Beam losses from radiative Bhabha and Beamstrahlung in FCC-ee

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Acknowledgements:

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Outline

→ Introduction: Beam losses and backgrounds

- **Results at both energies: 175 GeV (top) and 45.6 GeV (Z)**

→ Radiative Bhabha:

- Generators and Dynamics
- Tracking in the FCC rings

→ Beamstrahlung: Preliminary

- Spectrum and tracking

Introduction

→ Beam losses/detector backgrounds:

1) Single beam losses: beam-gas Bremsstrahlung, Touschek scattering, elastic Coulomb scattering, injection backgrounds

2) beam-beam backgrounds: radiatiative Bhabha scattering, Beamstrahlung, “pair production”

→ Beamstrahlung photons induce backgrounds in the detector through subsequent electron-positron pair production

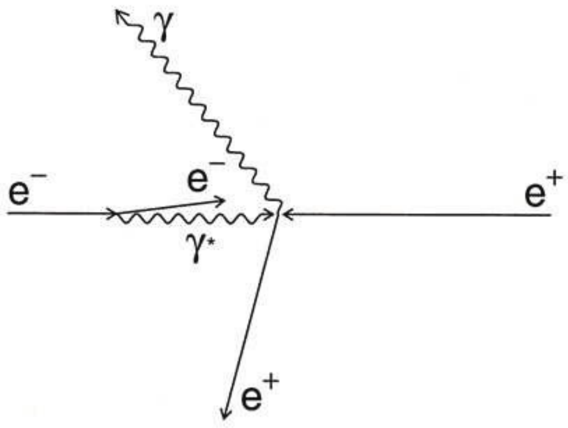
→ Beam particles which lost a few percentage of their energies due to Beamstrahlung will be lost from the beam after several turns inducing further background when lost in IR/detector

→ Radiative Bhabha photons will hit the beam pipe at some point downstream of the IP in both rings

→ Charged Bhabha particles lose energy and are lost downstream of the IP at several locations (including the IR, thus introducing backgrounds in the detector)

→ Losses from radiative Bhabha and Beamstrahlung (and others later) should be carefully studied and mitigation measurements (collimators) should be considered

Radiative Bhabha



- Scattering of the particles of opposite beams by exchange of a virtual photon
- One particle emits a photon and loses energy and thus is lost from the beam (2% momentum acceptance)
- The other particle maintains its energy and stays in the beam

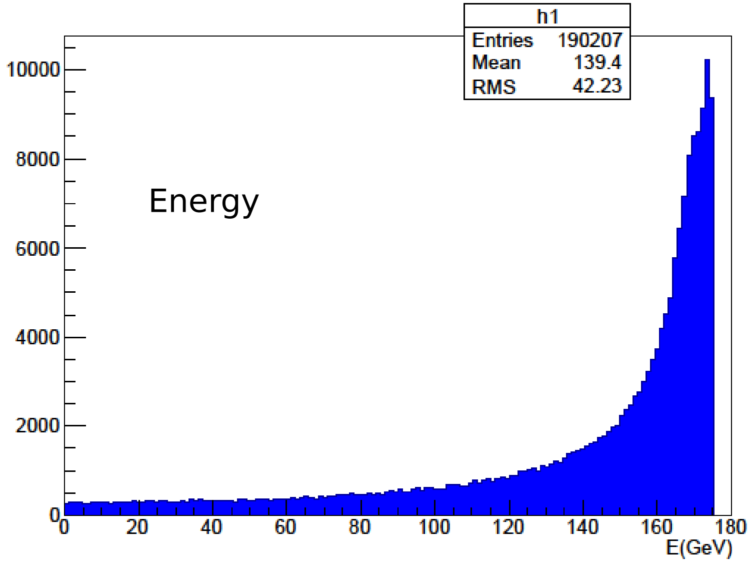
→ Two main event generators for radiative Bhabha could be used:

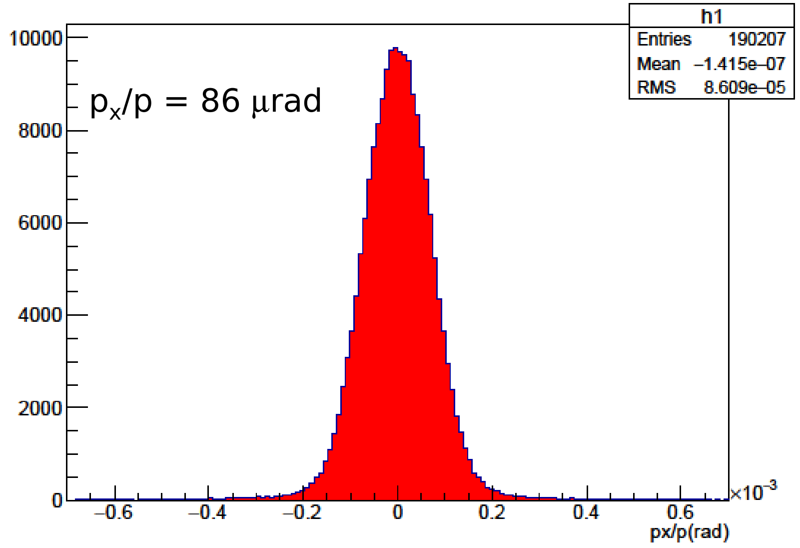
1) GuineaPIG++: uses the equivalent photon approximation to calculate the cross-section, considers full beam dynamics for particle generation, generates both radiative Bhabha and Beamstrahlung, track bhabhas in the field of the other beam

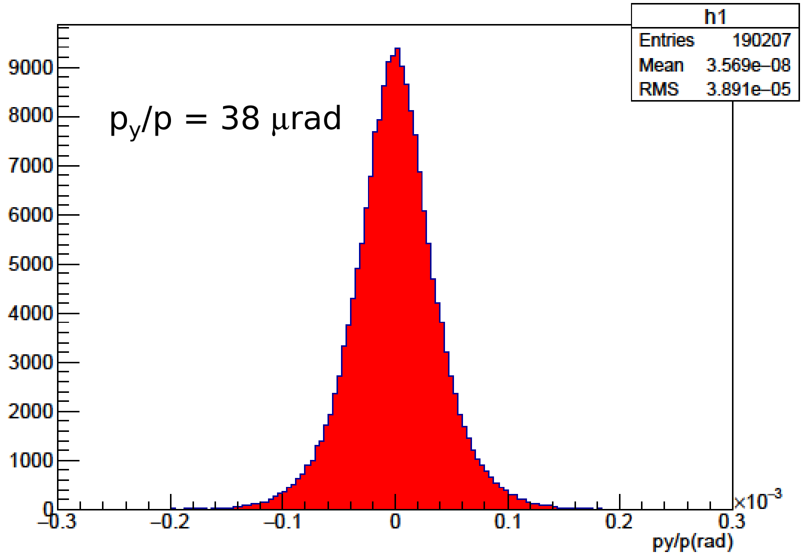
2) BBBrem: uses the full matrix element to calculate the cross section, generates radiative Bhabha

→ Both codes have an implementation of the beam size effect for cross section calculations

Radiative Bhabha @ 175 GeV







→ The generated Bhabha events have dynamics close to that of the beam (p_x/p = 37 μrad and p_y/p = 36 μrad)

→ The generated dynamics are then tracked in SAD (energies, positions and angles)

→ The format of the output files from GuineaPIG++ is then adapted to the SAD format

Cross section (mbarn)	w/o beam size effect	w/ beam size effect
GuinePIG++	**312**	**145**
BBBrem	**347**	**158**

Radiative Bhabha : tracking (1)

→ The new lattice file is used: FCCee_t_202_nosol_16.plain.sad

→ Apertures were inserted:
IR until the exit of QC1 (R=15 mm)
Exit of QC1 until exit of QC2 (R increases)
Outside these regions (R=35 mm)

→ Masks were inserted as well:

+8.25 m to +8.27 m radius 18 mm
-8.25 m to -8.27m radius 18 mm

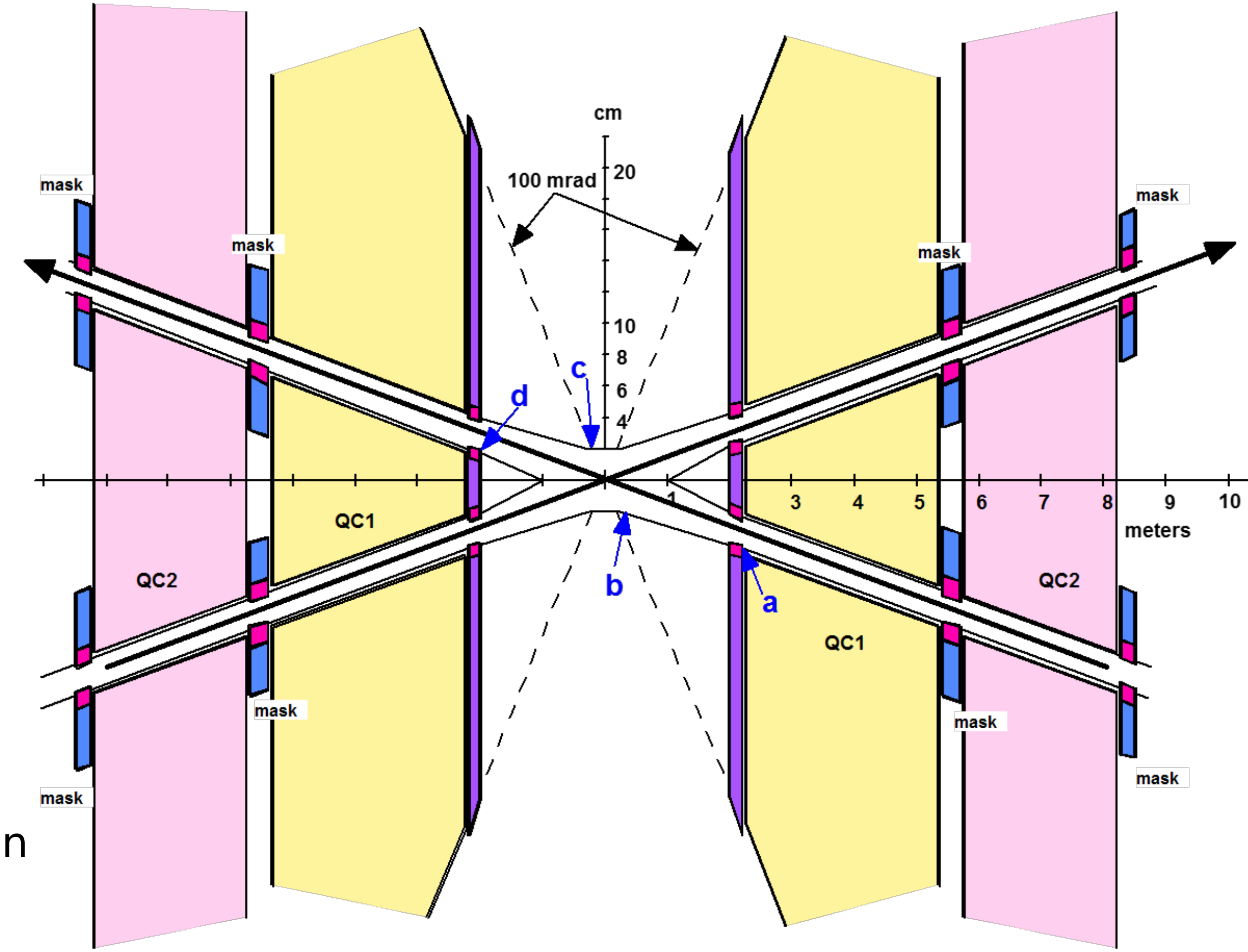
+5.42 m to +5.44 m radius 12 mm
- 5.42 m to -5.42 m radius 12 mm

+2.10 m to +2.12 m radius 12 mm
-2.10 m to -2.12 m radius 12 mm

→ Tapered lattice was considered, radiation and fluctuation and cavities were switched on.

→ Bhabhas were tracked with open masks and closed masks.

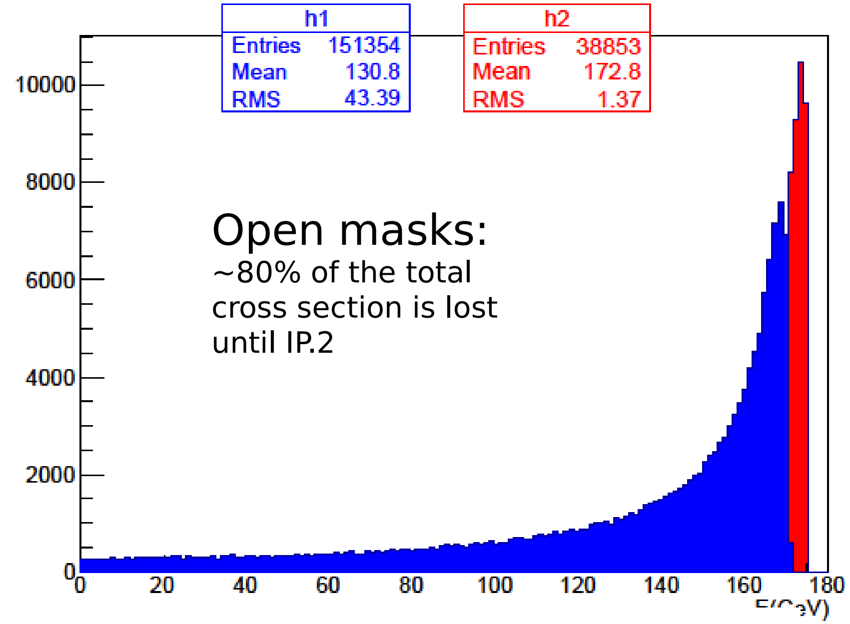
→ Track: half ring, full ring and several turns.

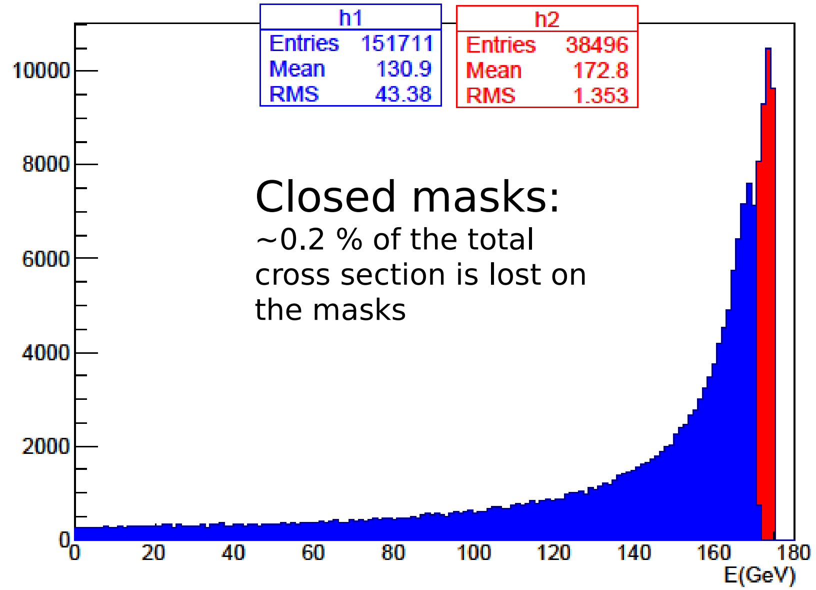


M. Sullivan

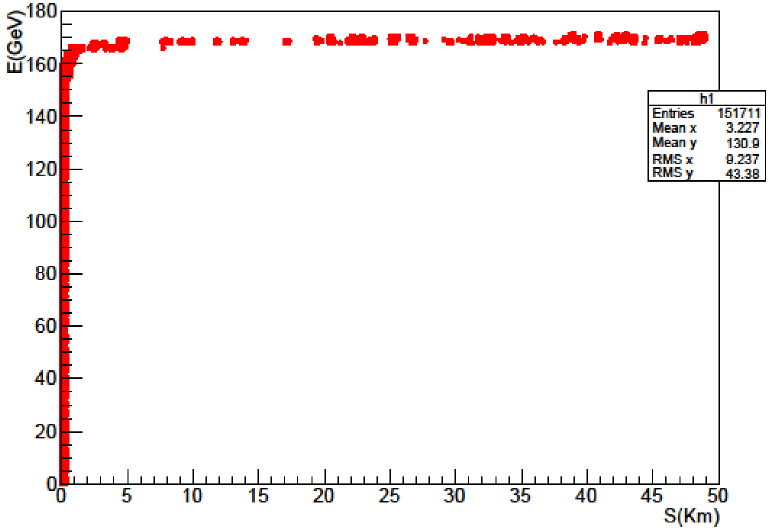
Radiative Bhabha : tracking (2)

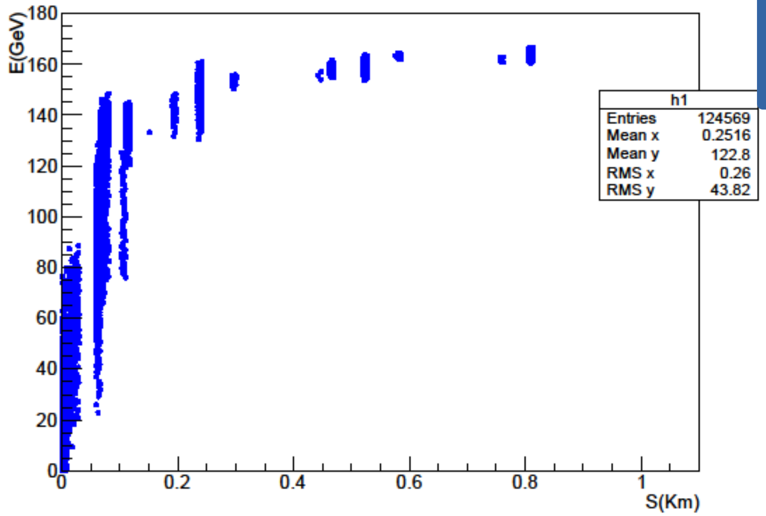
→ Track until the second IP: Lost particles and particles still in the beam





For closed masks compared to open masks, the particle are mainly lost on the last masks upstream the IP.2 with a relatively large energy ~ 173 GeV

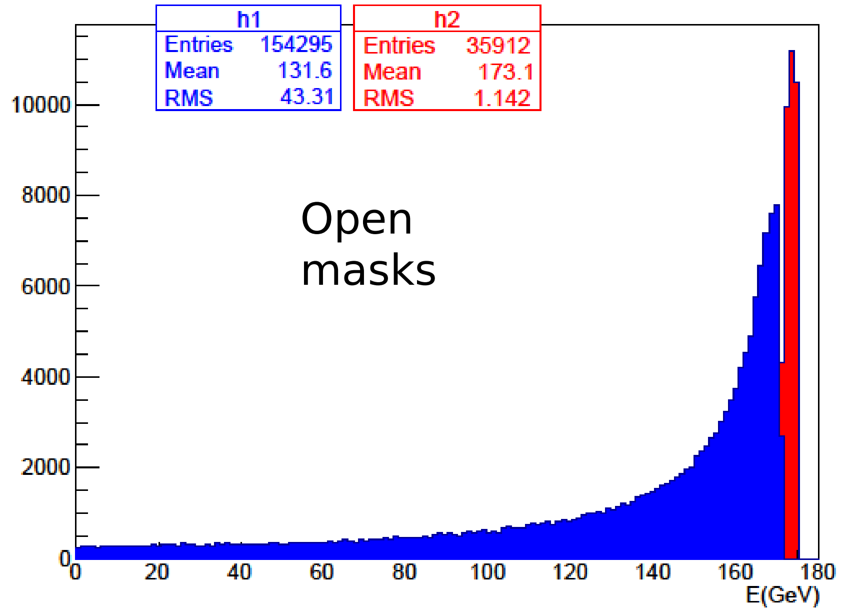




Energy of lost particles as function of their position of loss

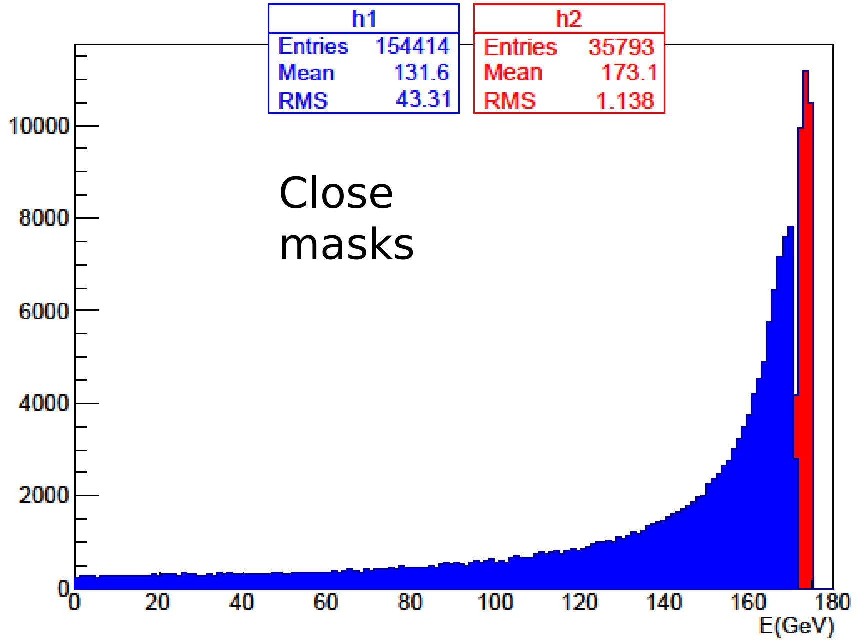
Radiative Bhabha : tracking (3)

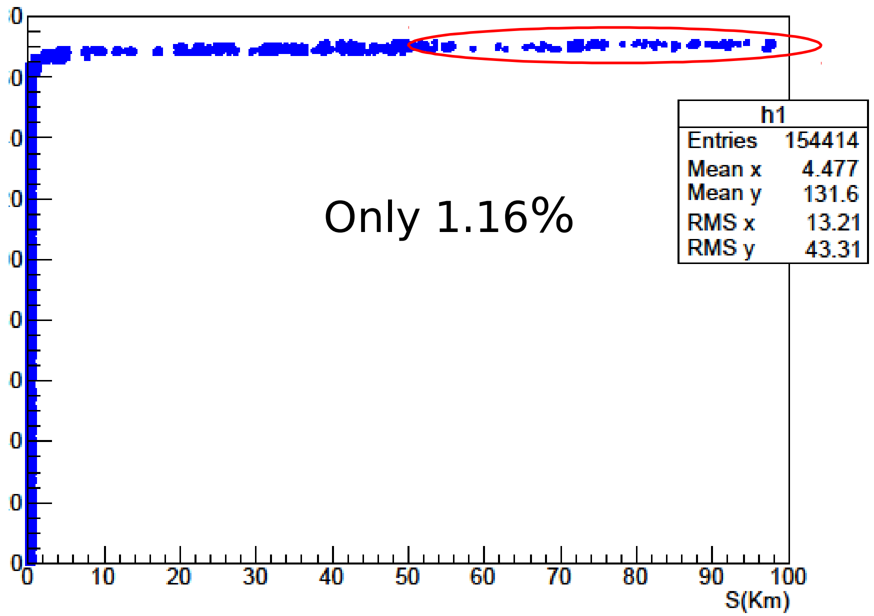
→ Track full ring:



Open masks 81.1% of the total cross section is lost

Only 1.1% are lost on the other half ring

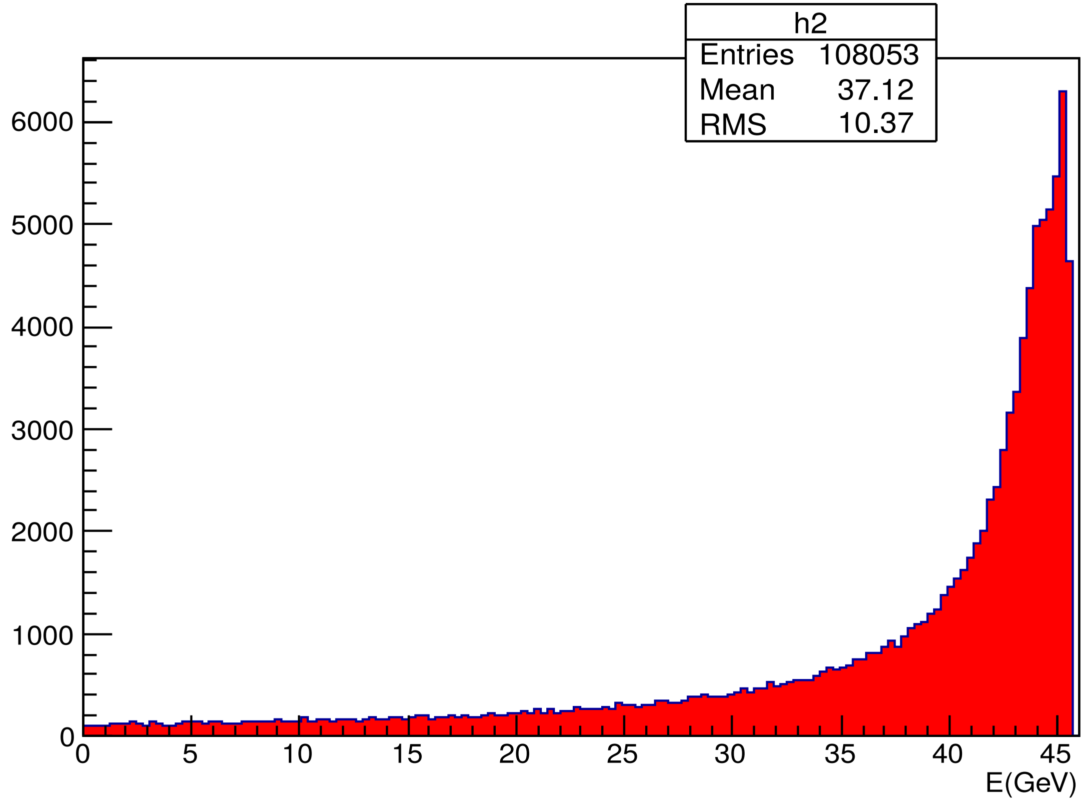


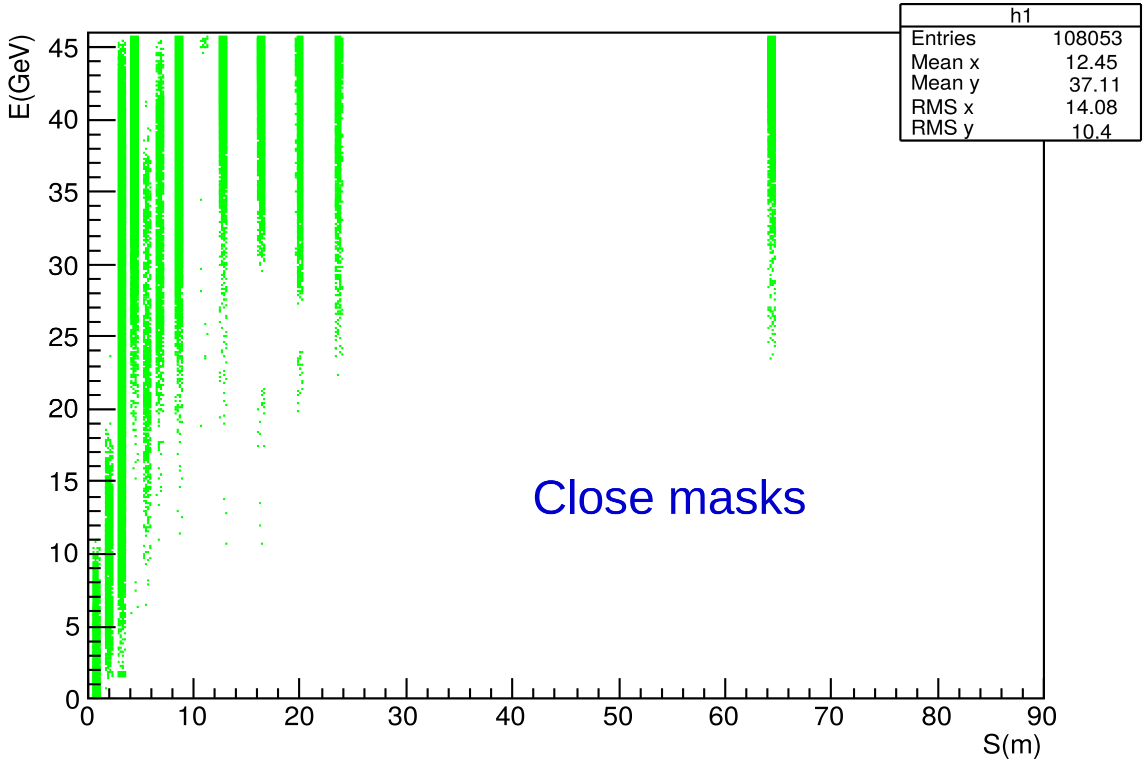


Only 0.06 % of the total cross section are lost on the masks

→ Tracking multi turns (30 turns) gives the same result as one turn

Radiative Bhabha @ 45.6 GeV





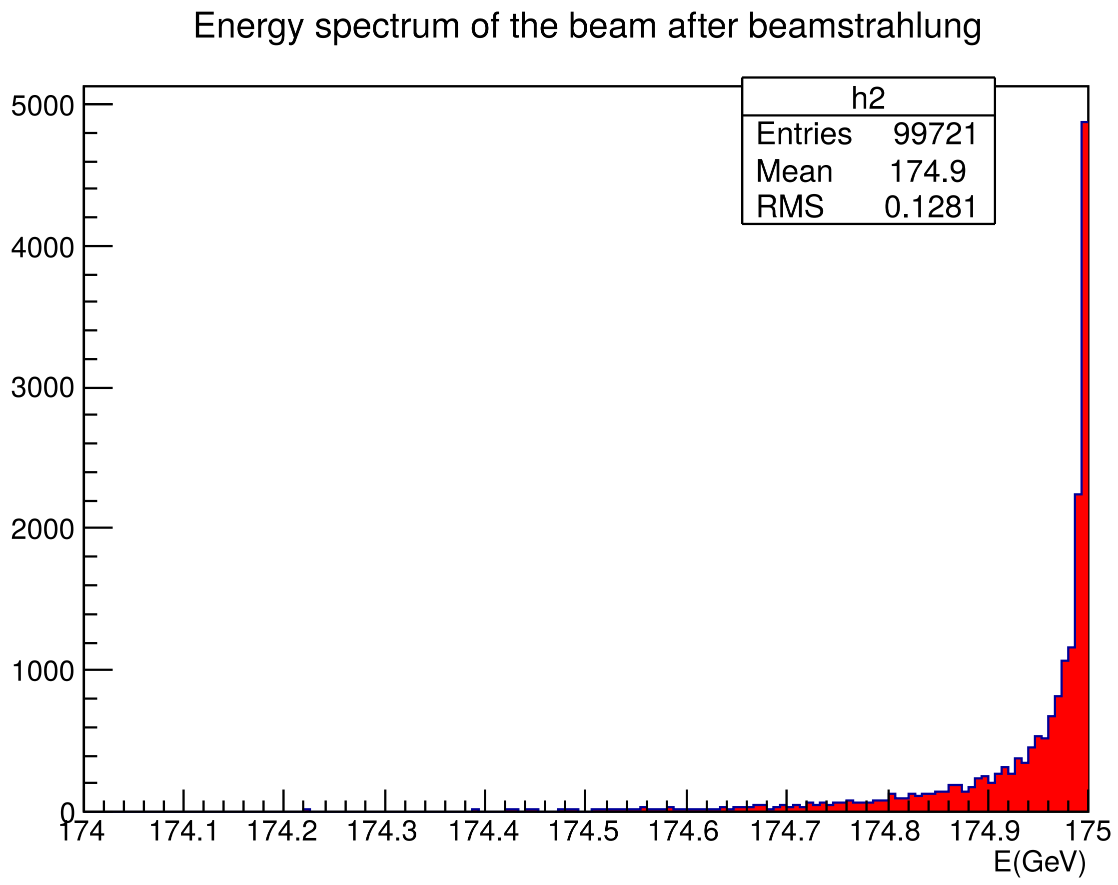
→ All Bhabhas are lost in the first turn until ~ 70 meters downstream of the first IP

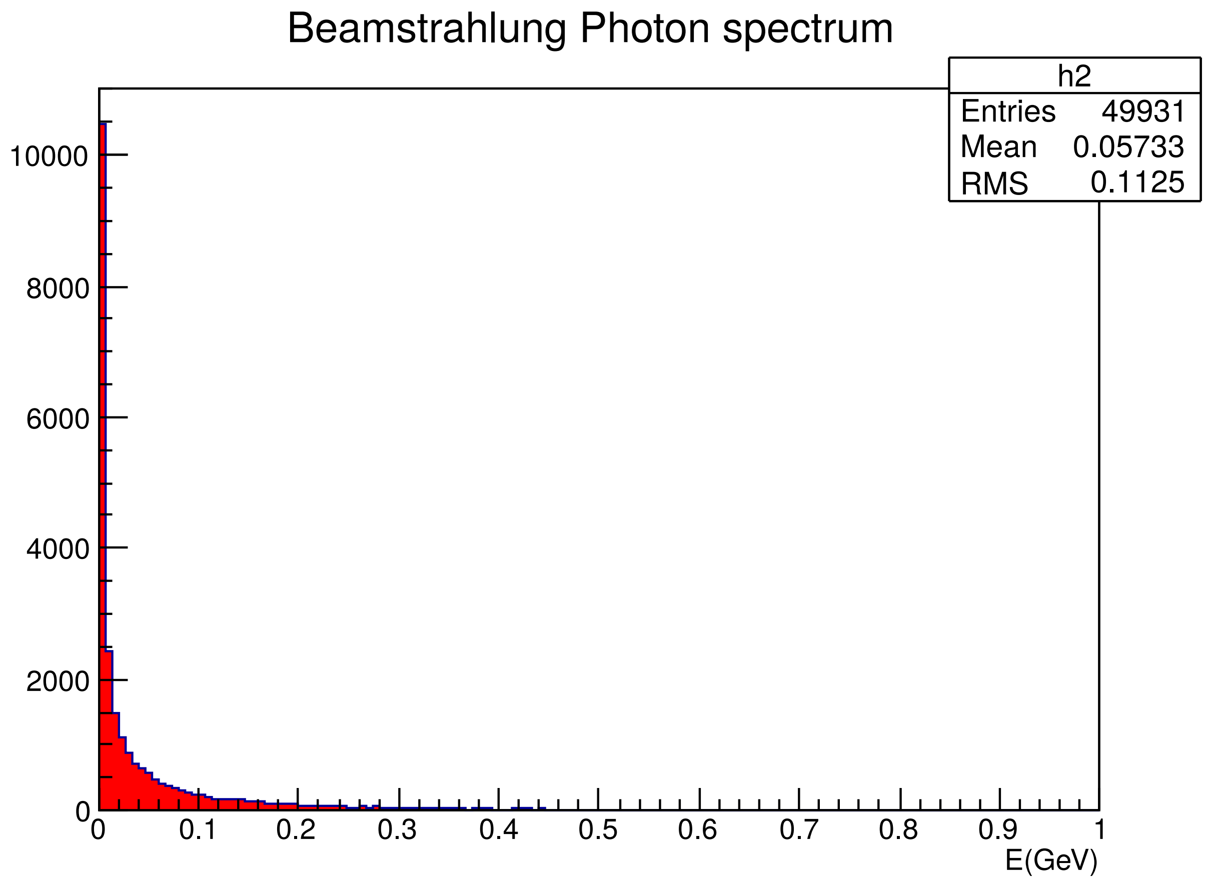
→ No Bhabhas reach the second interaction region

Beamstrahlung @ 175 GeV

→ Beamstrahlung was generated by GuineaPIG++ again

→ Consider Gaussian energy spread distribution of the initial beam (0.144 %)





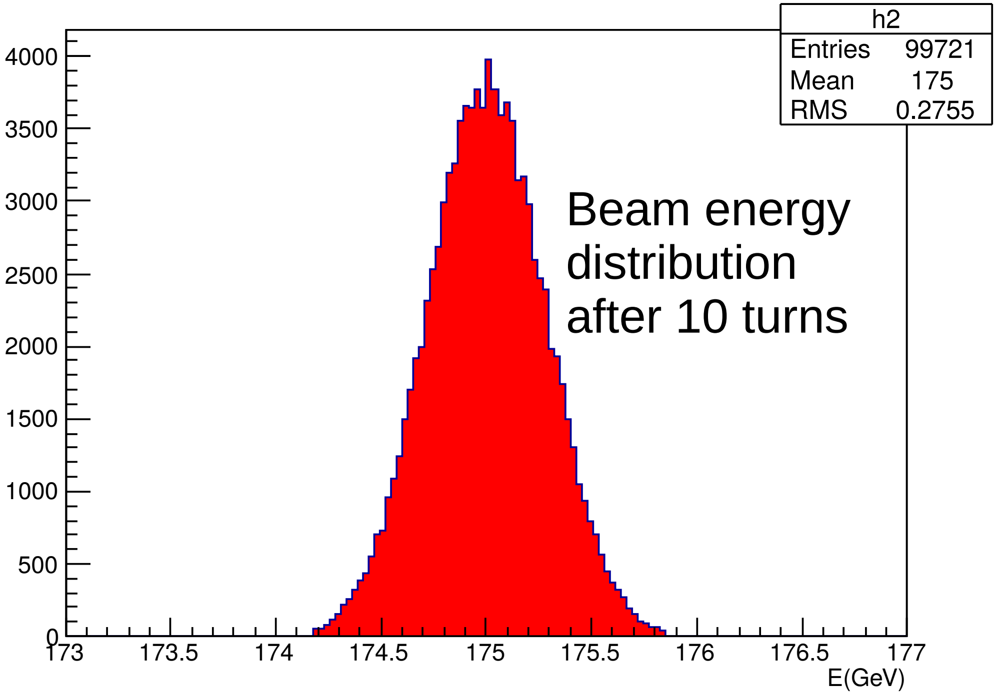
Beamstrahlung @ 175 GeV

→ No beam beam effects considered

→ Track one 10 turns starting from the IP with close masks:

1) **Tapered lattice, turn off radiation and fluctuation, no beam beam effects at the IP were considered**

2) No losses were reported



3) Turn on beam beam effects (still radiation off): no losses as well

Conclusions and next steps

→ Radiative Bhabhas were generated and tracked at two energies

→ For 175 GeV ring, Bhabhas are lost overall the ring

→ For 45.6 GeV ring, Bhabhas are lost until ~ 70 meters downstream of the IP

→ Masks have a tiny effect on the total loss in the rings due to radiative Bhabha

→ Concerning Beamstrahlung:

1) Consider higher number of turns for tracking

2) include beam beam effects and turn on Beamstrahlung at both IP in SAD (Ohmi san simulation)

→ Study losses from Touschek and other single beam losses in SAD

→ Collimation study to mitigate losses

→ Study the beam beam effects of the injected beam and simulate injection backgrounds

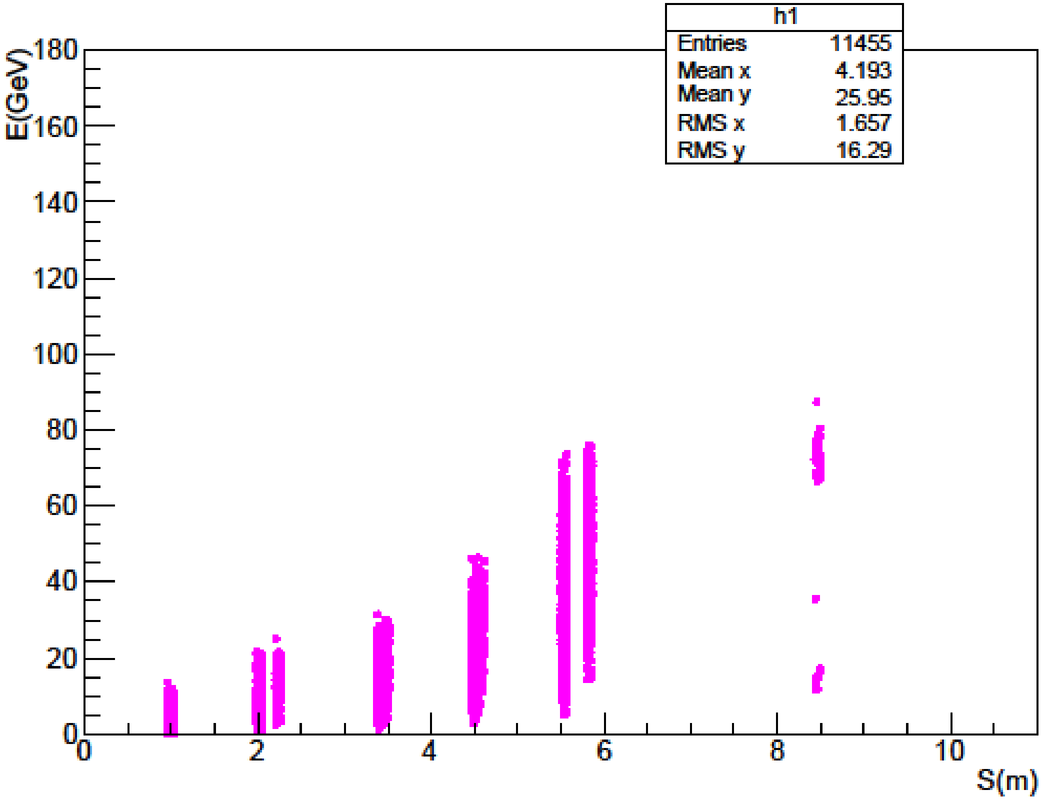
Thank you for your attention

Backup slides

Parameters

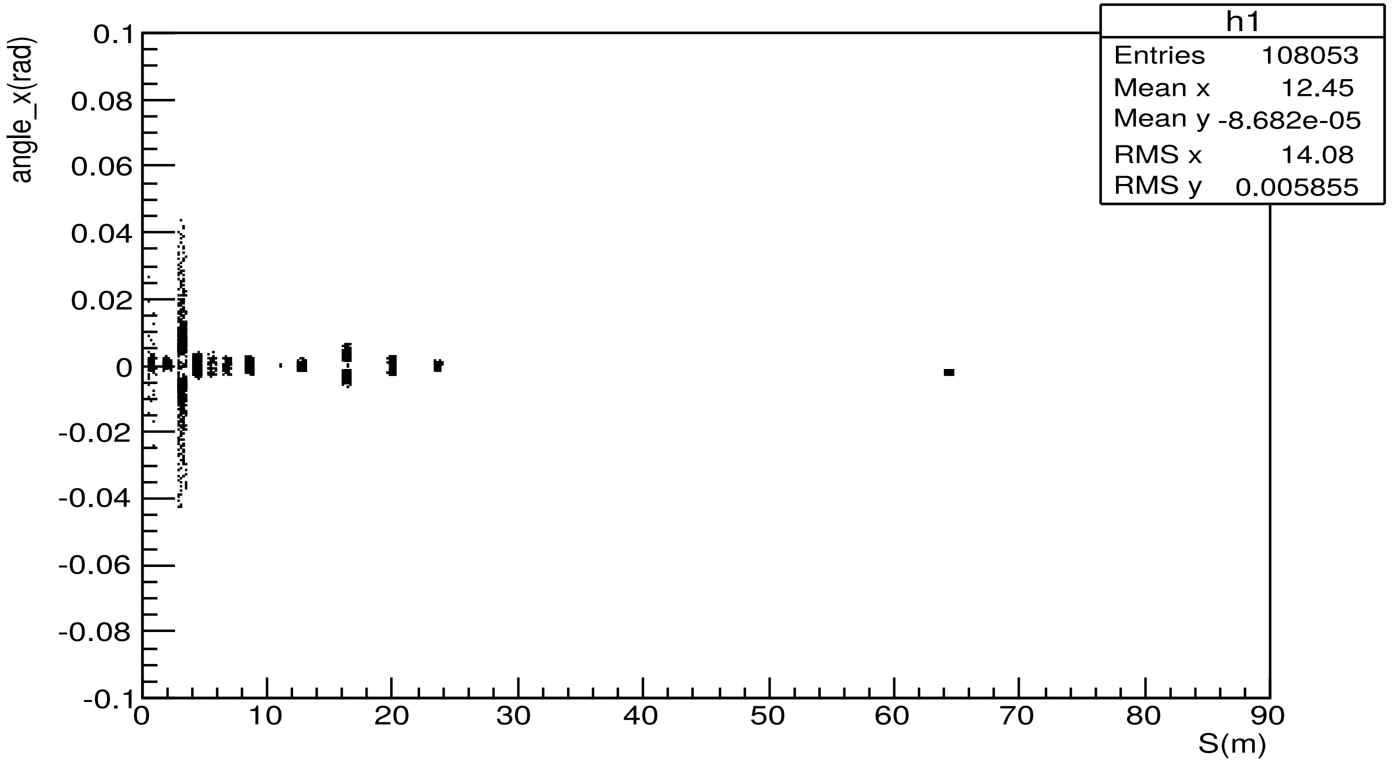
Circumference	[km]	97.750	
Arc quadrupole scheme		common	
Bend. radius of arc dipole	[km]	10.747	
Number of IPs / ring		2	
Crossing angle at IP	[mrad]	30	
Solenoid field at IP	[T]	± 2	
ℓ^*	[m]	2.2	
Local chrom. correction		y-plane with crab-sextupole effect	
RF frequency	[MHz]	400	
Total SR power	[MW]	100	
Beam energy	[GeV]	45.6	175
SR energy loss/turn	[GeV]	0.0360	7.80
Long. damping time	[ms]	414	7.49
Polarization time	[s]	9.2×10^5	1080
Current/beam	[mA]	1390	6.4
Bunches/ring		70760	62
Particles/bunch	$[10^{10}]$	4.0	21.1
Arc cell		$60^\circ/60^\circ$	$90^\circ/90^\circ$
Mom. compaction α_p	$[10^{-6}]$	14.79	7.31
Horizontal tune ν_x		269.14	389.08
Vertical tune ν_y		267.22	389.18
Arc sext. families		208	292
Horizontal emittance ε_x	[nm]	0.267	1.34
$\varepsilon_y/\varepsilon_x$ at collision	[%]	0.38	0.2
β_x^*	[m]	0.15	1
β_y^*	[mm]	1	2
Energy spread by SR	[%]	0.038	0.144
RF Voltage	[MV]	255	9500
Bunch length by SR	[mm]	2.1	2.4
Synchrotron tune ν_z		-0.0413	-0.0684
RF bucket height	[%]	3.8	10.3
Luminosity/IP	$[10^{34}/\mathrm{cm}^2\mathrm{s}]$	121	1.32

Details : radiative Bhabha @ 175 GeV



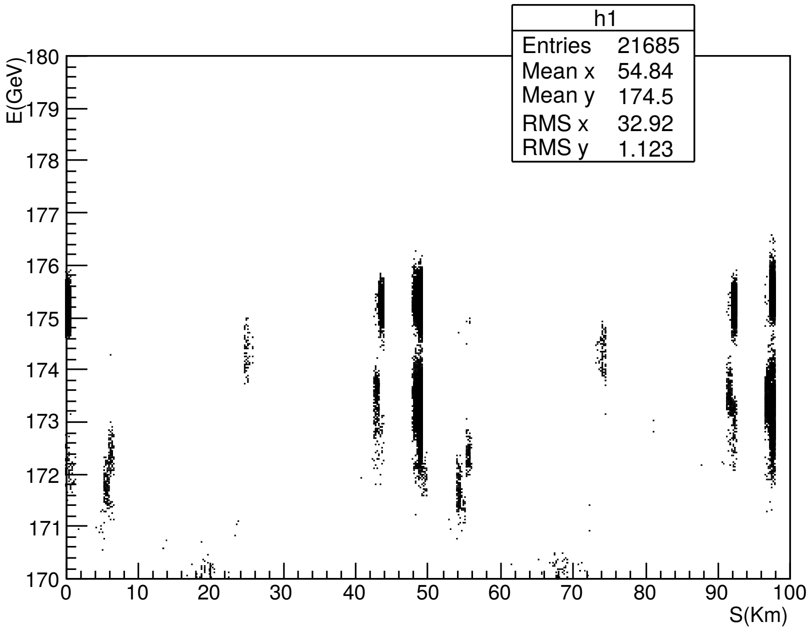
→ Initial number of charged Bhabha at the IP : **190207**

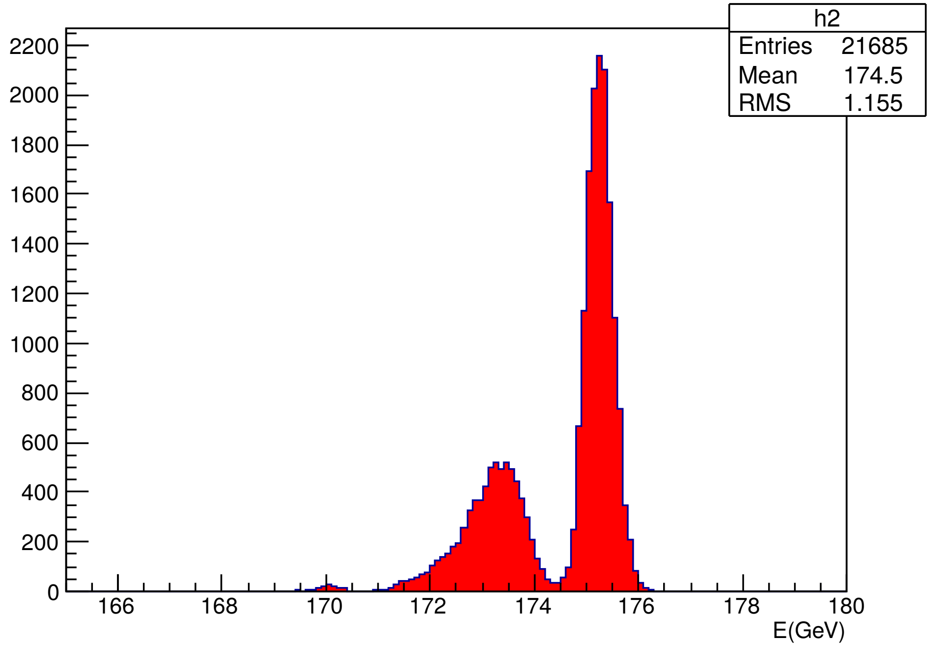
Details : radiative Bhabha @ 45 GeV



Details on Beamstrahlung

Radiation on: track 10 turns





→ Considering radiation: very preliminary

- Significant amount of loss is obtained!!
- Due to an unstable close orbit ? (study more)