Fast luminosity monitoring based on radiative Bhabha scattering measurement using diamond sensors

Cecile Rimbault, LAL-Orsay, in2p3/CNRS

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Fast luminosity monitoring based on radiative Bhabha scattering measurement using diamond sensors

Motivation
Bhabha generators study
Best location for the sensors
Next plan

LAL group resources

Contributors:
P. Bambade, C. Rimbault, F. Blampuy (Master student), Stefano Tammaro (Master student), F. Bogard & S. Wallon (mech. eng.), S. Conforti (FE electronics), P. Barillon (sensors)

Pending applications / t.b.c. :
Post-doc, PhD student

Budget: P2IO LABEX grant, IN2P3, France-Japan bilateral funds

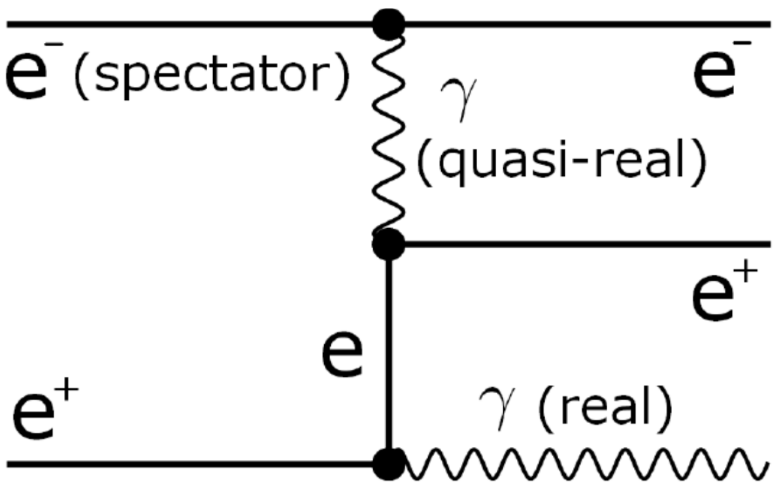
Collaboration

Italy:
INFN Pisa: E. Paoloni, A. Perez (Bruno)
INFN Frascati: M. Boscolo (Touschek)
Roma II University: A. di Ciaccio

Japan: (S.Uehara) KEK

CEA Saclay: M. Pomorski LIST Diamond Sensors Laboratory

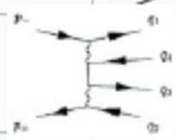
Radiative Bhabha process



e^+e^- beam part. scattering via quasi-real photon exchange at quasi-zero angle.
Can be understood as a Compton scattering convoluted with the quasi - real photon spectrum (Equivalent Photon Approximation)

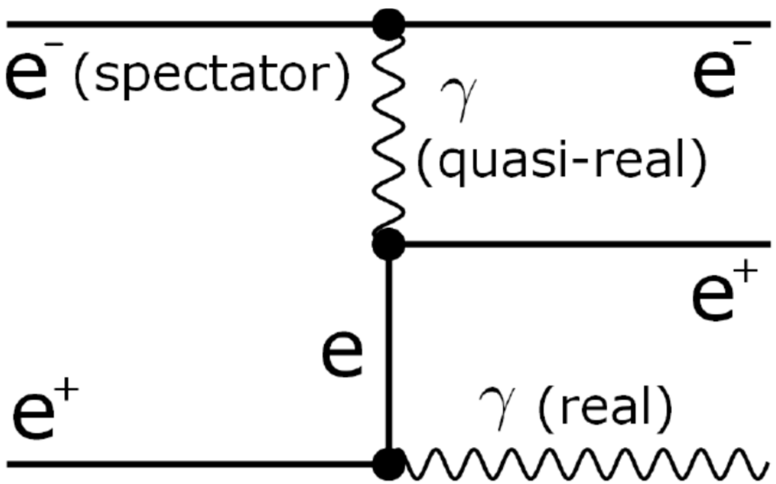
- Main source of background
- Main contribution to beam life time limitation

Radiative Bhabha and other backgrounds

	Cross section	Evt/bunch xing	Rate
Radiative Bhabha	~340 mbarn (Eγ/Ebeam > 1%)	 ~850	0.3THz
e^+e^- pair production	~7.3 mbarn 	~18	7GHz
e^+e^- pair (seen by L0 @ 1.5 cm)	~0.3 mbarn	~0.8	0.3GHz
Elastic Bhabha	O(10^{-4}) mbarn (Det. acceptance)	~250/Million	100KHz
ϒ(4S)	O(10^{-6}) mbarn	~2.5/Million	1 KHz
	Loss rate	Loss/bunch pass	Rate
Touschek (LER)	14kHz / bunch (+/- 2 m from IP)	~7/100	14 MHz

lifetime	HER τ(min)	LER τ(min)
Radiative Bhabha lifetime	4.7	7
Touschek No collimators, ε_x with IBS	26	10.2
Touschek With Collimators, ε_x with IBS	22	7

Radiative Bhabha process



e^+e^- beam part. scattering via quasi-real photon exchange at quasi-zero angle.
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- Main source of background
- Main contribution to beam life time limitation

- Large cross section (~250mbarn) proportional to luminosity ➔ used for luminosity measurement and control
- Requirement: $\Delta L/L<10^{-3}$ in 10 to 1ms

Radiative Bhabha process-simulation tools

BBbrem: MC simulation for radiative Bhabha process, performed in CM.

Input: CM energy, min energy of real photon i.e. E_{γ}> x E_{beam}, Nb of events

Output: Cross section, 4momentum of each particle (including virtual γ)

GuineaPig ++ : Beam-beam interaction simulation tools. Beam-beam effect such as beamstrahlung and beam size effect

Input: beams spec. Asked backgrounds: Compton

min energy of virtual i.e $E_{\gamma*}$>x E_0^2/E_{beam}

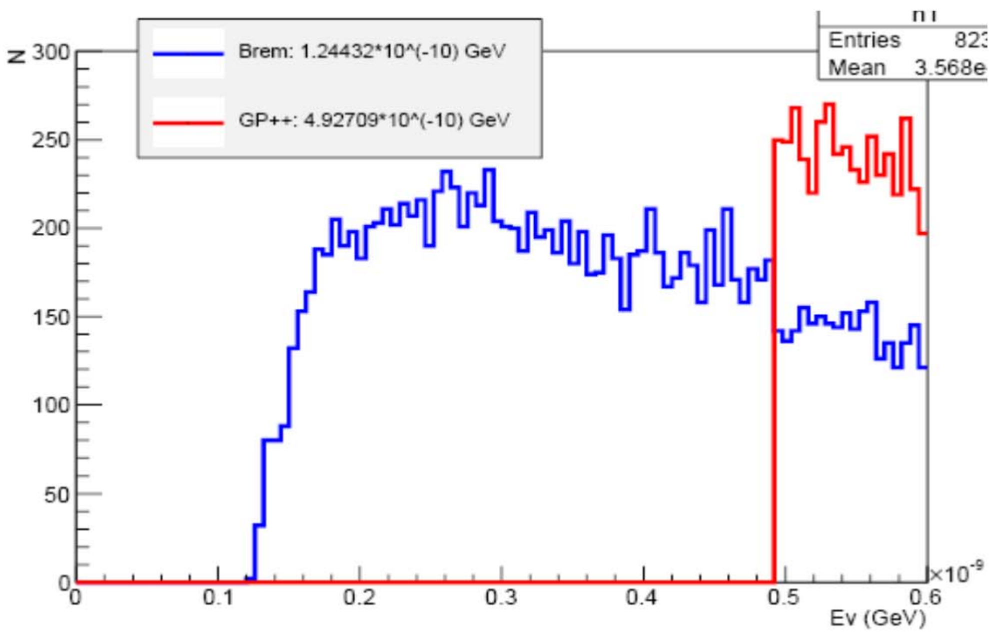
Output: Luminosity, Nb of Bhabha produced, 4momentum of final particle

BBbrem / GP++ energy cuts comparison (x_{min} = 1%)

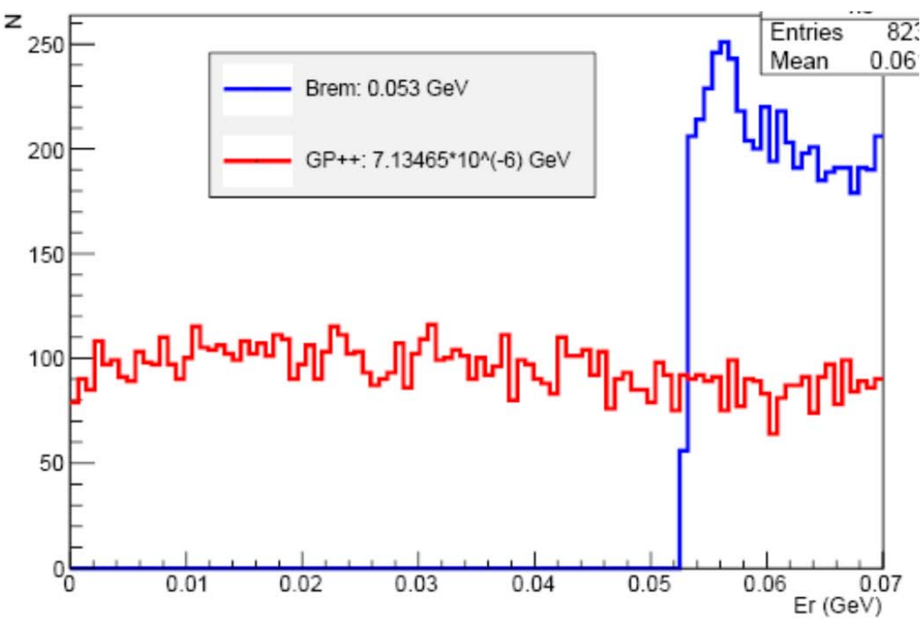
BBbrem: min energy of real photon $E_\gamma > x_{min} E_{beam}$ (0.053GeV)

GP++ : min energy of virtual $E_{\gamma*} > x_{min} E_0^2/E_{beam}$ (~5 10^{-10} GeV)

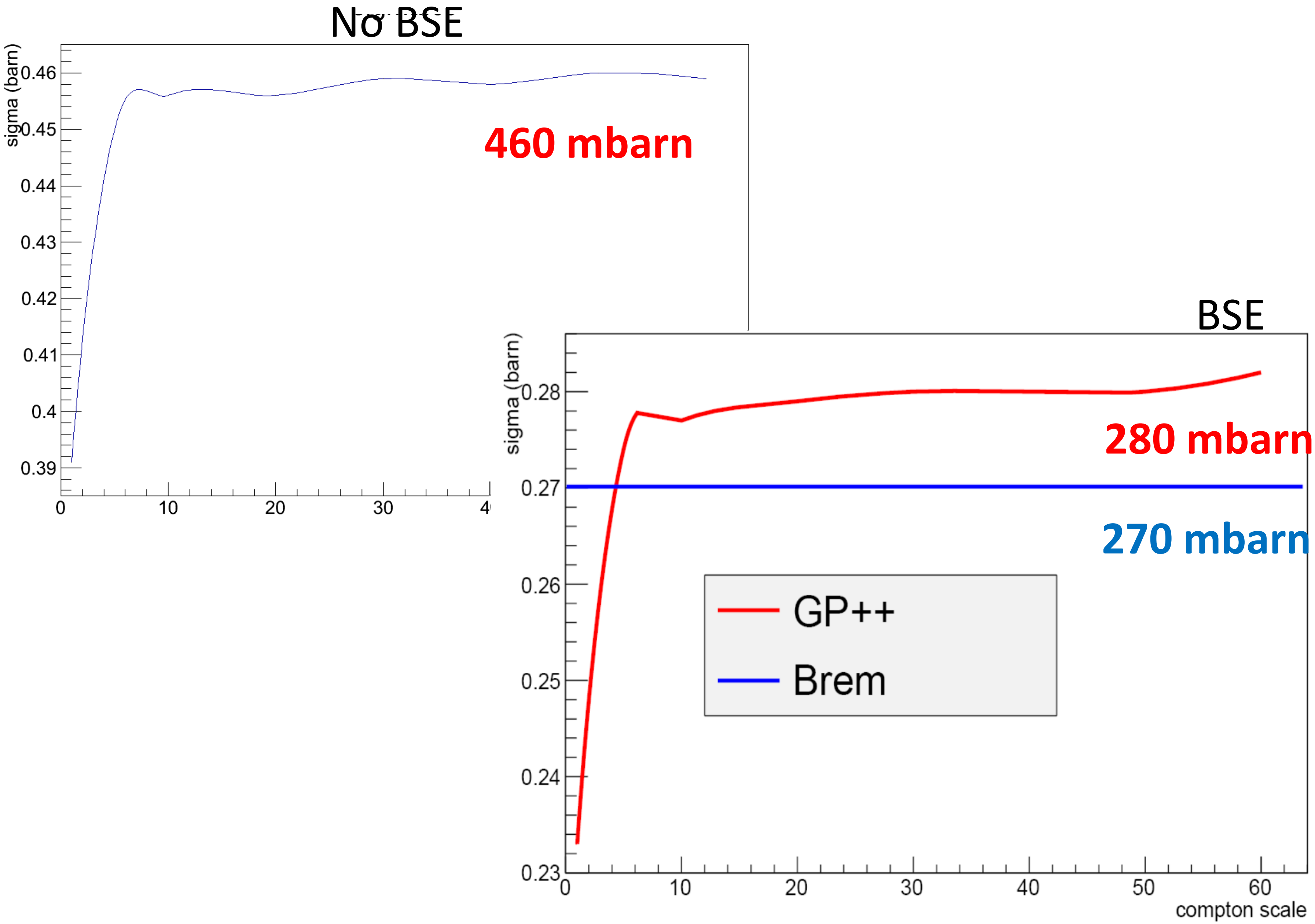
Virtual photon E_{min}



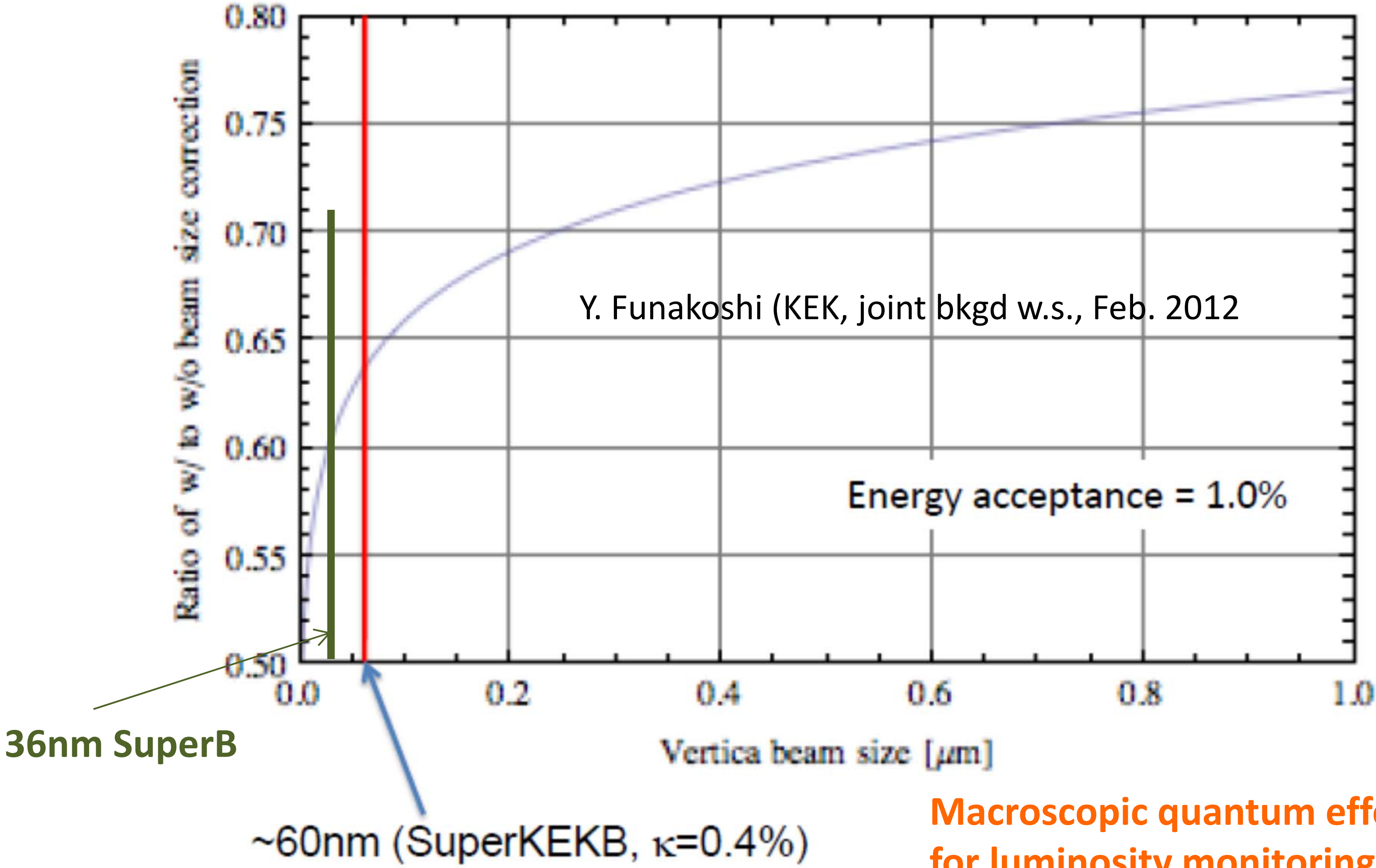
Real photon E_{min}



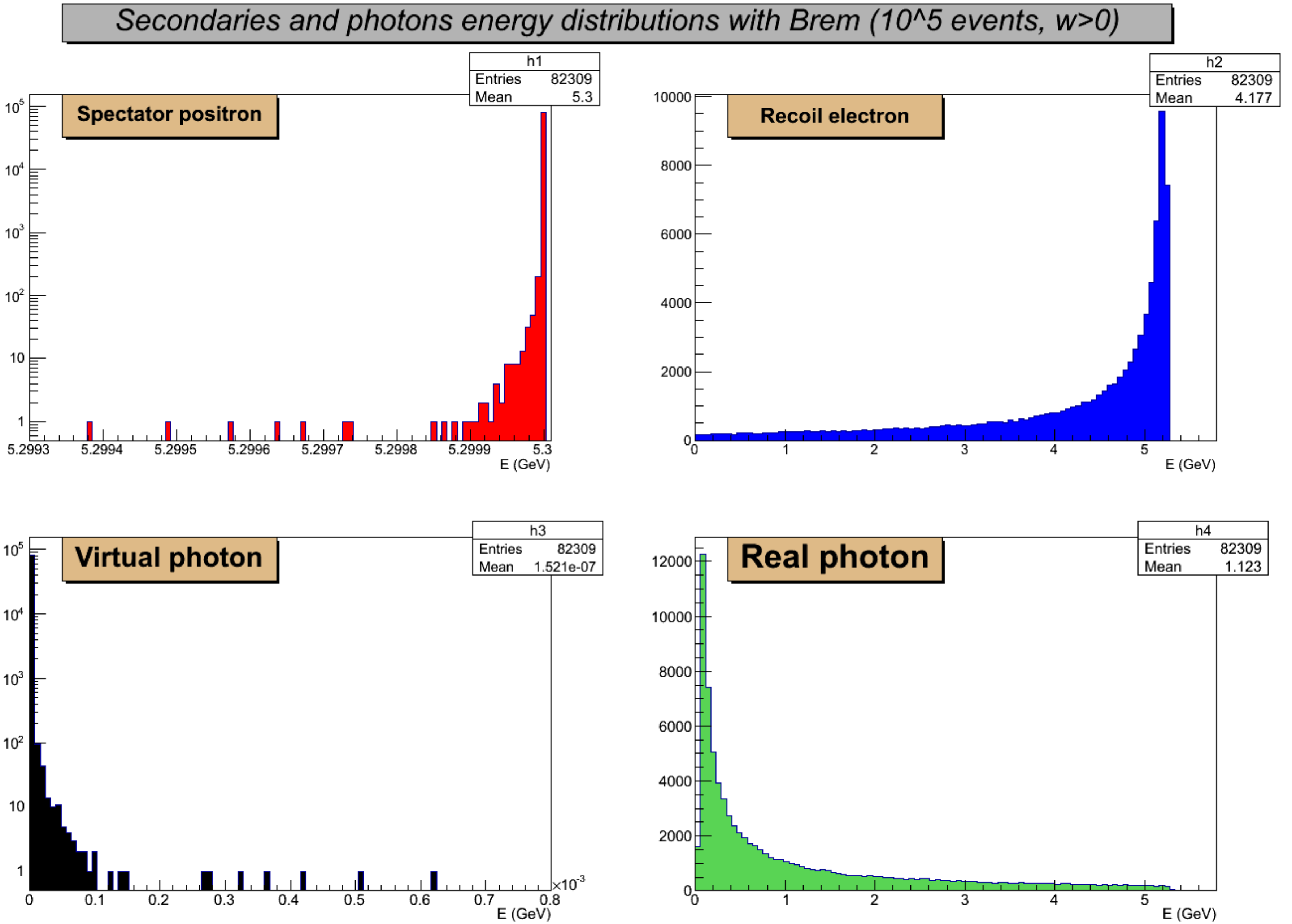
Cross section and Beam Size Effect



Correction for cross section due to finite beam size

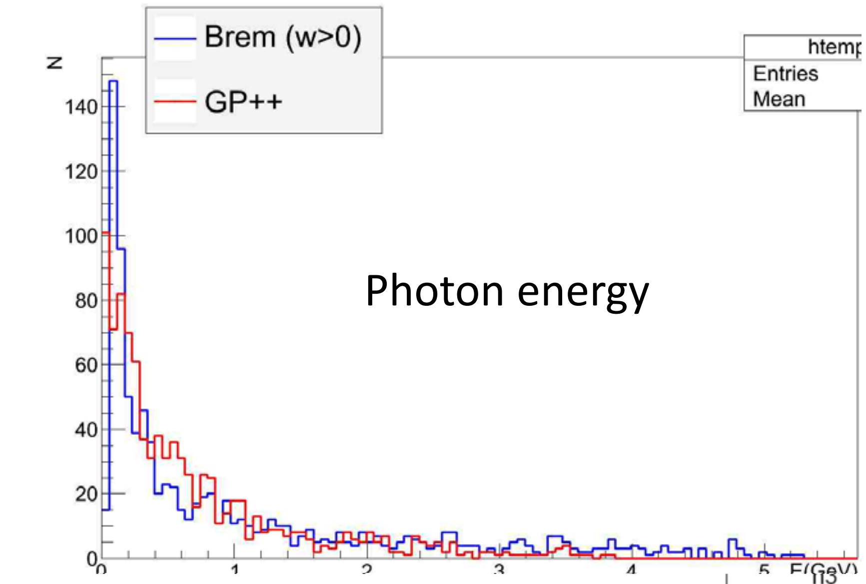


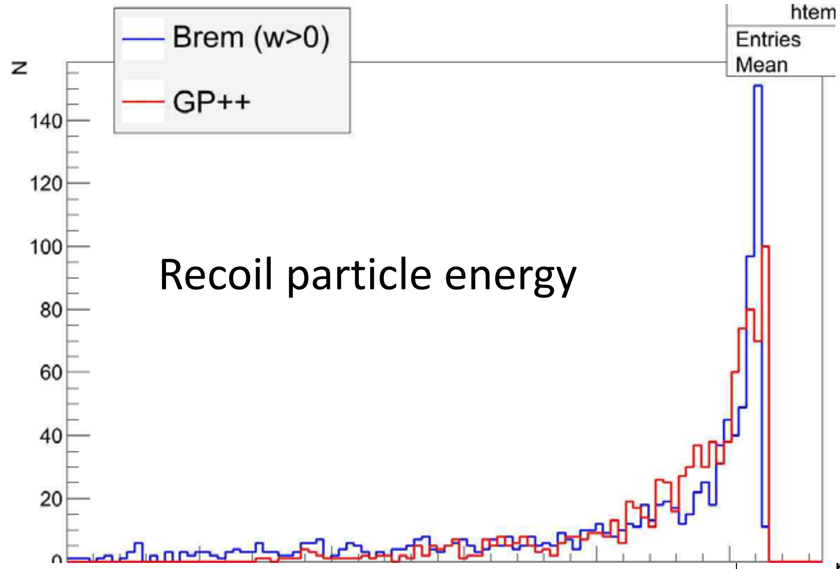
Macroscopic quantum effect… issue for luminosity monitoring ?

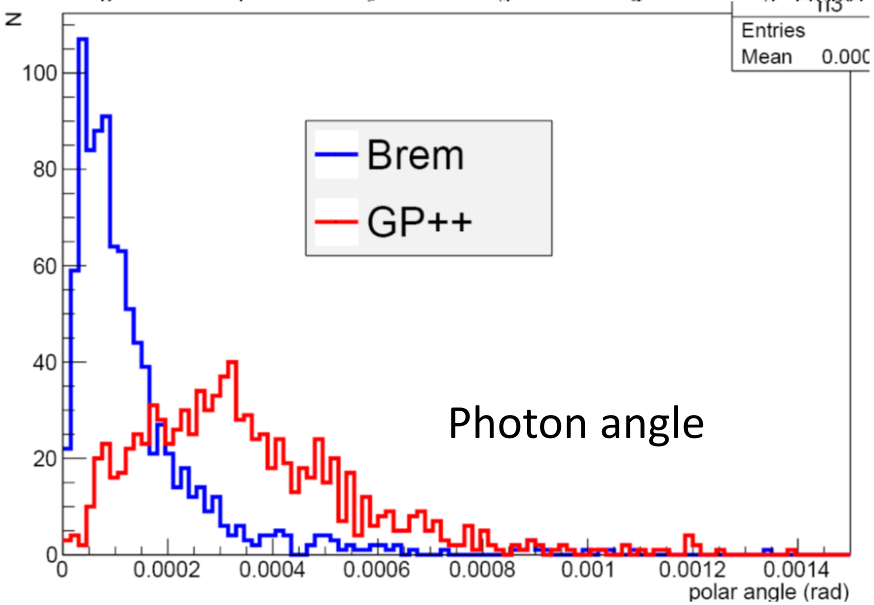


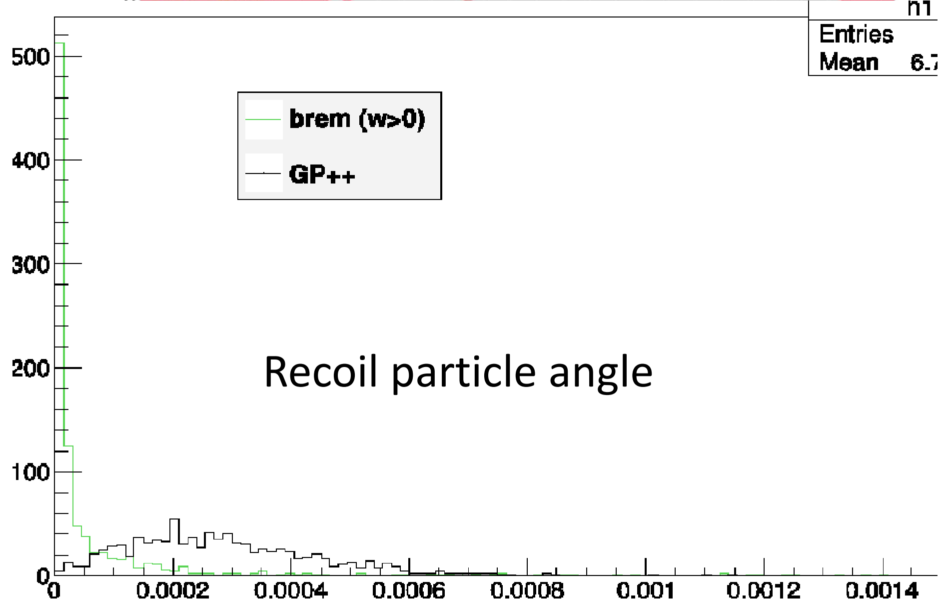
F. Blampuy (LAL)

Comparison of the energy and angular distributions



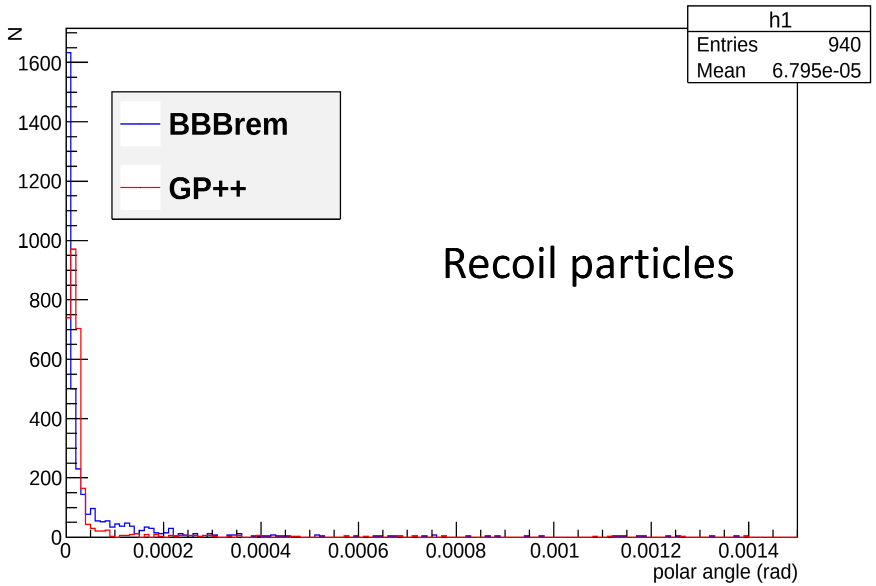


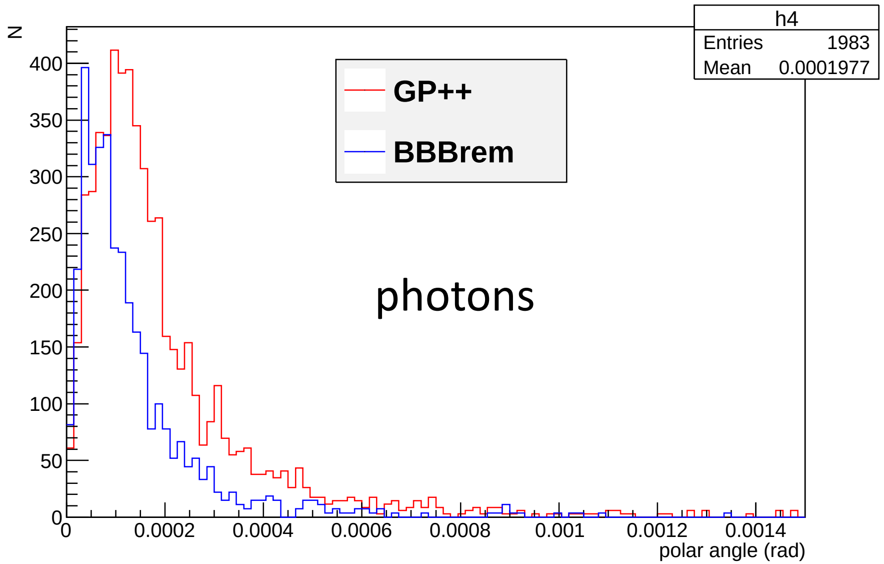


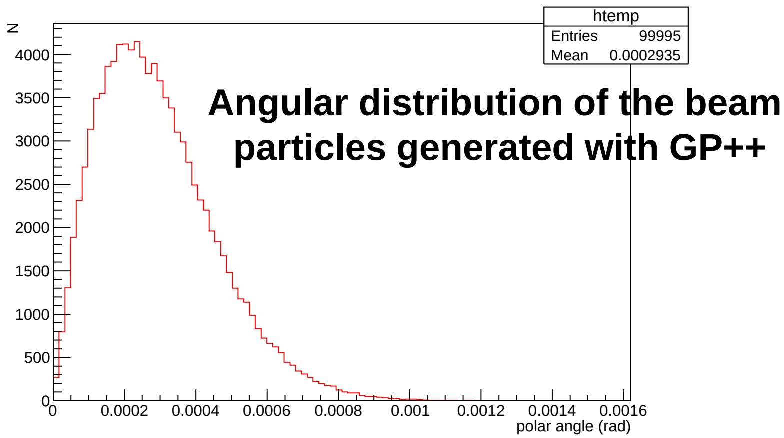


σ_x^{beam} ~ 0.3 mrad

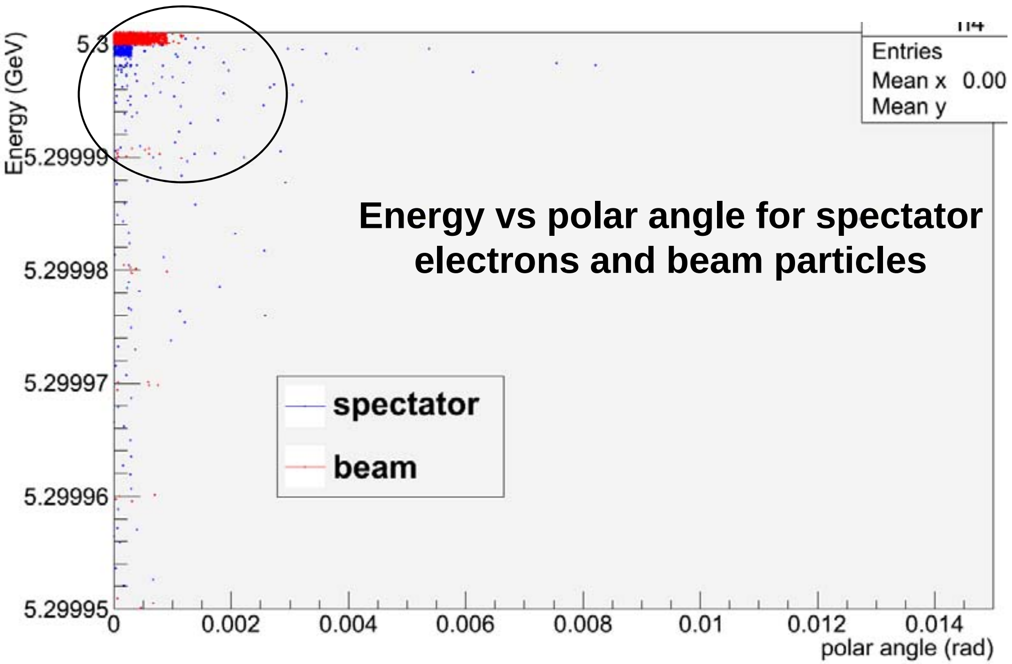
Comparison of the angular distributions without beam angular divergence

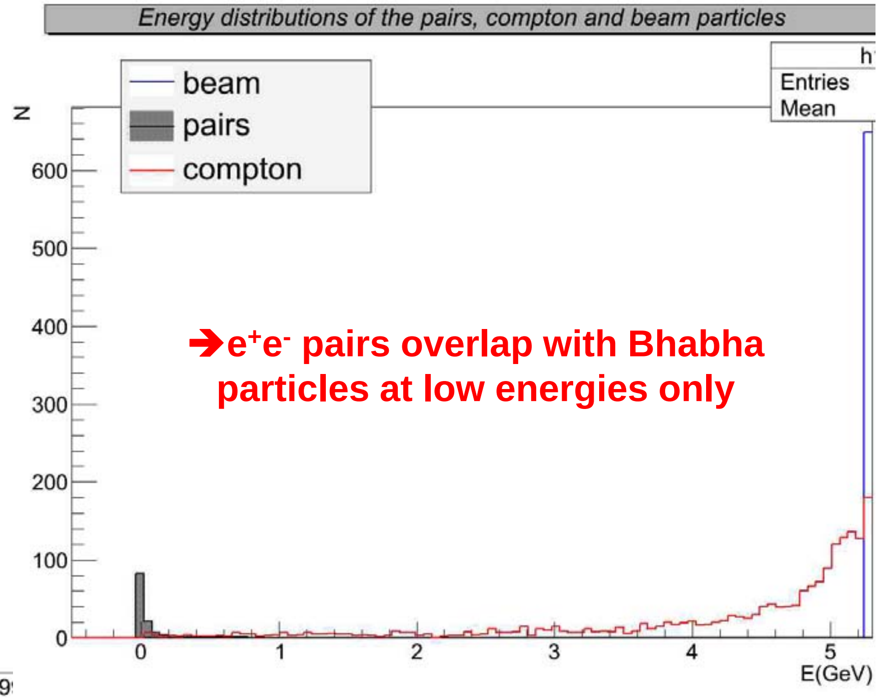


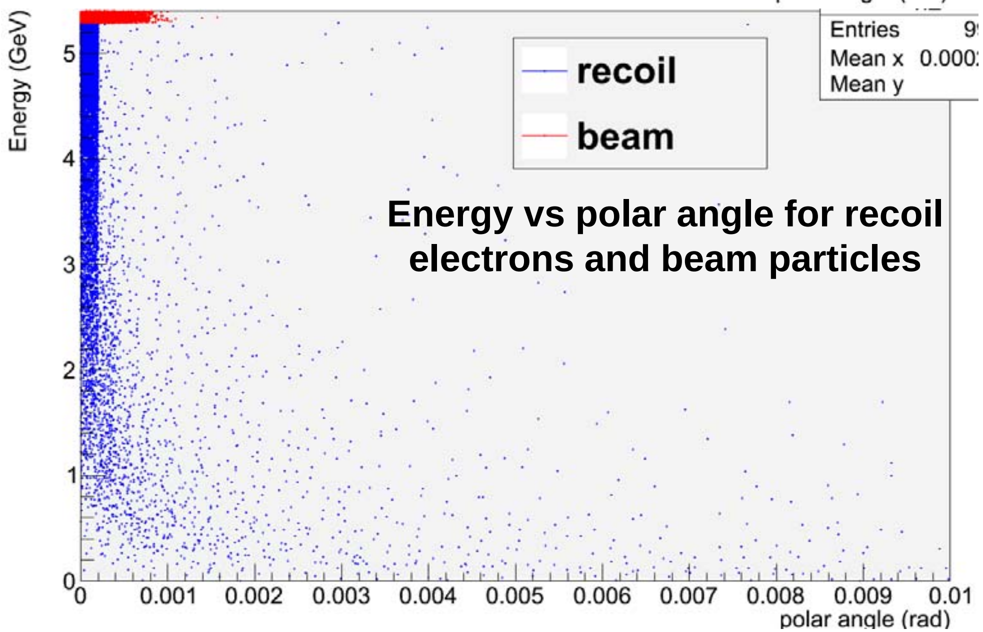




Delimitation of the useful phase space for luminosity measurements

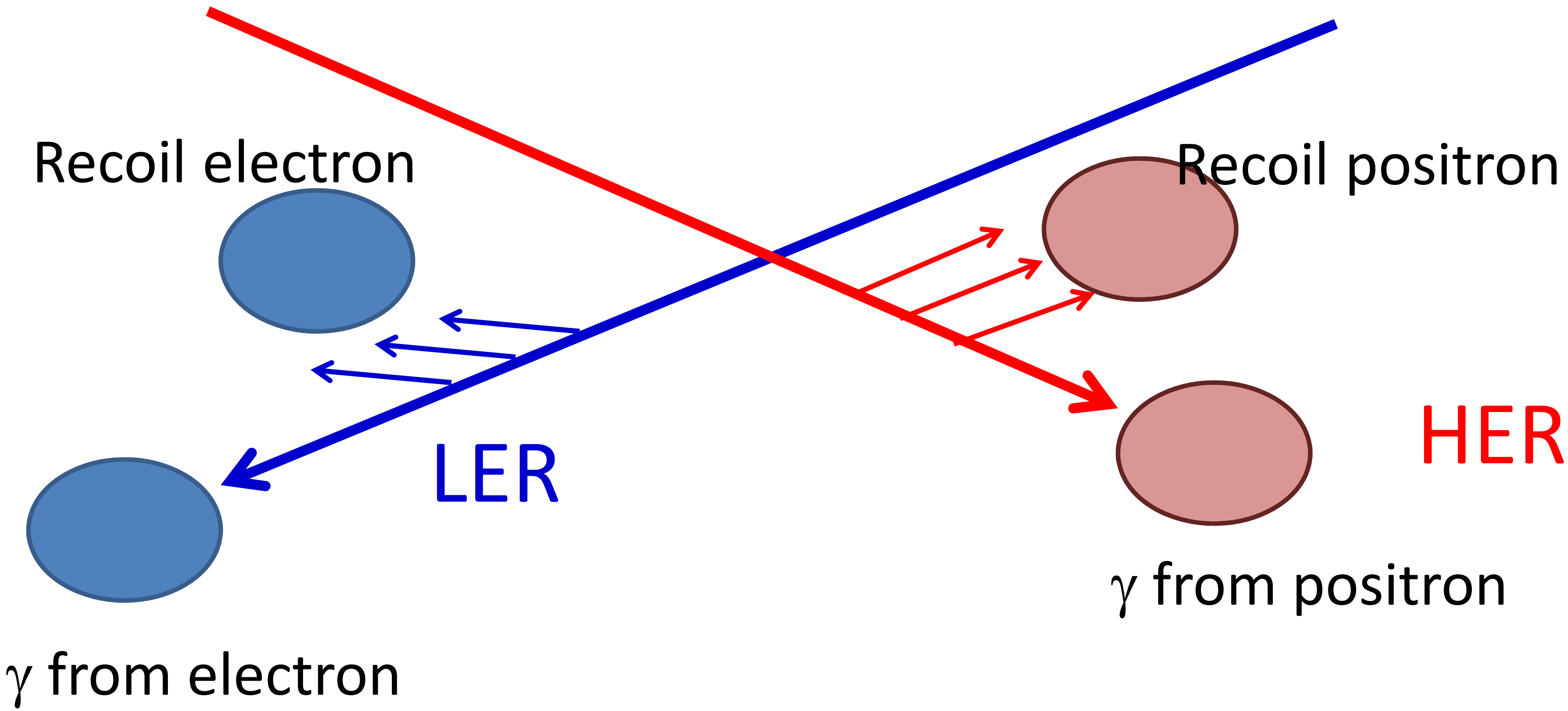






➔ **Recoil electrons: large energy spectrum**

Where are the signals?



Specifications and rates

1. average luminosity
2. bunch by bunch luminosity

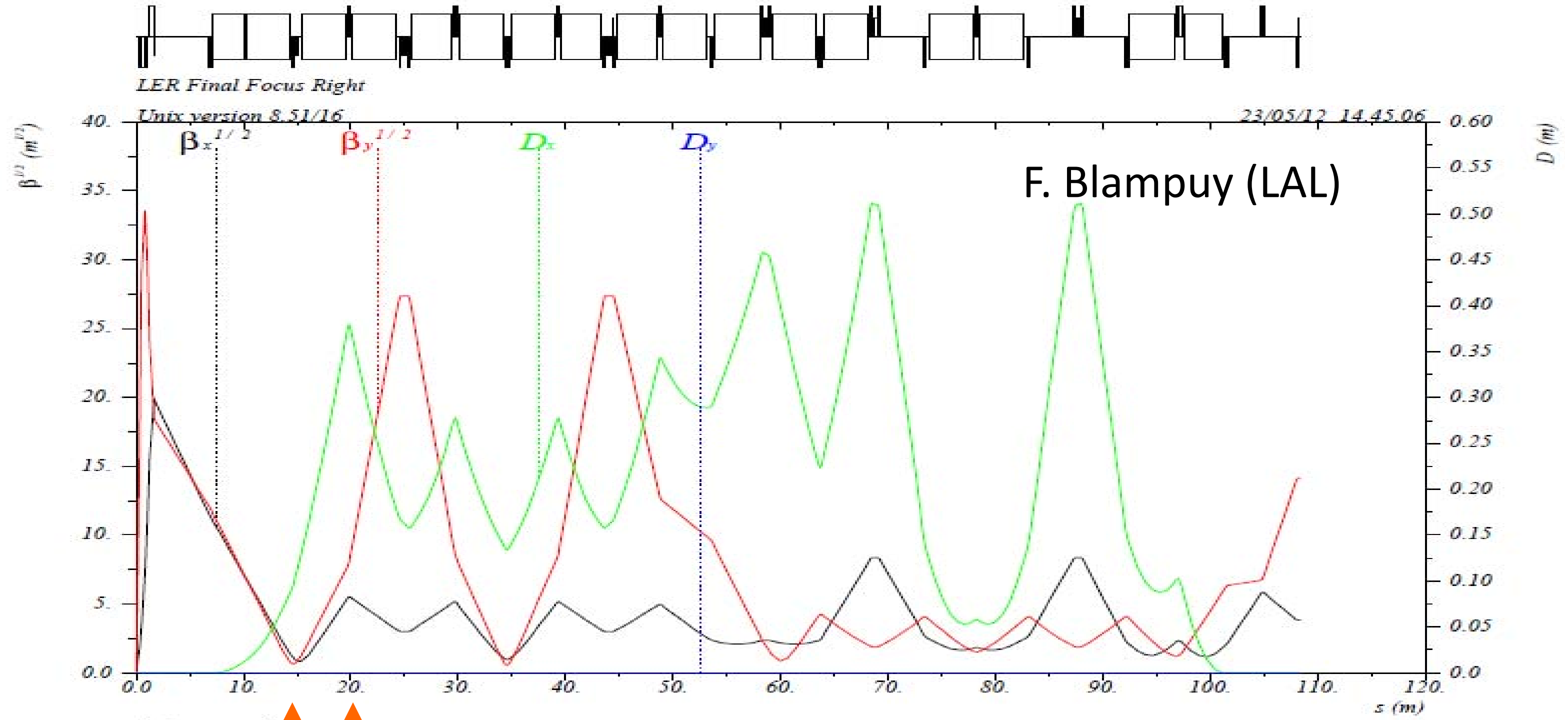
Ground motion analysis and experience from Belle & PEP-II

Relative accuracy $<10^{-3}$ at 0.1-1 kHz   Detected particles $>10^{6}$ at 0.1-1 kHz

$L \sim 10^{36}\ cm^{-2}s^{-1}$ $\sigma \sim 270$ mbarn ($E\gamma > 1\%$ Ebeam)

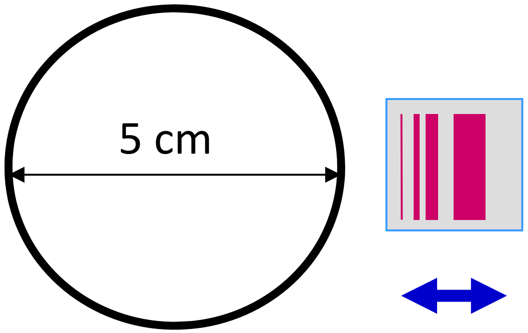
➔ expected total rate ~ $270\ 10^{6}$ / 0.001 s

- Must also work for lower initial luminosities: 10^{2-4} dynamic range
- Non luminosity scaling contamination (e.g. from Touschek and beam gas Coulomb losses) < 1%



2 first candidate locations in SuperB LER

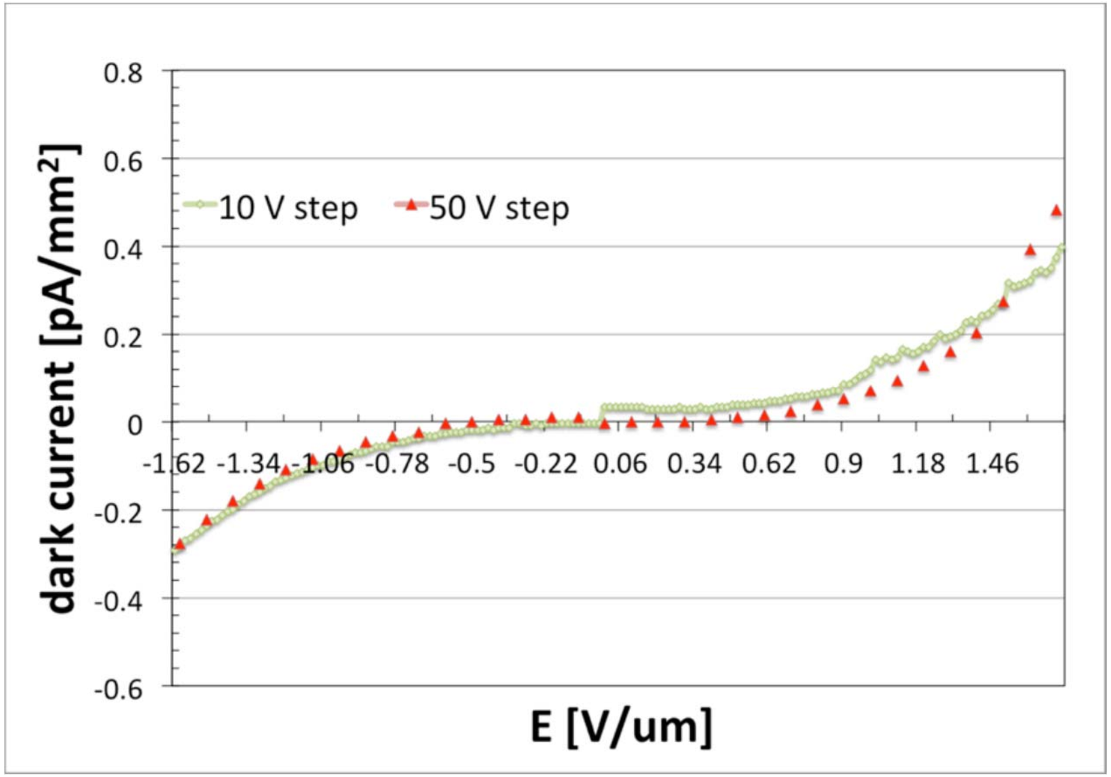
Estimated counting rate in 5 × 5 mm^2 **sensor** placed ~2.5 cm from beam ~ 10^7 / 0.001 s



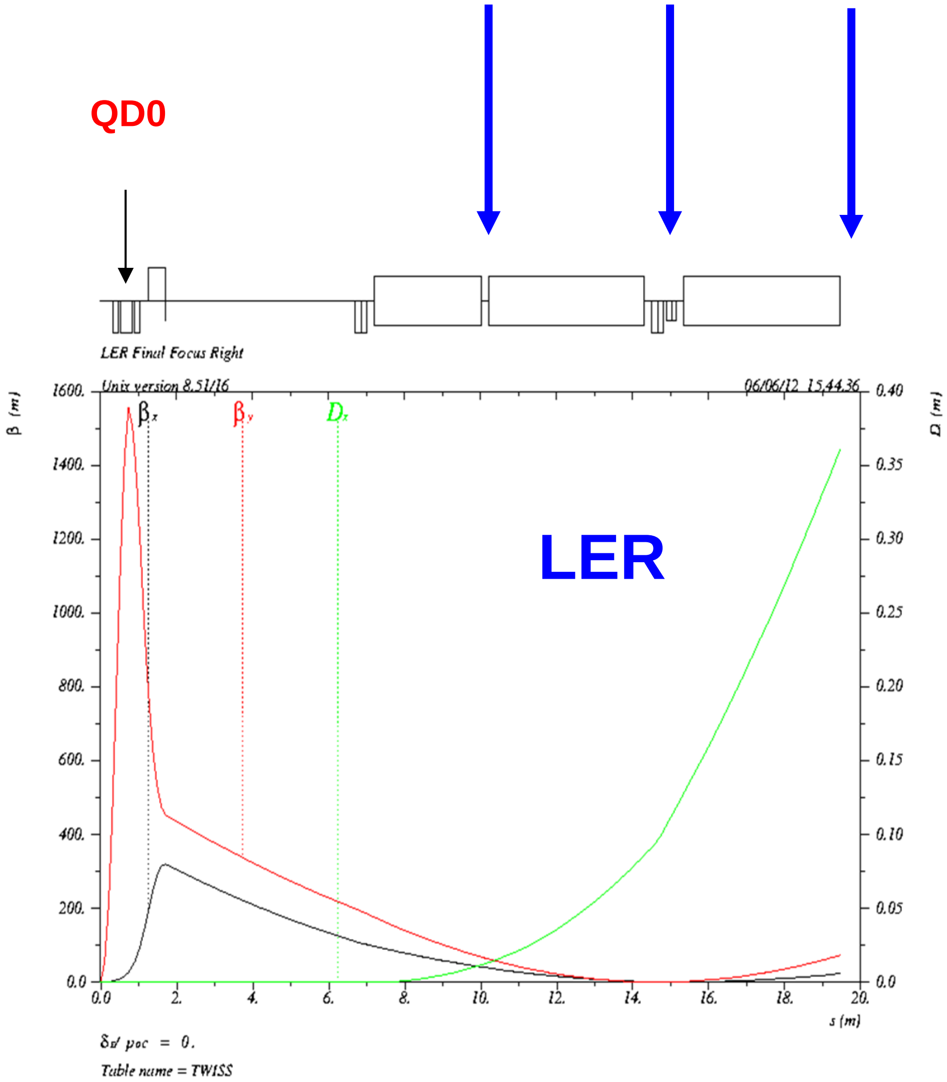
sCVD diamond radiation resistant (up to ~ 10 MGy)

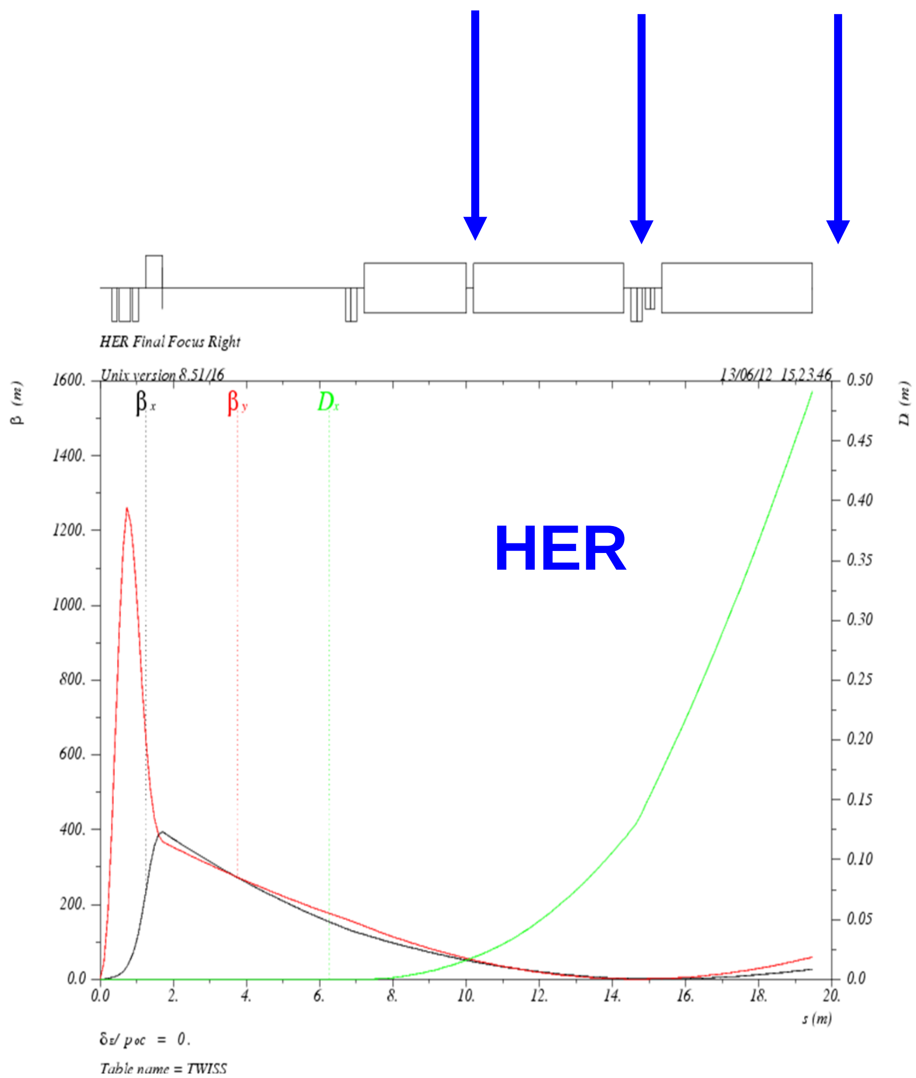
Tracking in FF of SuperB with MAD8 simulation

Diamond sensors studies started at LAL in context of ATF2

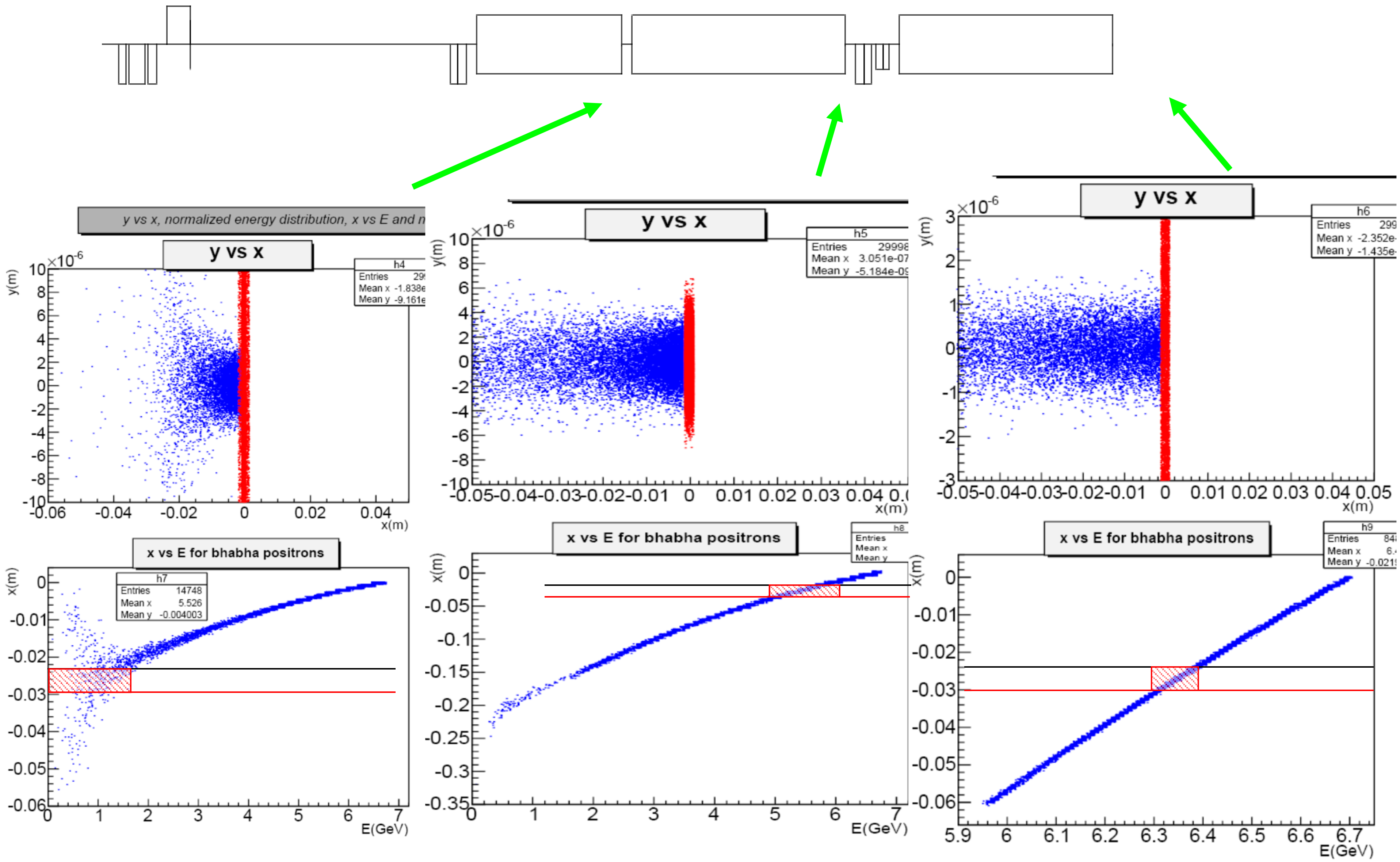


Best locations to maximise Bhabha / Touschek & beam gas rates





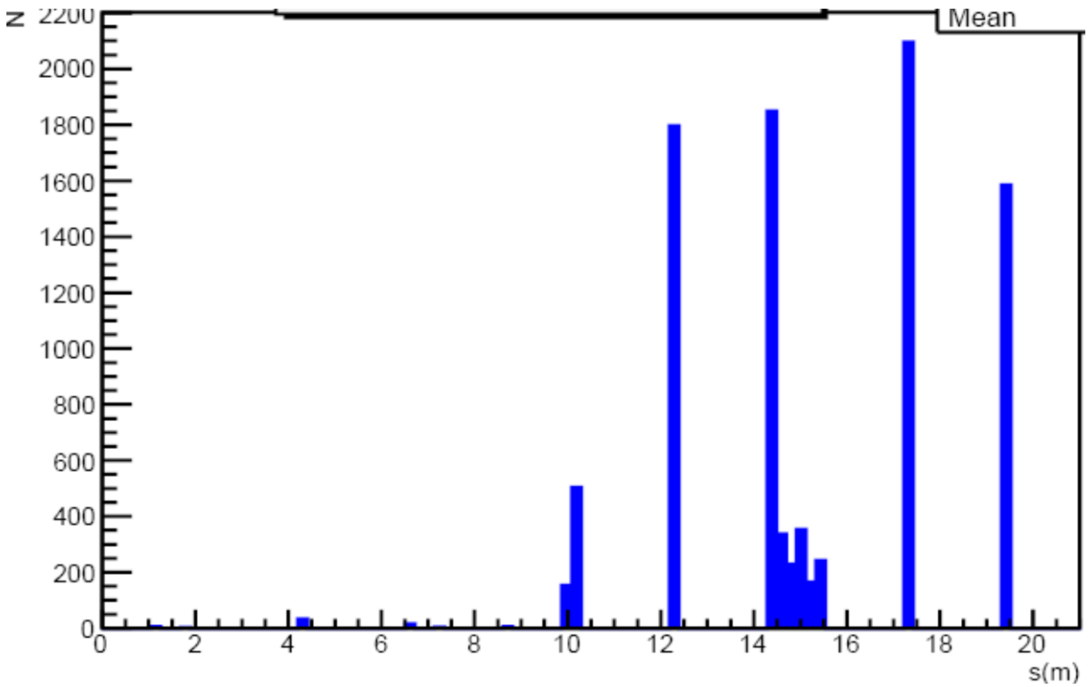
Distribution of scattered Bhabha positron

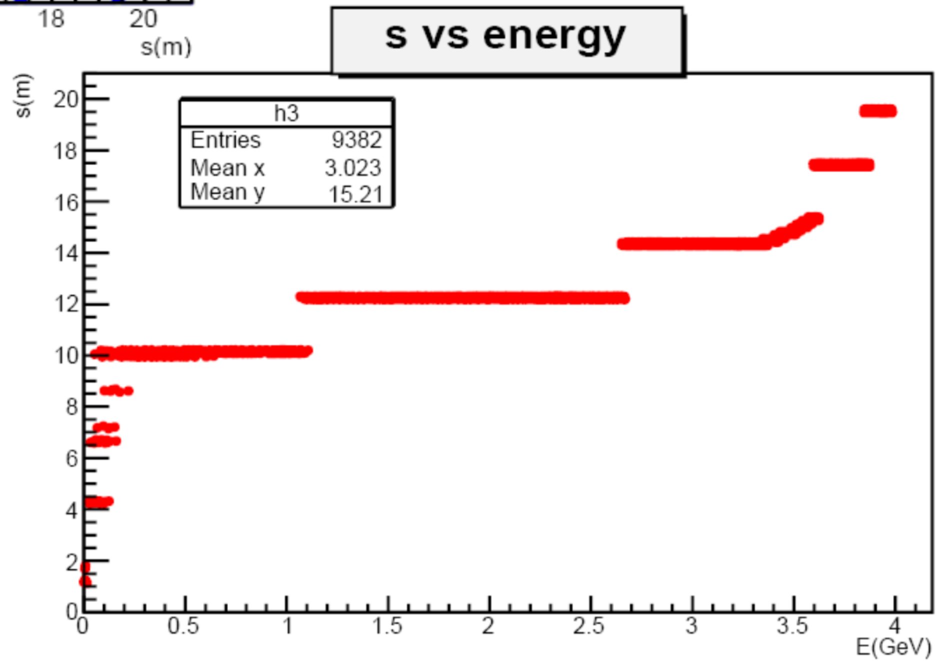


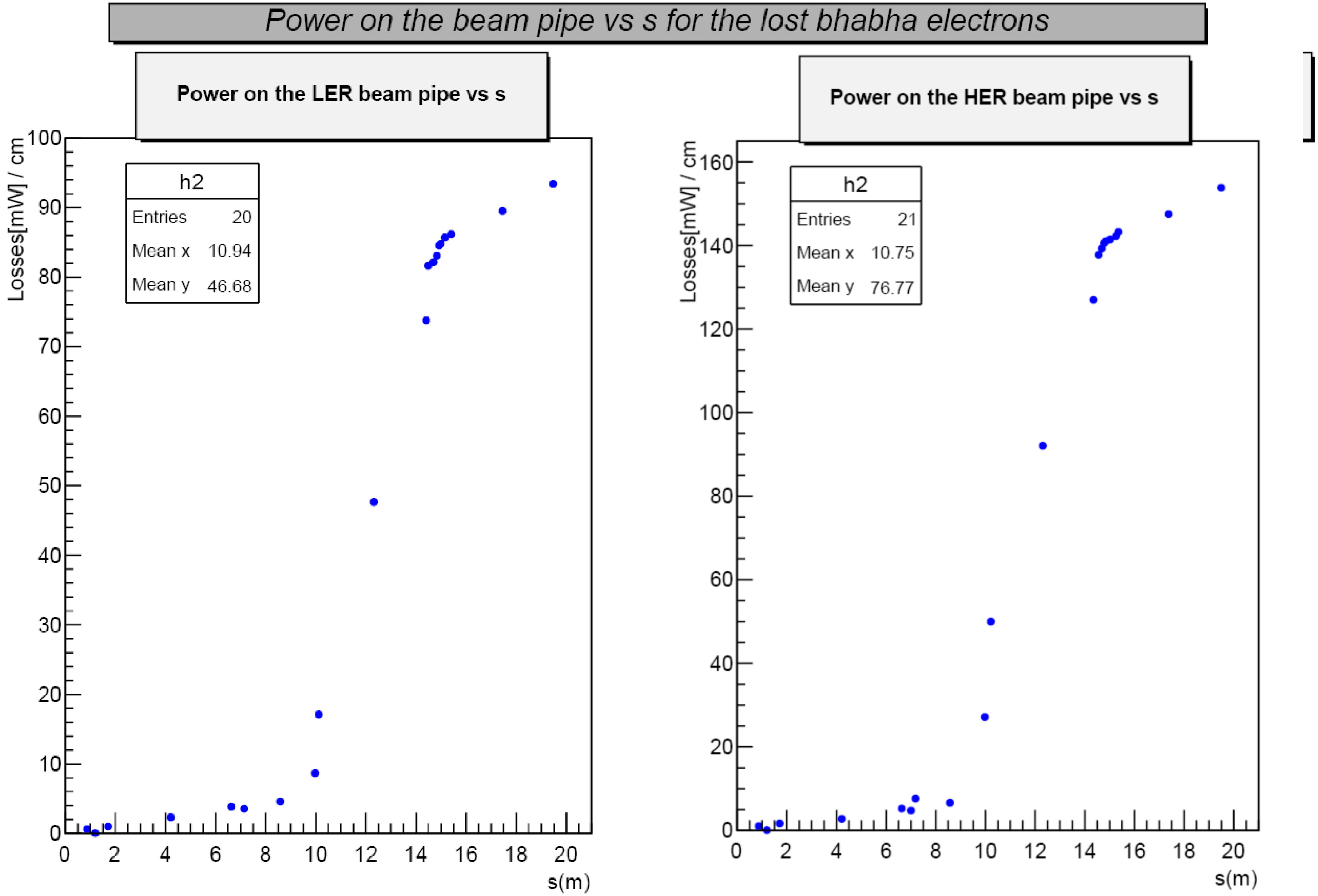
Estimation of the fraction of Bhabha particles generated with GP++ in the sensor acceptance

	With apertures in MAD8 (5X5mm diamond sensor)	With apertures in MAD8 (horizontal length of 10mm)
1‰ specification at L_{nom} ($10^6/N_{Bhabha}$ produced)	3.10^{-3}	
1‰ specification at $L_{nom}/10^2$	3.10^{-1}	
1% specification at $L_{nom}/10^2$ ($10^4/N_{Bhabha}$ produced)	3.10^{-3}	
LER: $N_{Bhabha\ detected}$ / 15188 after the 1st bend	$1{,}98.10^{-3}$	$2{,}90.10^{-3}$
LER: $N_{Bhabha\ detected}$ / 15188 after the 2nd bend	$2{,}87.10^{-2}$	$5{,}33.10^{-2}$
LER: $N_{Bhabha\ detected}$ / 15188 after the 3rd bend	$4{,}56.10^{-2}$	$5{,}16.10^{-2}$
HER: $N_{Bhabha\ detected}$ / 14911 after the 1st bend	$9{,}99.10^{-3}$	$1{,}23.10^{-2}$
HER: $N_{Bhabha\ detected}$ / 14911 after the 2nd bend	$3{,}41.10^{-2}$	$6{,}18.10^{-2}$
HER: $N_{Bhabha\ detected}$ / 14911 after the 3rd bend	$4{,}40.10^{-2}$	$4{,}97.10^{-2}$

Bhabha electron loss distribution in 20m after IP







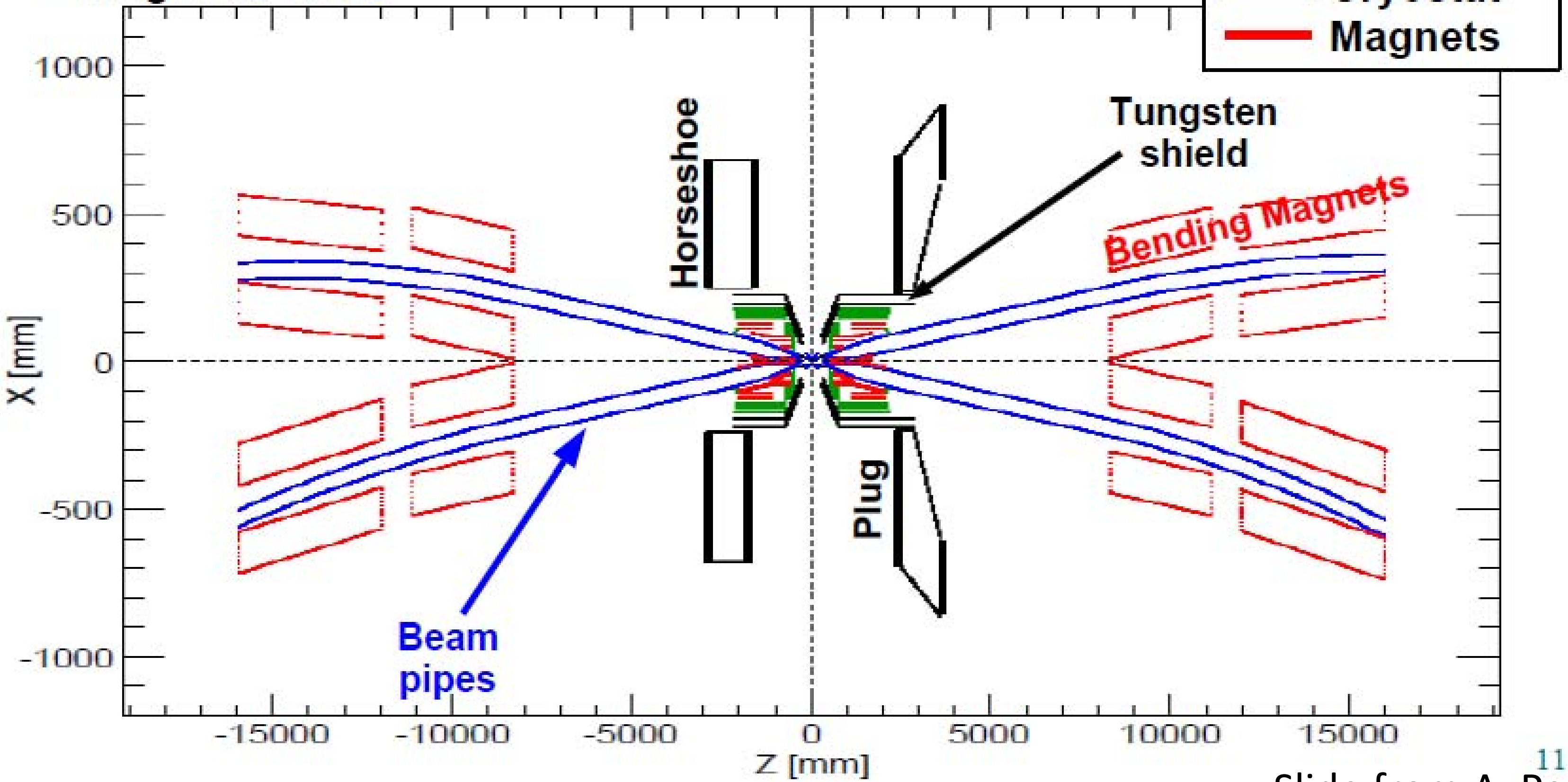
Power on the beam pipe vs s for the lost bhabha electrons
Power on the LER beam pipe vs s
h2
Entries 20
Mean x 10.94
Mean y 46.68
Losses[mW] / cm
s(m)
Power on the HER beam pipe vs s
h2
Entries 21
Mean x 10.75
Mean y 76.77
Losses[mW] / cm
s(m)

Short term SuperB plan

- Implement sensor in GEANT4 “IR +/- 21 m” for scattered electron/positron (on-going) (need extension of FF modelisation in Bruno)

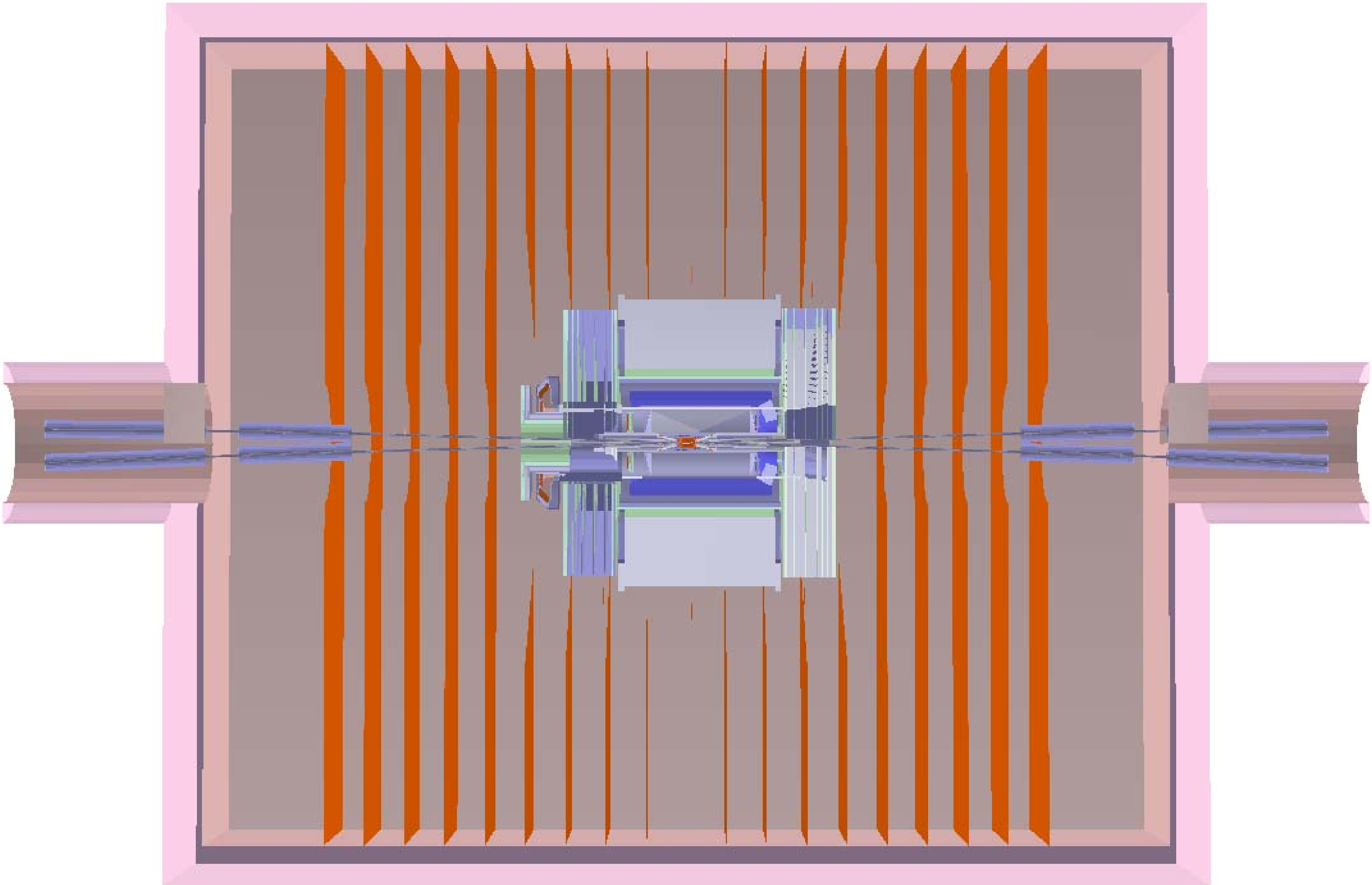
Final Focus (FF) Geometrical Model

- **Detailed Geant4 (Bruno) model of the FF from -16 to 16 mts from IP**
  - Beam pipes
  - Super-conducting magnets and cryostat
  - Stoppers: tungsten/Lead shield near by IP
  - Magnetic fields



Slide from A. Perez

Bruno modelisation of the FF from -16 to 16 m from IP



Slide from S. Tammaro

Short term plan

- Implement sensor in GEANT4 “IR +/- 21 m” for scattered electron/positron (on-going) (need extension of FF modelisation in Bruno)
- Optimize vacuum chamber geometry (impedance constraint)
- Input to optics lattice and magnet design
- Touschek and beam gas rates at sensor location to limit non-luminosity scaling (started)
- Radiation estimation
- Design sensor & readout prototype for DAPHNE test

Longer term

- Further study of scattered photon detection
- Radiation hardness investigation
- Bunch by bunch luminosities (specification, requirements,…)
- Feedback methods (dither method, calibration,…)
- Beam size effect

Thank you