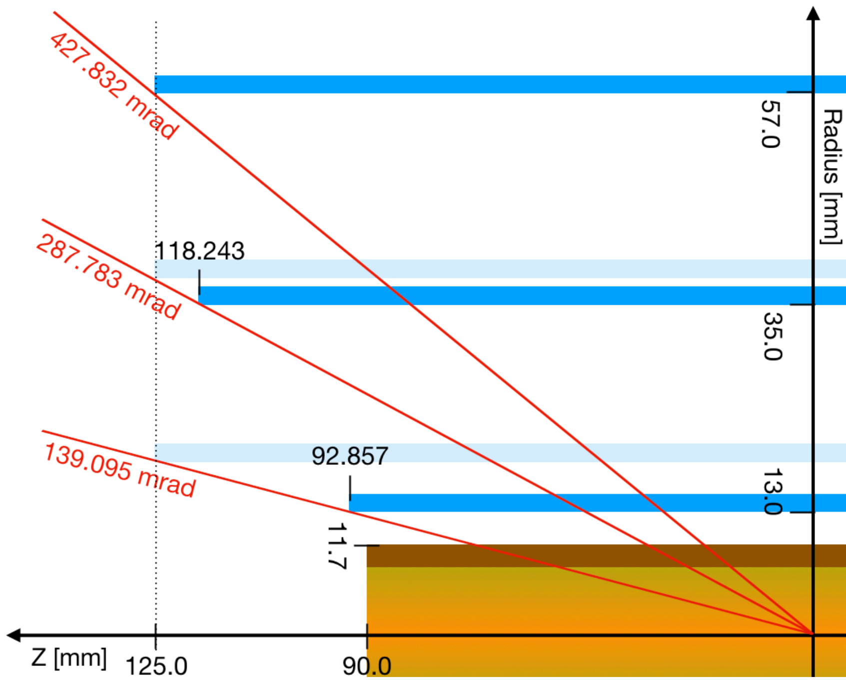


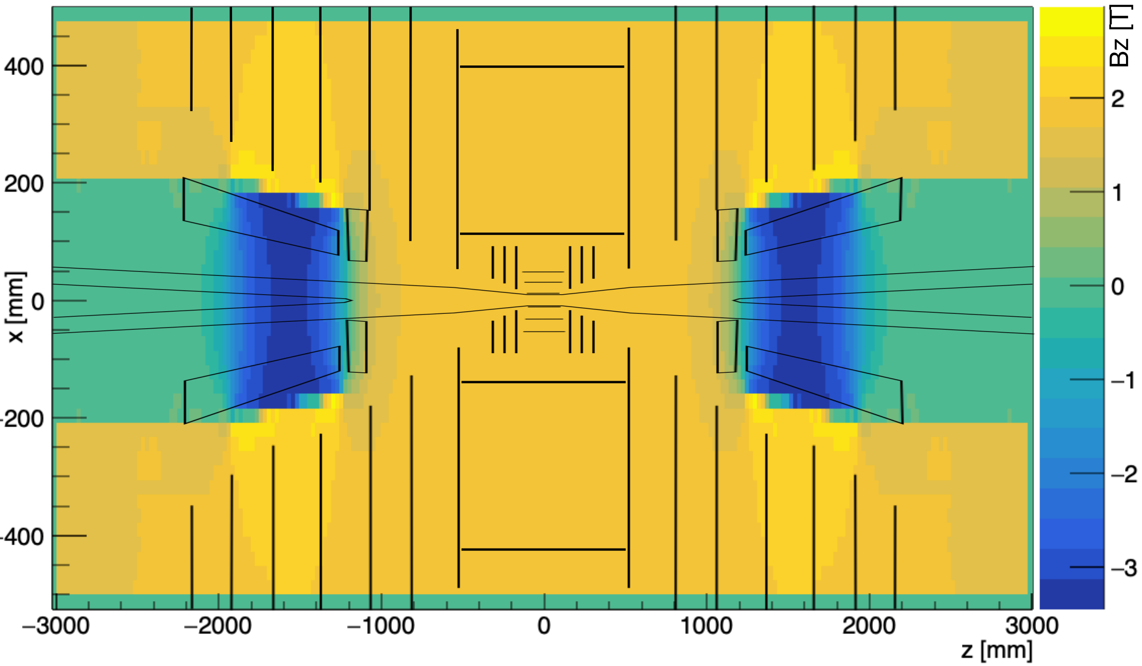
After the CDR, the design for the central chamber of the FCC-ee beam pipe has changed to a reduced radius of **R=10mm** and length of **L=18cm,** allowing to have the inner layer of the Vertex Detector Barrel **closer to the interaction point**.

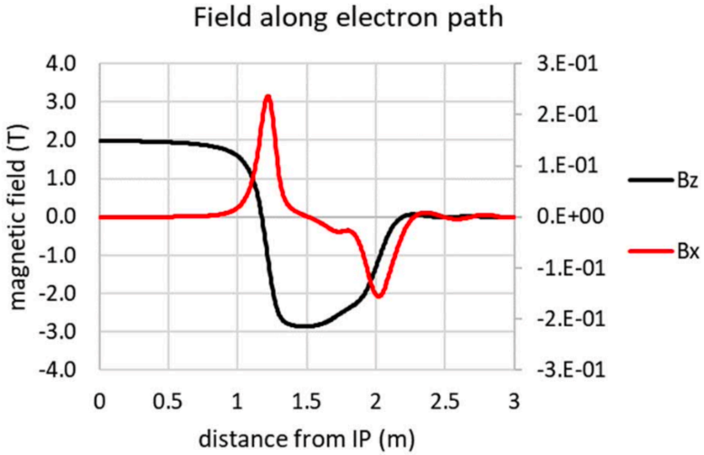
Keeping the **same distance** between the external surface of the beam pipe and the begin of the first ladder, and also the **same stave width**, I have reduced the **number of sectors to 12** (from 16) in order to avoid overlaps.

Also the **second layer** has been moved closer to the IP in order to have it **midway** between the two outermost layers.

The **length** of the first and second layer has therefore been changed in order to maintain the **same angular acceptance** of the original design.







Magnetic Field in the Detector Area

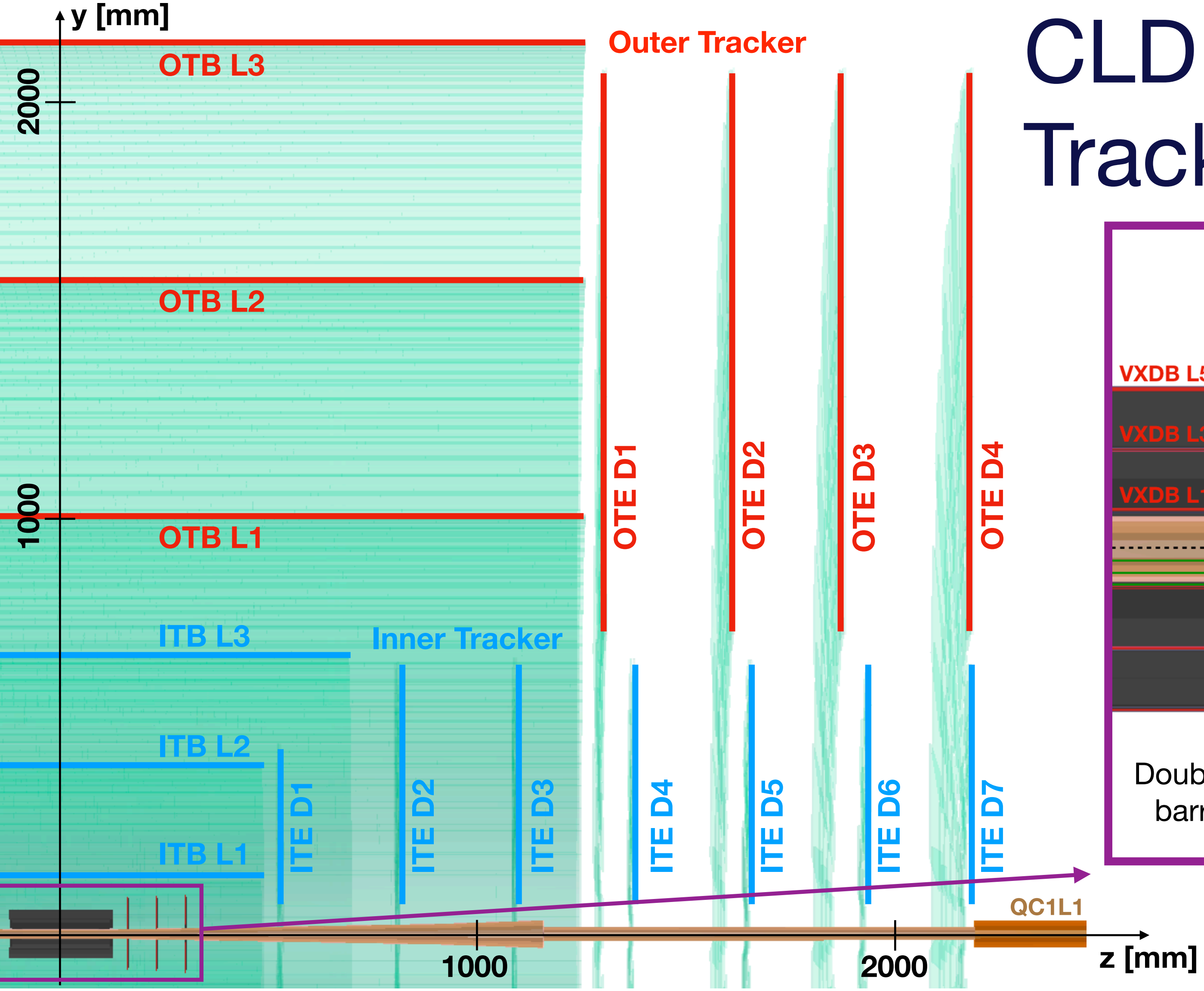
Improved description of the magnetic field in the detector, thanks to the possibility to **import field map** in key4hep geometry.

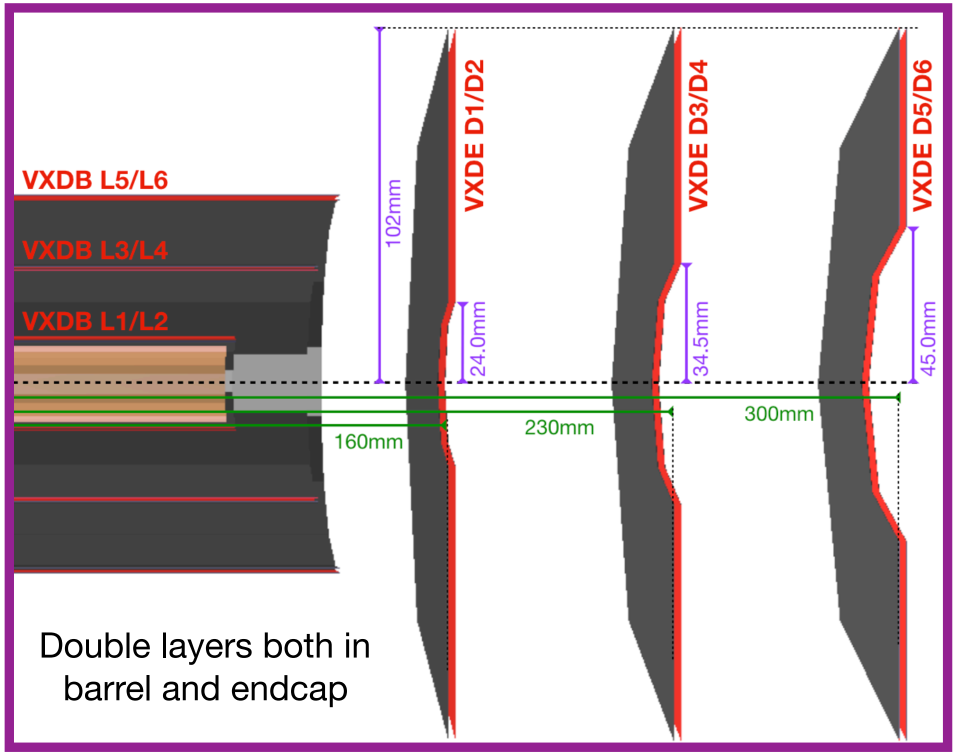
Screening and **compensating** solenoids contribution now introduced in addition to the 2T of the main solenoid.

Repeat background studies and compare with previous results:

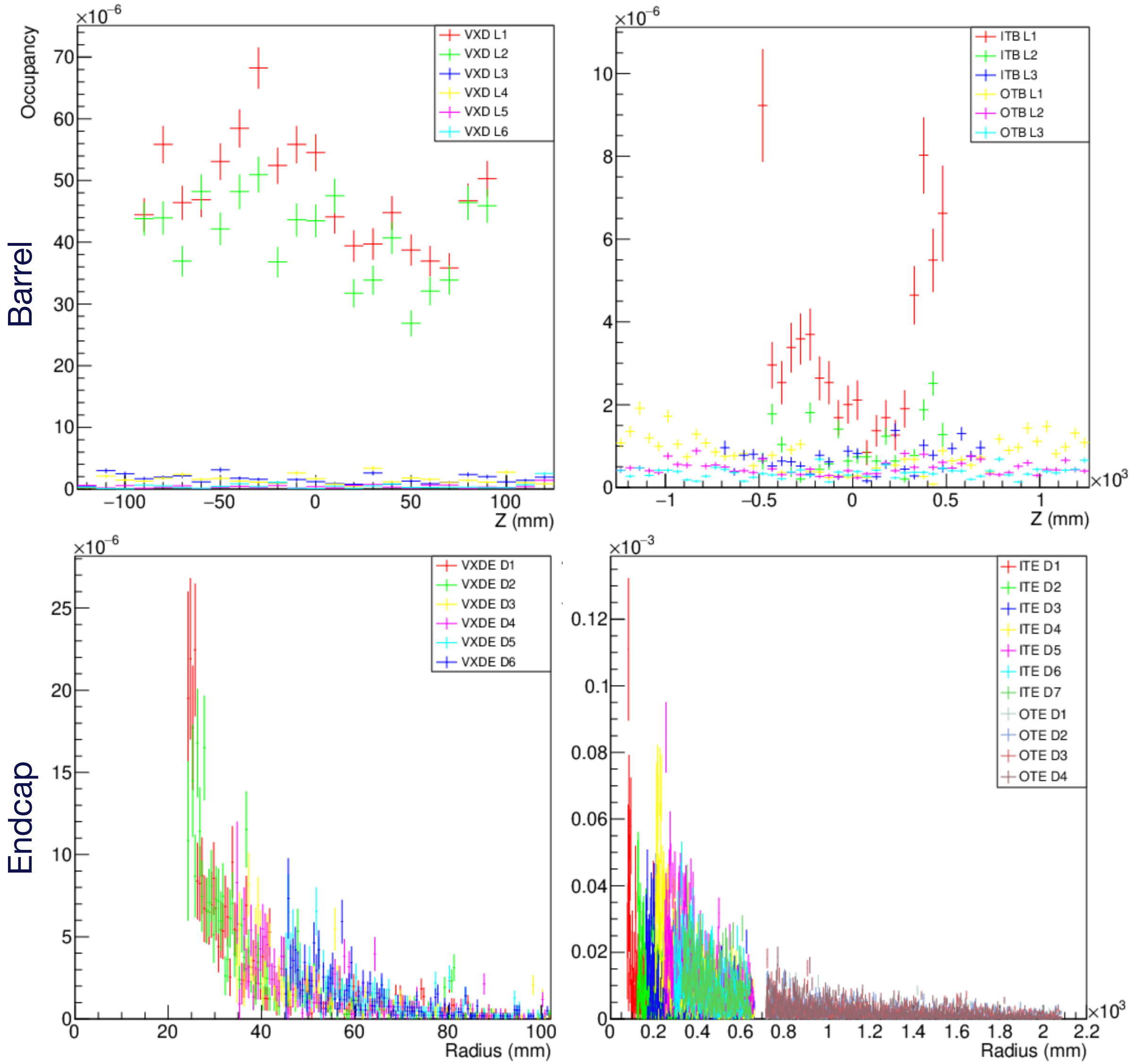
- no difference expected for IP produced particles
- significant effect expected for particles produced upstream (e.g. beam losses)

CLD Subdetectors: Trackers and Vertex

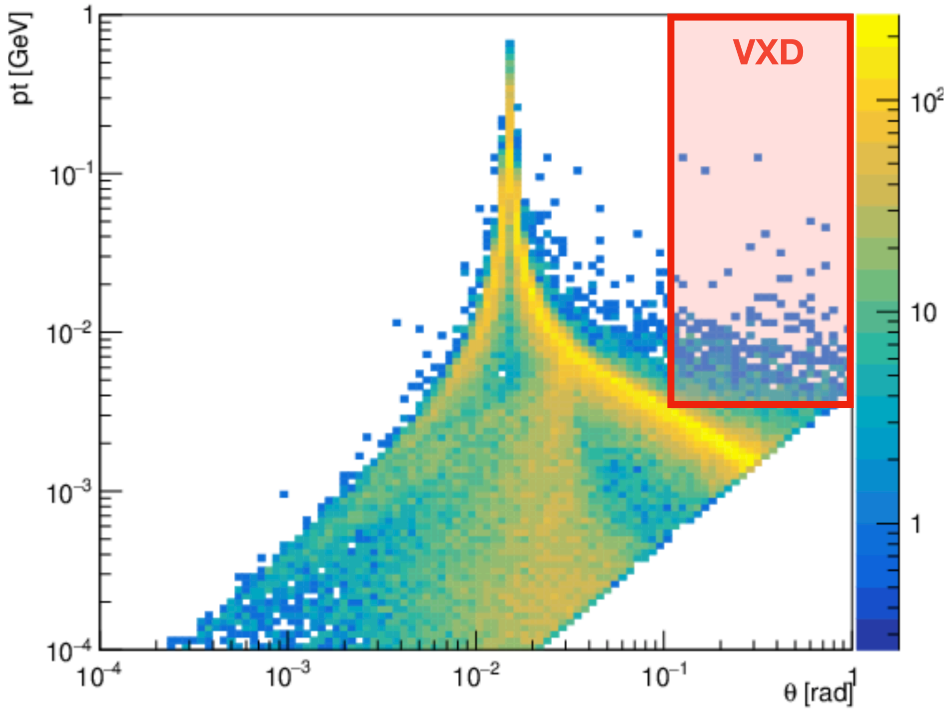


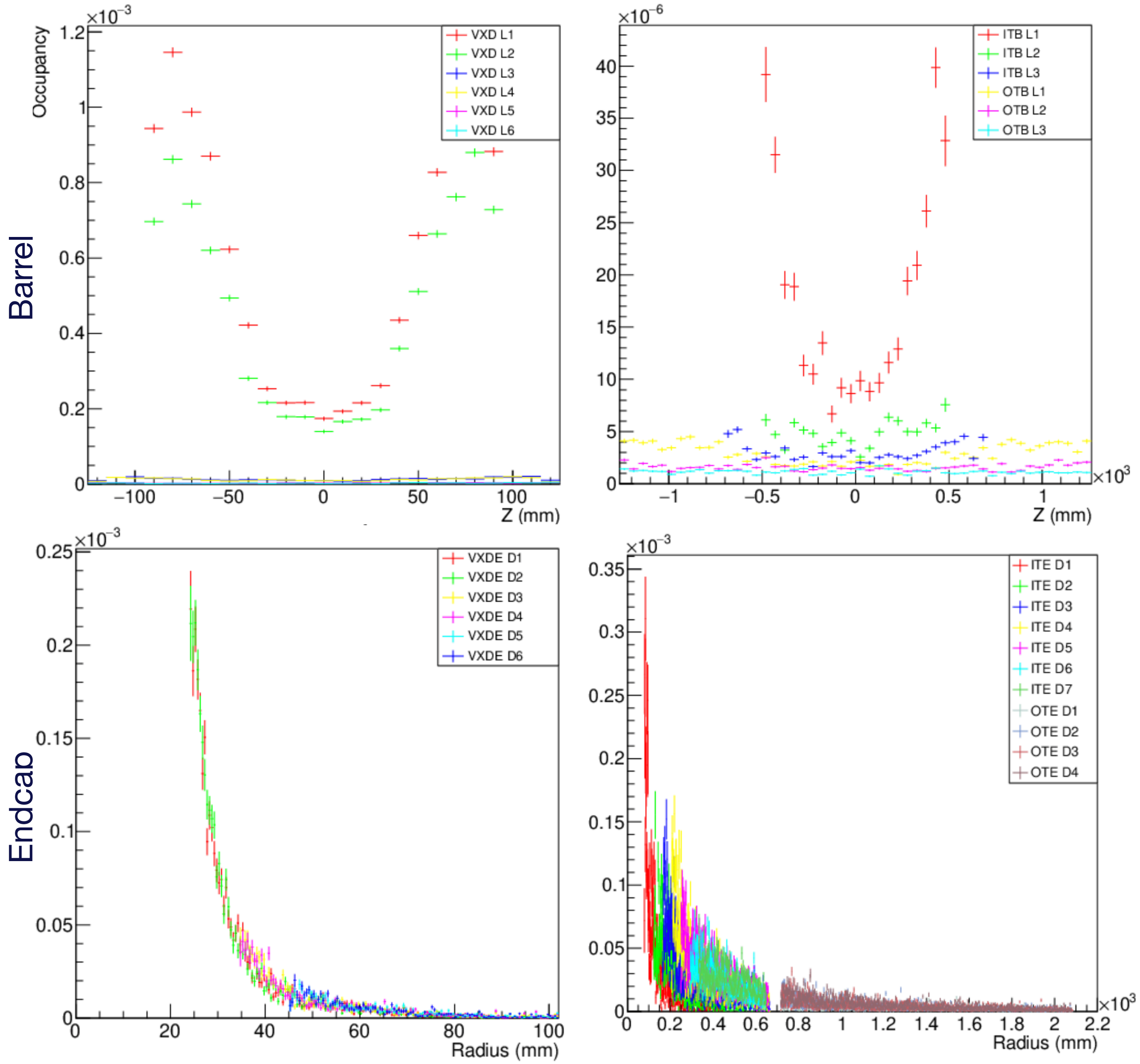


Vertex Detector



	Z	WW	ZH	Top
Pairs/BX	1300	1800	2700	3300
Max occup. VXDB	70e-6	280e-6	410e-6	1150e-6
Max occup. VXDE	22.5e-6	95e-6	140e-6	220e-6
Max occup. TRKB	9e-6	20e-6	38e-6	40e-6
Max occup. TRKE	110e-6	150e-6	230e-6	290e-6





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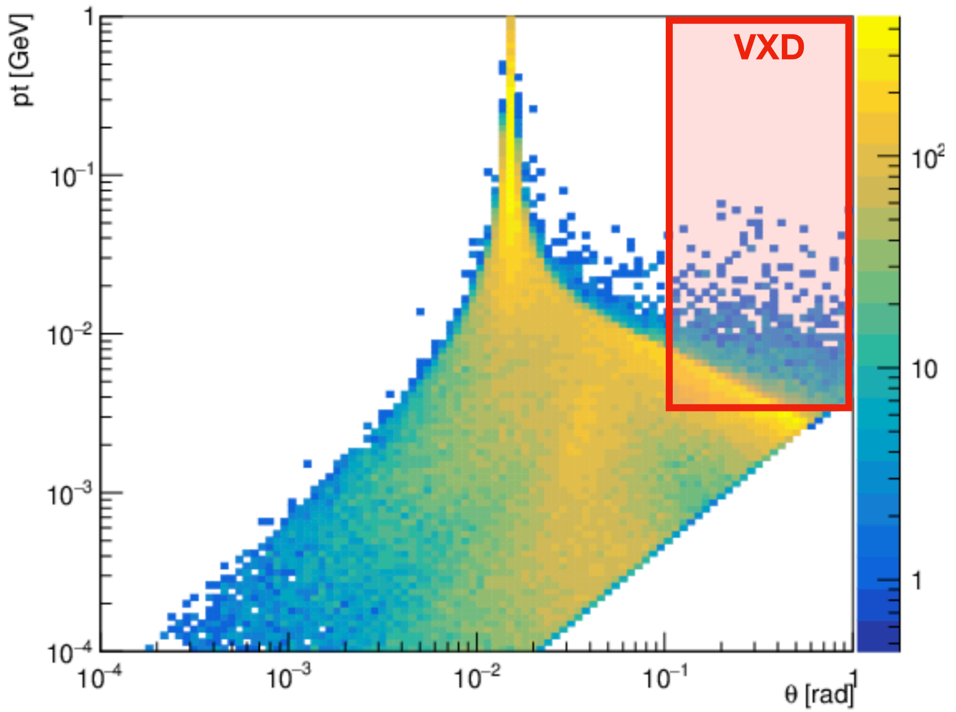
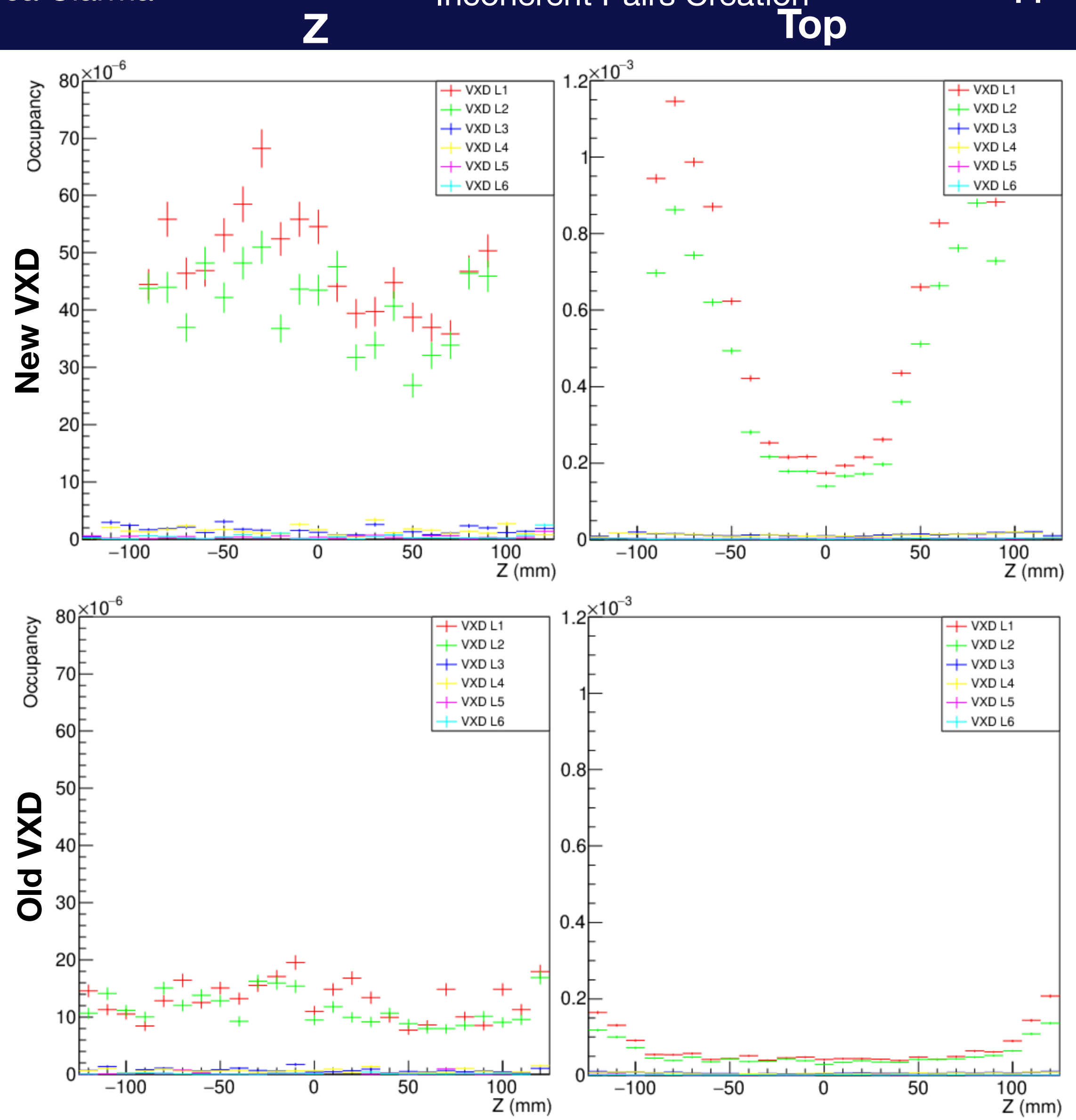


Preliminary studies on the occupancy due to the IPCs (generated with GuineaPig++ using the latest 4IP lattice beam parameters) show an increase of a **factor ~5** in particular in the **innermost layers** of the VXD barrel.

According to the electronics **readout time**, the sensors may integrate over more BXs.

Considering a (very conservative) $10\mu s$ window, the occupancies will remain below the 1% everywhere **except for the VXD barrel** at the **Z**. While the pile-up of the detectors has not been defined yet, it is important to **overlay this background** to physics event to verify the **reconstruction efficiency.**

	Z	WW	ZH	Top
Bunch spacing [ns]	30	345	1225	7598
Max VXD occ. 1us	2.33e-3	0.81e-3	0.047e-3	0.18e-3
Max VXD occ.10us	23.3e-3	8.12e-3	3.34e-3	1.51e-3
Max TRK occ. 1us	3.66e-3	0.43e-3	0.12e-3	0.13e-3
Max TRK occ.10us	36.6e-3	4.35e-3	1.88e-3	0.38e-6

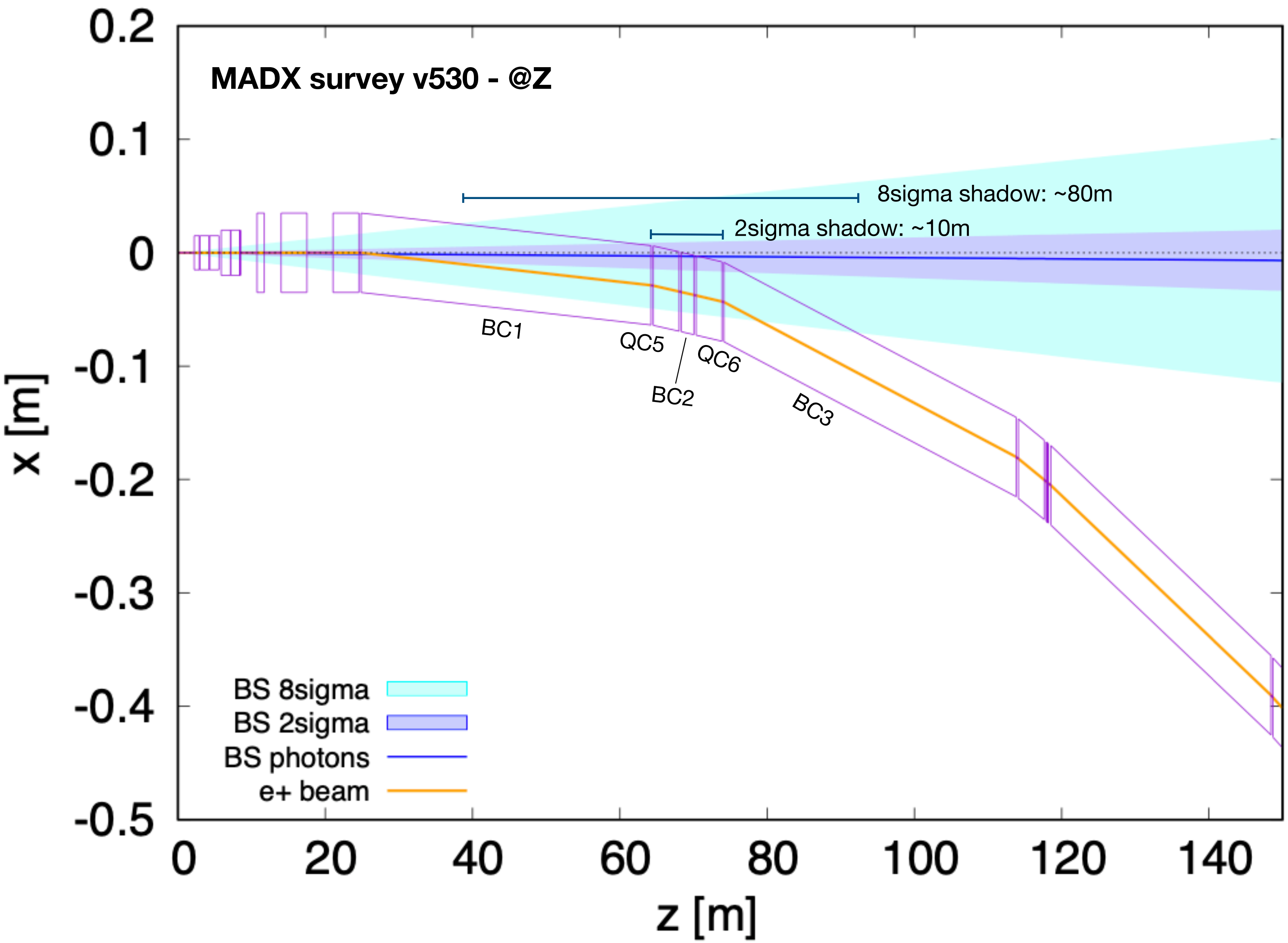


Failure Scenario Beam Losses: Induced Background Recap and Power in FFQs

	TT: horizontal primary collimator	Z: off-mom. collimator	Z: off-mom. collimator + betatron osc.
	Losses per second (10^9)		
IPA	0.15	1.66	0.15
IPD	0.11	0.38	0.24
IPG	0.10	12.21	182.10
IPJ	0.16	2.41	37.24
	Highest occupancy		
IPA	5.73% (ITE)	0.06% (ITE)	— — —
IPD	3.98% (ITE)	0.04% (ITE)	— — —
IPG	3.16% (ITE)	0.41% (ITE)	8.45% (ITE)
IPJ	8.88% (ITE)	0.09% (ITE)	1.60% (ITE)
	QC1 hottest spot (W/cm3 in a 2mm3 bin)		
IPA	0.035	0.077	— — —
IPD	0.026	0.005	— — —
IPG	0.013	0.278	4.311
IPJ	0.025	0.053	1.669
	Total power in QC1 (W)		
IPA	1.77	3.42	— — —
IPD	1.34	0.35	— — —
IPG	1.09	24.22	442.86
IPJ	1.92	5.88	96.10

Despite the induced **background** has now reduced of about a **factor 2 in every scenario**, the **power** deposited on the **final focus** quadrupoles does now show the same trend, remaining almost at the **same values** of previous studies.

This is expected as the quadrupoles are the first material the particles traverse after hitting the beam pipe, so the effect of the field is not evident yet.



Comparison of the beamstrahlung photon distribution against the **MADX survey** for lattice **v530** show that the hits are localized in the "QC5-BC2-QC6" area - in agreement with the SR photons tracking in BDSIM (K. André 19/10).

This is further w.r.t. lattice v217 as BC1 is now a bit weaker.

The **size of the shadow** on the pipe wall depends on the amount of radiation which is necessary to collect with the extraction line, and it is **10 meters at just 2 sigmas**.