Beam-Beam interaction SIMulation: GUINEA-PIG

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Beam-Beam interaction SIMulation : GUINEA-PIG

1. Introduction: BBSIM tasks overview

2. Incoherent e^+e^- pair background study

- **BBSIMs predictions: GUINEA-PIG Vs CAIN**
- **Impact of beam parameter sets on microVertex Detector background**

3. In progress: Bhabhas in GUINEA-PIG

Beam-Beam SIMulation

- **When beams collide:**
  - Energy loss in the form of synchrotron radiation: beamstrahlung
  - Secondary backgrounds
    - Electromagnetic : $e^+ + e^- \rightarrow \gamma\gamma \rightarrow e^+e^-$ …
    - Hadronic : $e^+ + e^- \rightarrow \gamma\gamma \rightarrow$ hadrons
  - Electromagnetic deflections
    - effect on backgrounds (pairs ...)
    - effect on luminosity measurements ? (Bhabha scattering)
  - $e^+ e^-$ spin depolarisation effects

- **GUINEA-PIG check-up & benchmarking**
  - Comparison with simulation codes
    - General Beam-Beam interactions: CAIN
    - Dedicated codes: BDK, BHLUMI ...
  - Improvement, adding new options/ phenomena
  - Management (Web doc, version updating...)

Incoherent Pair Creation Processes

1. Breit-Wheeler : $\gamma\gamma \rightarrow e^+e^-$ ← *x-section exact calculation*
2. Bethe-Heitler : $\gamma e^\pm \rightarrow e^\pm e^+e^-$
3. Landau-Lifshitz : $e^+e^- \rightarrow e^+e^- e^+e^-$

← **Weizäcker-Williams approximation**

Equivalent photon spectrum, associated to a virtuality parameter, Q

Simulation inputs

GuineaPig & ***Cain*** : **Tracking[1], Beam Size Effect[2] , $Q^2_{max} = s/4$, m_e^2**

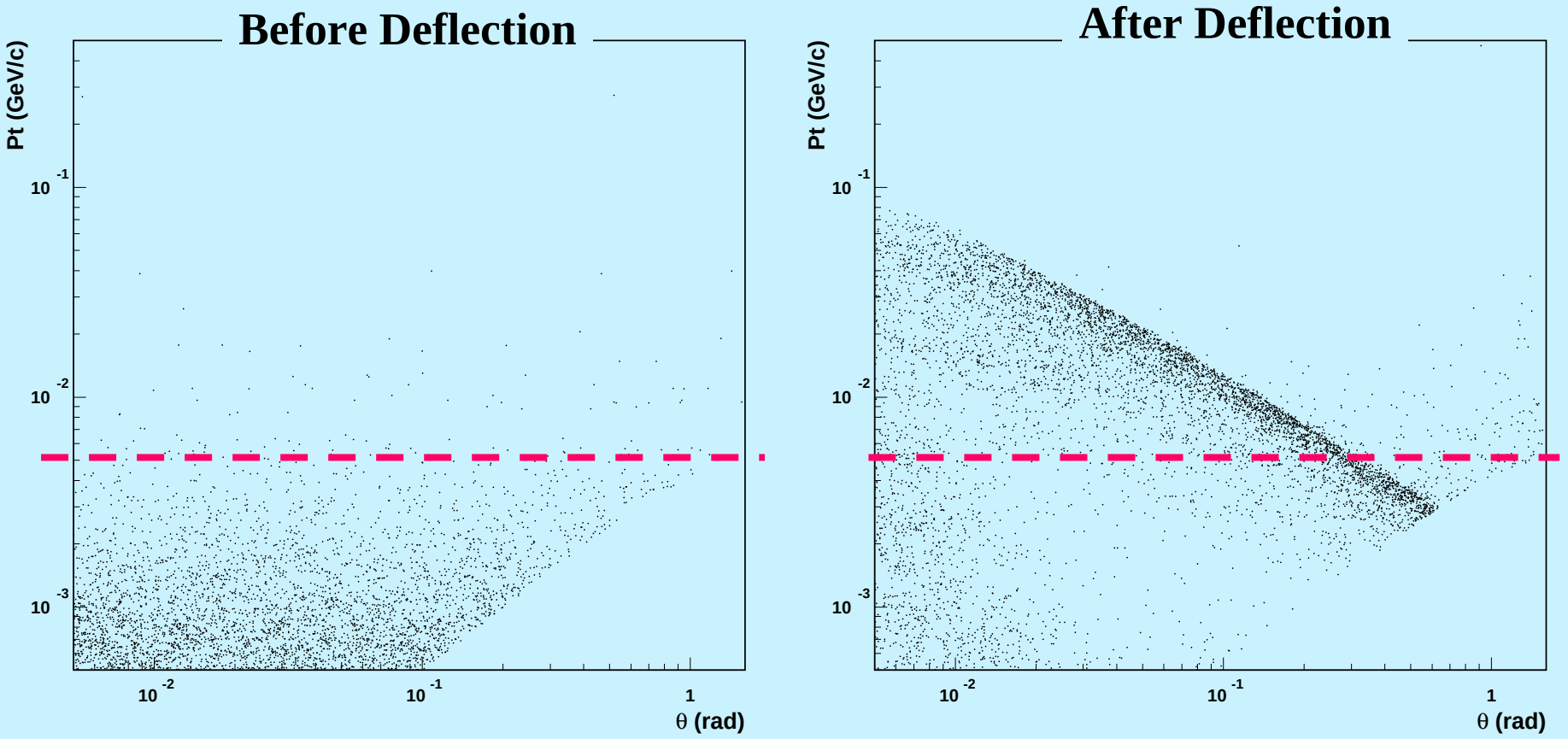
BDK: **$e^+e^- \rightarrow e^+e^-e^+e^-$, $s_{min} = 4m_e^2$ used as a reference for the LL process**

E_{min}= 5 MeV ; Beam parameter set: USSC 500 GeV ; VD: r_1=15mm, B=4T (LDC)

[1]***Tracking*** *: Deflection of low energy pairs due to the field of the opposite beam.*
[2]***Beam Size Effect****: Reduction of cross section due to the position uncertainty for the virtual photons with low Pt.*

Deflection of the pairs Pt vs θ

GuineaPig

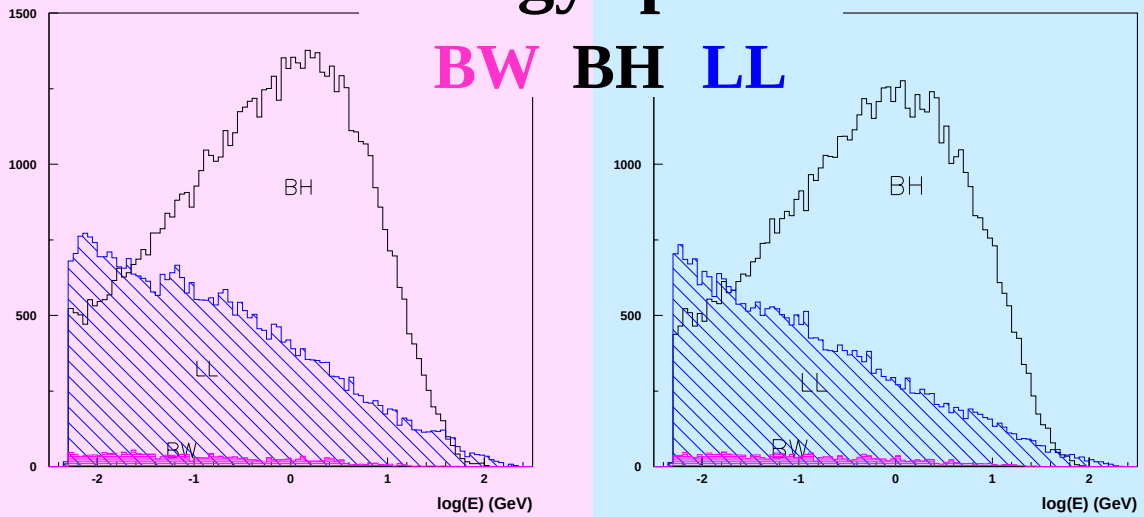


Pt > 5 MeV/c mostly due to electromagnetic deflections

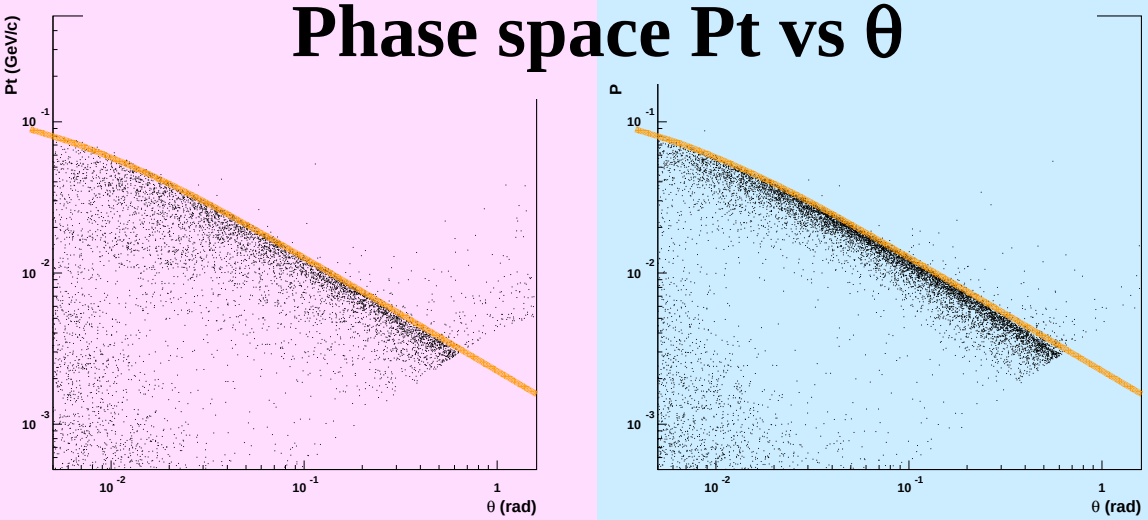
GuineaPig / CAIN

Energy spectra

BW BH LL

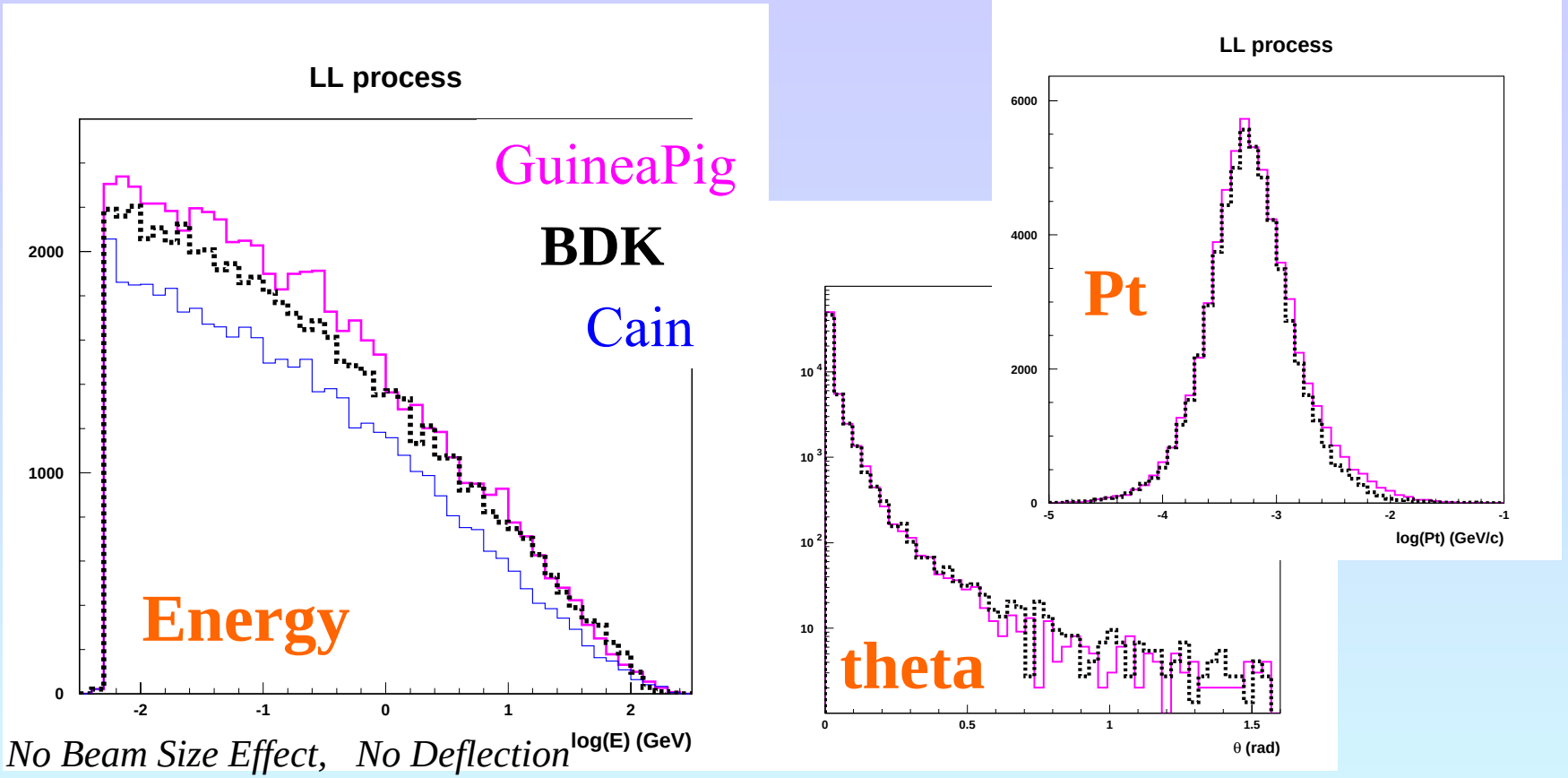


Phase space Pt vs θ



Qualitative agreement between Guinea-Pig and CAIN

Landau-Lifshitz : Comparison with BDK



No Beam Size Effect, No Deflection

Very good agreement for Guinea-Pig and BDK

$e^+ + e^-$ production (effective) cross sections E > 5 MeV

σ (mb)	**Guinea-Pig** $Q^2_{max}=s/4$	**CAIN** $Q^2_{max}=m_e^2$	**BDK**	(GP-CAIN)/GP
All IPC particles	**101**	**89.5**	**-**	**0.12**
Breit-Wheeler	**1.01**	**1.11**	**-**	**0.01**
Bethe-Heitler	**66.3**	**61.7**	**-**	**0.07**
Landau-Lifshitz	**33.9**	**26.7**	**31.8** -	**0.21**

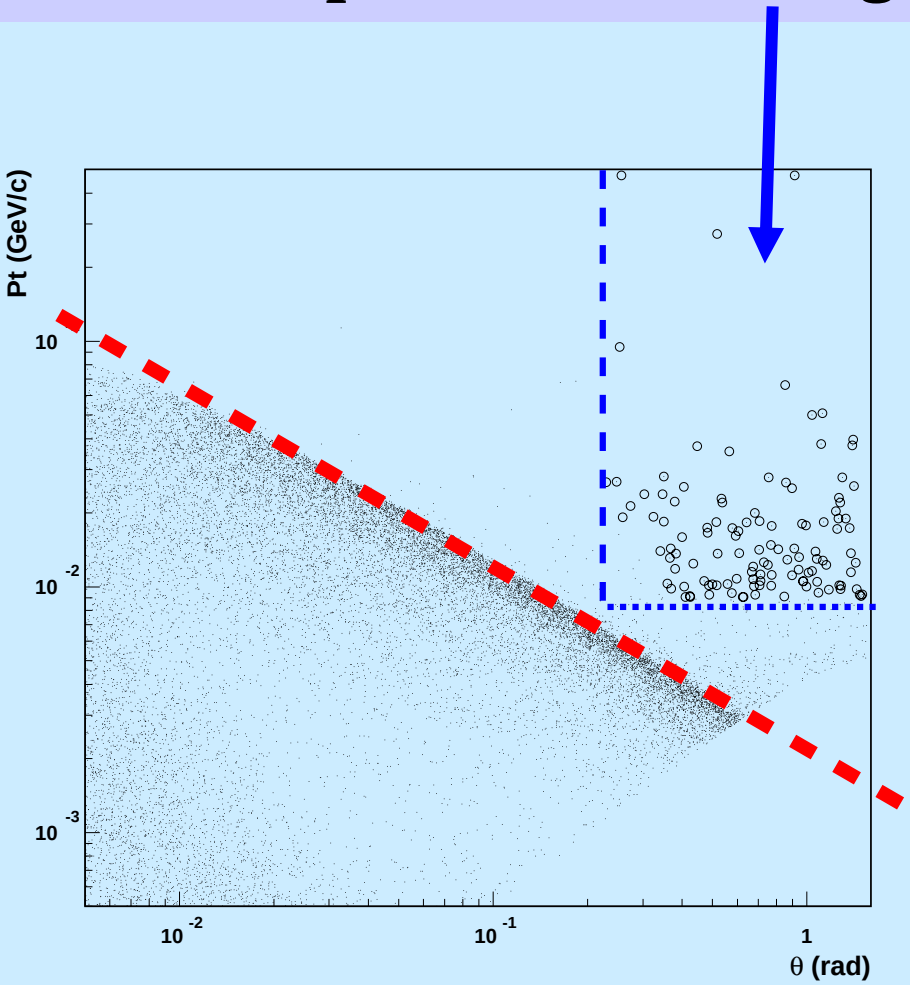
without Beam Size Effect

$e^+ + e^-$ production (effective) cross sections E > 5 MeV

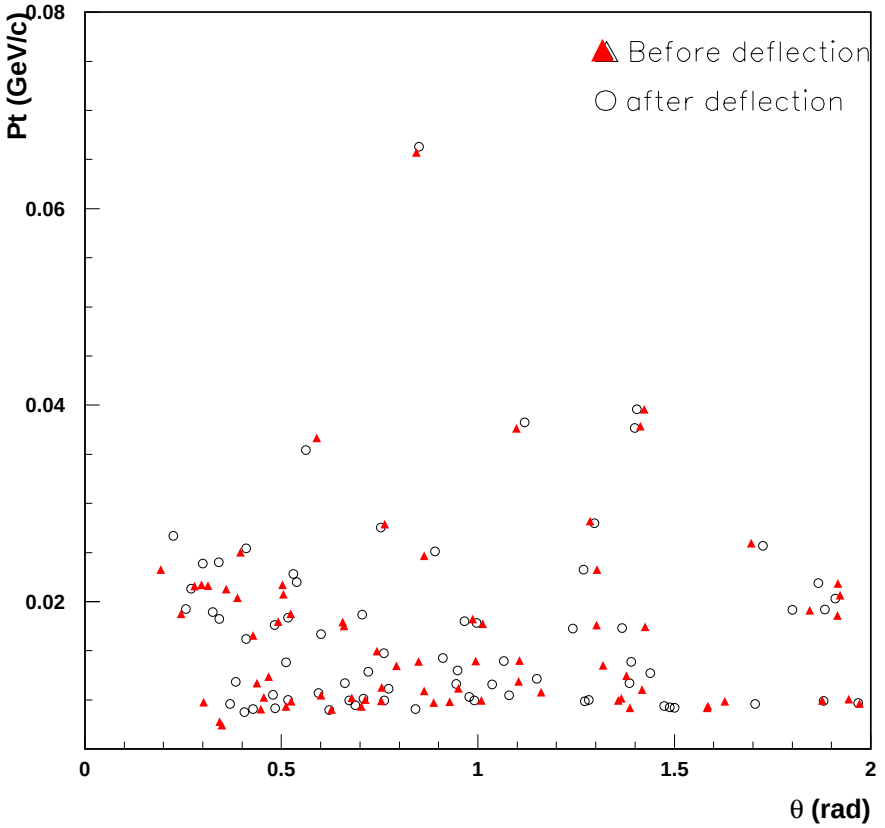
σ (mb)	Guinea-Pig $Q^2_{max}=s/4$	CAIN $Q^2_{max}=m_e^2$	BDK	(GP-CAIN)/GP
All IPC particles	**101** ***58.0***	**89.5** ***50.7***	-	**0.12**
Breit-Wheeler	**1.01** ***1.05***	**1.11** ***1.04***	-	**0.01**
Bethe-Heitler	**66.3** ***37.7***	**61.7** ***34.5***	-	**0.07**
Landau-Lifshitz	**33.9** ***19.2***	**26.7** ***15.2***	**31.8** -	**0.21**

without & *with* Beam Size Effect

IPC particles reaching the VD (LDC) Pt vs θ



Comparison Deflection / No Deflection



Pt > 5 MeV & θ > 20 mrad

VD bkg does not come from magnetic deflection

Events reaching the VD effective σ(μb)

σ(μb)	GuineaPig $Q^2_{max}=s/4$	CAIN $Q^2_{max}=m_e^2$	BDK	(GP-CAIN)/GP
All	**60.5 ± 6.0**	**36.5 ± 4.5**	- -	**~ 0.41 ± 0.12**
BW	**10.3 ± 2.4**	**7.0 ± 2.0**	- -	~ 0.27 ± 0.33
BH	**20.5 ± 3.3**	**16.6 ± 3.0**	- -	~ 0.20 ± 0.20
LL	**29.7 ± 4.0**	**13.4 ± 2.7**	**37.5 ± 5.3** -	**~ 0.60 ± 0.18**

without Beam Size Effect

Events reaching the VD effective σ(μb)

σ(μb)	GuineaPig $Q^2_{max}=s/4$	CAIN $Q^2_{max}=m_e^2$	BDK	(GP-CAIN)/GP
All	**60.5 ± 6.0** ***64.1 ± 5.9***	**36.5 ± 4.5** ***37.4 ± 4.5***	- -	**~ 0.41 ± 0.12**
BW	**10.3 ± 2.4** ***8.2 ± 2.1***	**7.0 ± 2.0** ***6.4 ± 1.9***	- -	~ 0.27 ± 0.33
BH	**20.5 ± 3.3** ***26.6 ± 3.8***	**16.6 ± 3.0** ***20.9 ± 3.3***	- -	~ 0.20 ± 0.20
LL	**29.7 ± 4.0** ***29.3 ± 4.0***	**13.4 ± 2.7** ***10.2 ± 2.3***	**37.5 ± 5.3** -	**~ 0.60 ± 0.18**

without & *with* Beam Size Effect

Where does the difference between GUINEA-PIG and CAIN comes from ?

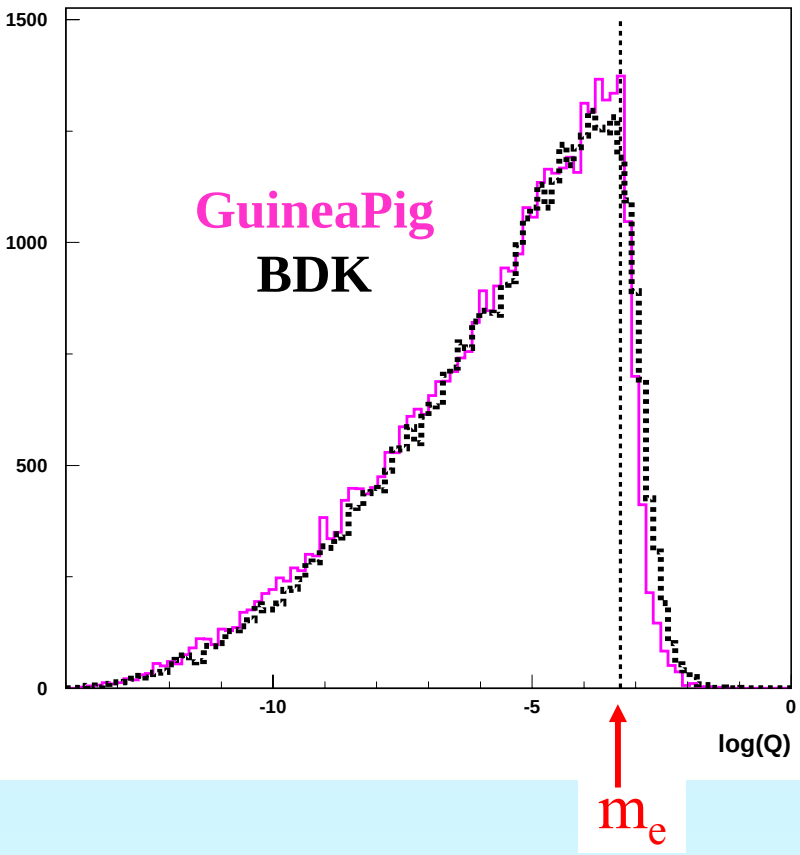
Origin of the difference GuineaPig / CAIN : Q^2_{max}

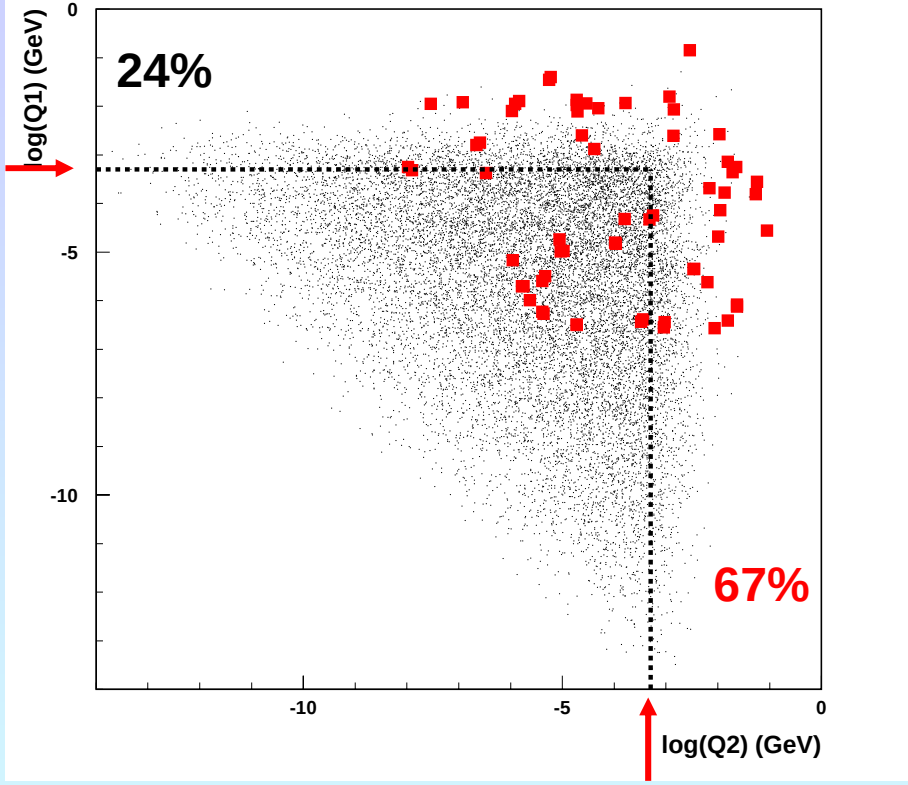
$Q^2_{max} = m_e^2$	IPC particles σ(mb)		IPC particles in VD σ(μb)	
	GuineaPig	**CAIN**	**GuineaPig**	**CAIN**
All	*51.8*	*50.7*	*32.0 ± 4.3*	*37.4 ± 4.5*
BW	*1.09*	*1.04*	*5.7 ± 1.8*	*6.4 ± 1.9*
BH	*35.2*	*34.5*	*16.5 ± 3.1*	*20.9 ± 3.3*
LL	*15.6*	*15.2*	*9.7 ± 2.4*	*10.2 ± 2.3*

Same virtuality limit, same results :
agreement between GP & CAIN at low virtuality

Is it correct to choose s/4 as the virtuality upper limit ?

The photon virtuality spectrum in BDK



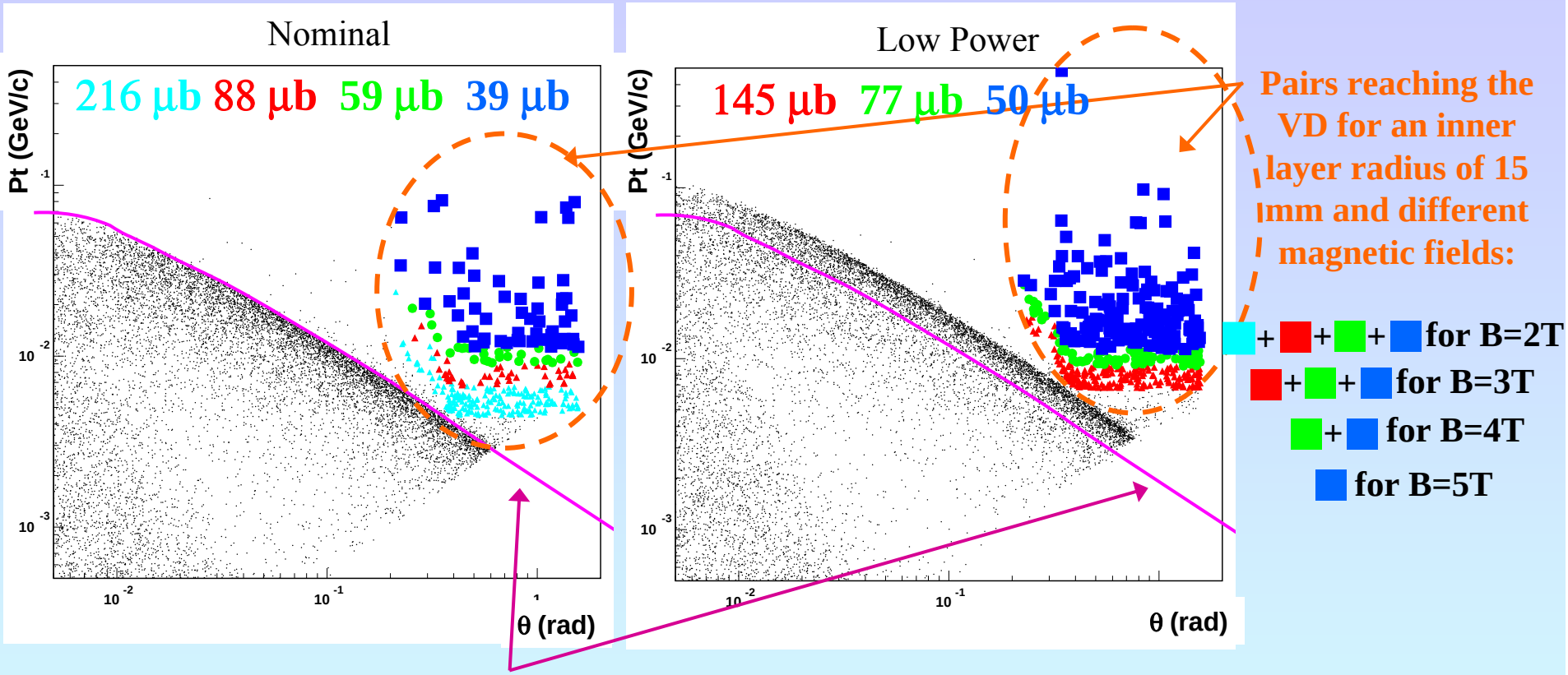


Nice agreement between GuineaPig & BDK both at low and large virtuality

BKD prediction at low virtuality:
σ_{prod} = 24 mb ; σ_{VD} = 12 μb
~ CAIN results

Impact of beam parameter sets on VD background

for r_1 = 15 mm

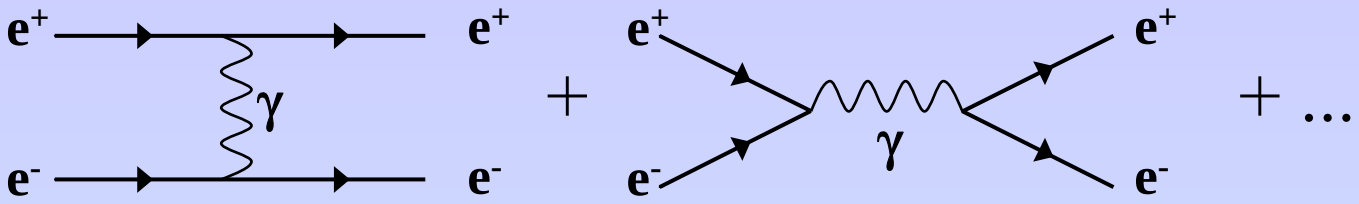


Pairs deflection limit for Nominal option: **for the Low Power option this limit is higher !**

➔ **too close to the background inflation region**

- ***A careful choice is required for Low Power option:***
  Incompatibility with Vertex Detector designs at low B and small radius
- ***2T: not safe with r_i = 15 mm***

Bhabha scattering & electromagnetic deflections



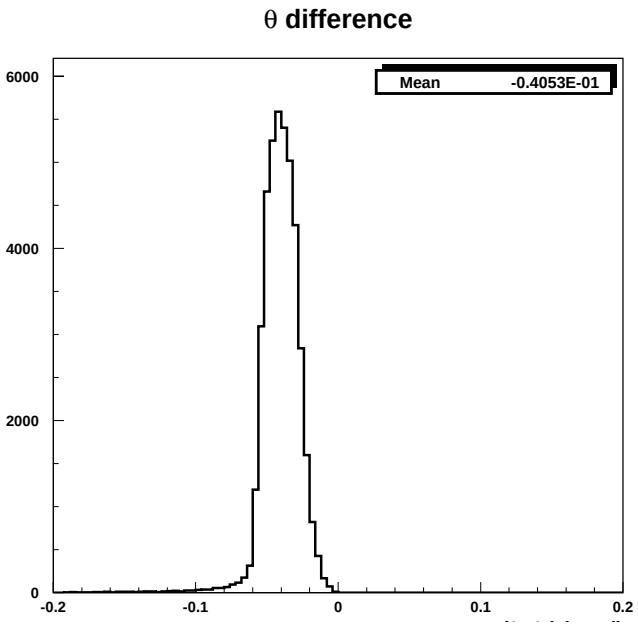
- Bhabhas are used to measure the luminosity: $\mathcal{L}_{int} = N_{Bhabha}/\sigma_{Bhabha}$
- Bhabha cross section : $$\frac{d\sigma}{d\vartheta} = \frac{2\pi\alpha^2}{s}\frac{\sin\vartheta}{\sin^4\vartheta/2} \approx \frac{32\pi\alpha^2}{s}\frac{1}{\vartheta^3}$$
- Beam-Beam effect ➔ **EM deflections**
  - ➔ **Modification of the angular distribution ?**
  - ➔ **Modification of the theoretical cross section ?**
  - ➔ **Would it be possible to estimate $\mathcal{L}$ with $\Delta\mathcal{L}/\mathcal{L} < 10^{-4}$?**

Bhabha scattering & electromagnetic deflections:

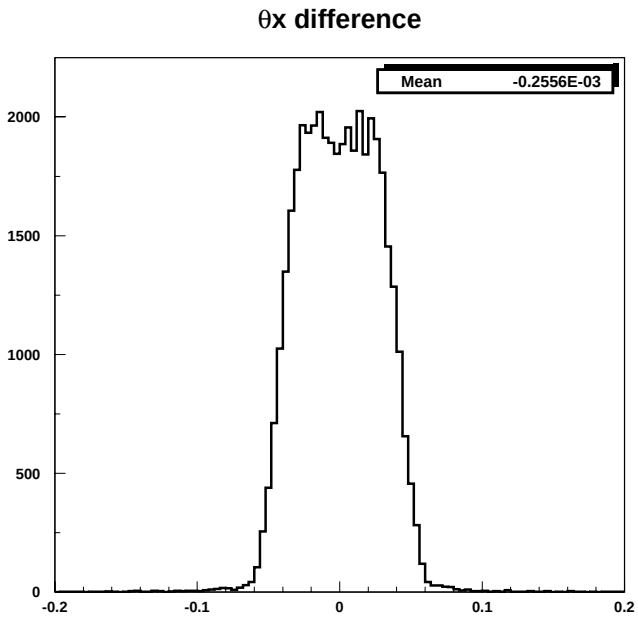
Very Prelimary results

- 10^6 Bhabhas produced with BHLUMI, $\sqrt{s}$=500 GeV, $25 \leq \theta \leq 90$ mrad :
- GUINEA-PIG EM deflection treatment (same as for the e+e- pairs)
- for the analysis : $30 \leq \theta \leq 75$ mrad, no cut on energy

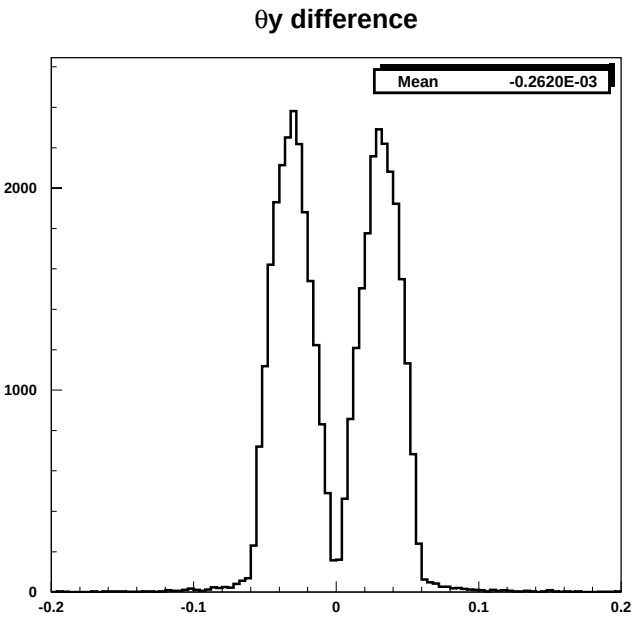
Effect of the deflection on angles



$(\theta_1 - \theta_0)$ (mrad)



$(\theta_{x1} - \theta_{x0})$ (mrad)



$(\theta_{y1} - \theta_{y0})$ (mrad)

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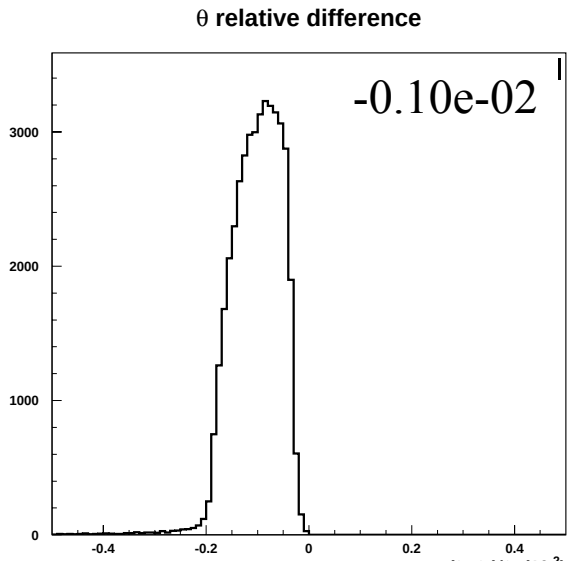
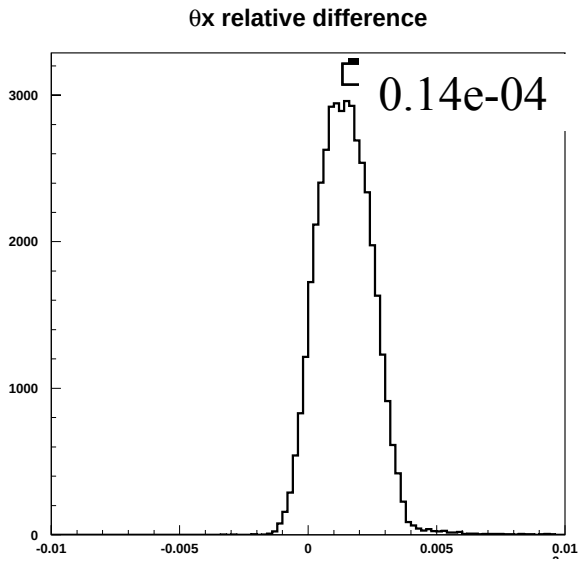
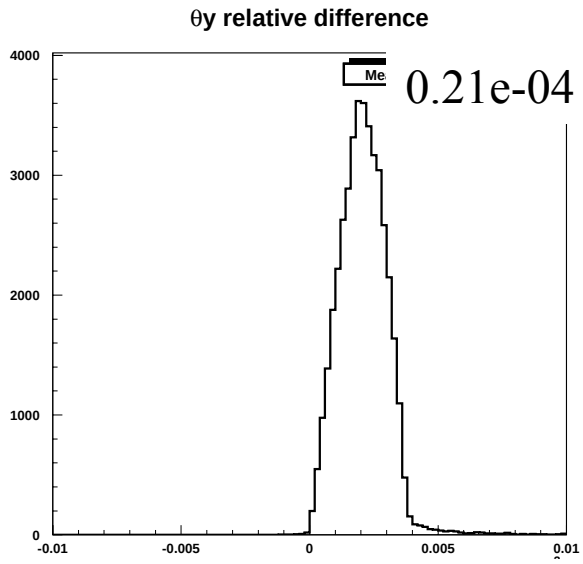


$(\theta_1 - \theta_0)/\theta_0$ (10^{-2})



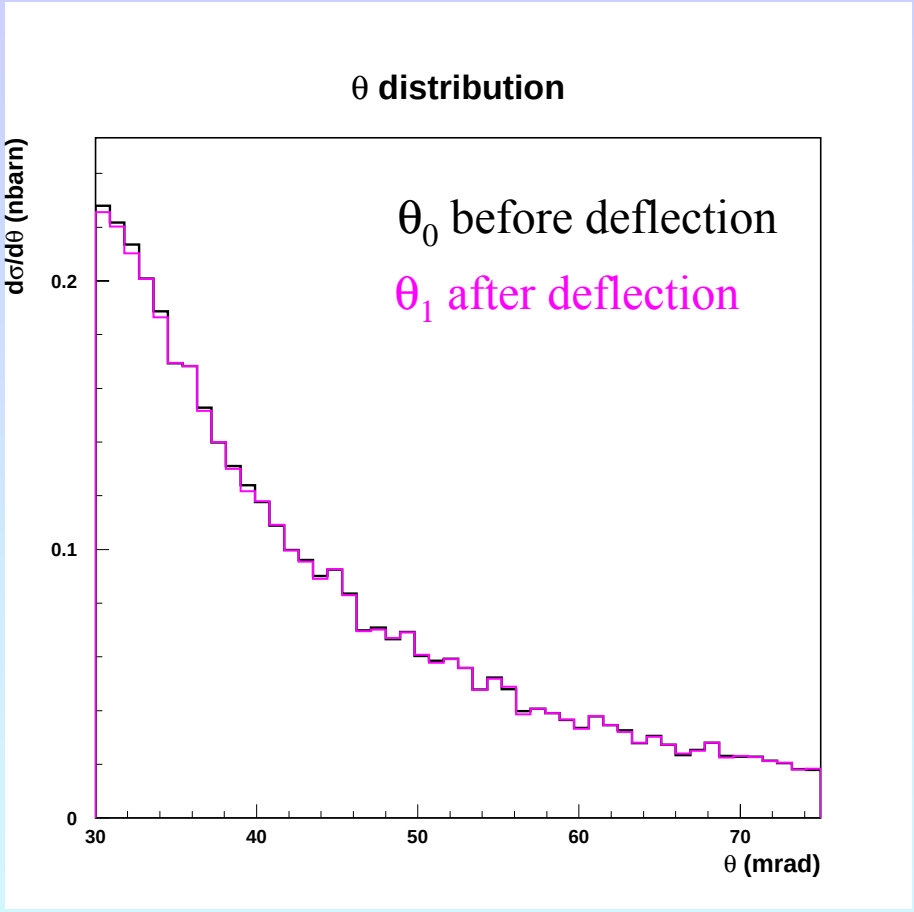
$(\theta_{x1} - \theta_{x0})/\theta_{x0}$ (10^{-2})

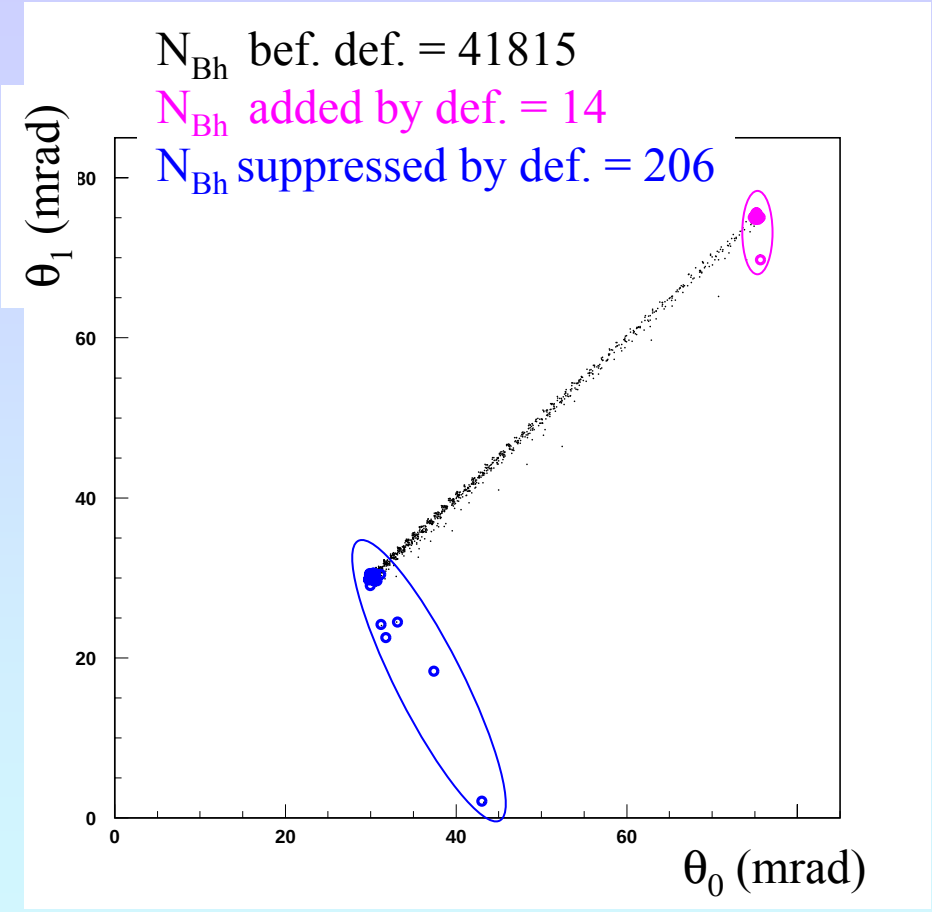


$(\theta_{y1} - \theta_{y0})/\theta_{y0}$ (10^{-2})

Bhabha scattering & electromagnetic deflections:

Very preliminary results





Difference between theoretical and "real" nb of Bhabhas : -0.46%

Summary

- **Incoherent e^+e^- pairs**

  GUINEA-PIG modelisation is more convenient than CAIN:

  m_e is a too small limit for the photon virtuality.

  Be careful with pair accumulation region after deflection :

  LowPower ➔ constraints on VD design (B, radius, readout)

  2T detector concept needs a VD inner radius >20 mm

reference: ***EUROTeV-Report-2005-016-1***

- **First study of EM Deflection effect on Bhabha scattering:**

  Effect > 10×10^{-4}

  ➔ ***Necessity to know well the impact of EM deflection***

  ➔ ***Tool will be provided (BHLUMI + GUINEA-PIG)***