Study of incoherent e^+e^- background in the Vertex Detector with GuineaPig

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1. GuineaPig[1]/CAIN[2]/BDK[3] comparison

GuineaPig & CAIN : beam-beam simulation
BDK : 4 fermions interaction dedicated code,
including all EW diagrams (but no radiative corrections)

2. Impact of beam parameter sets
on microVertex Detector background

[1] D. Schulte *[2] K. Yokoya* *[3] Berends, Daverveldt, Kleiss*

Incoherent Pair Creation Processes

1. Breit-Wheeler : $\gamma\gamma \rightarrow e^+e^-$ — *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**

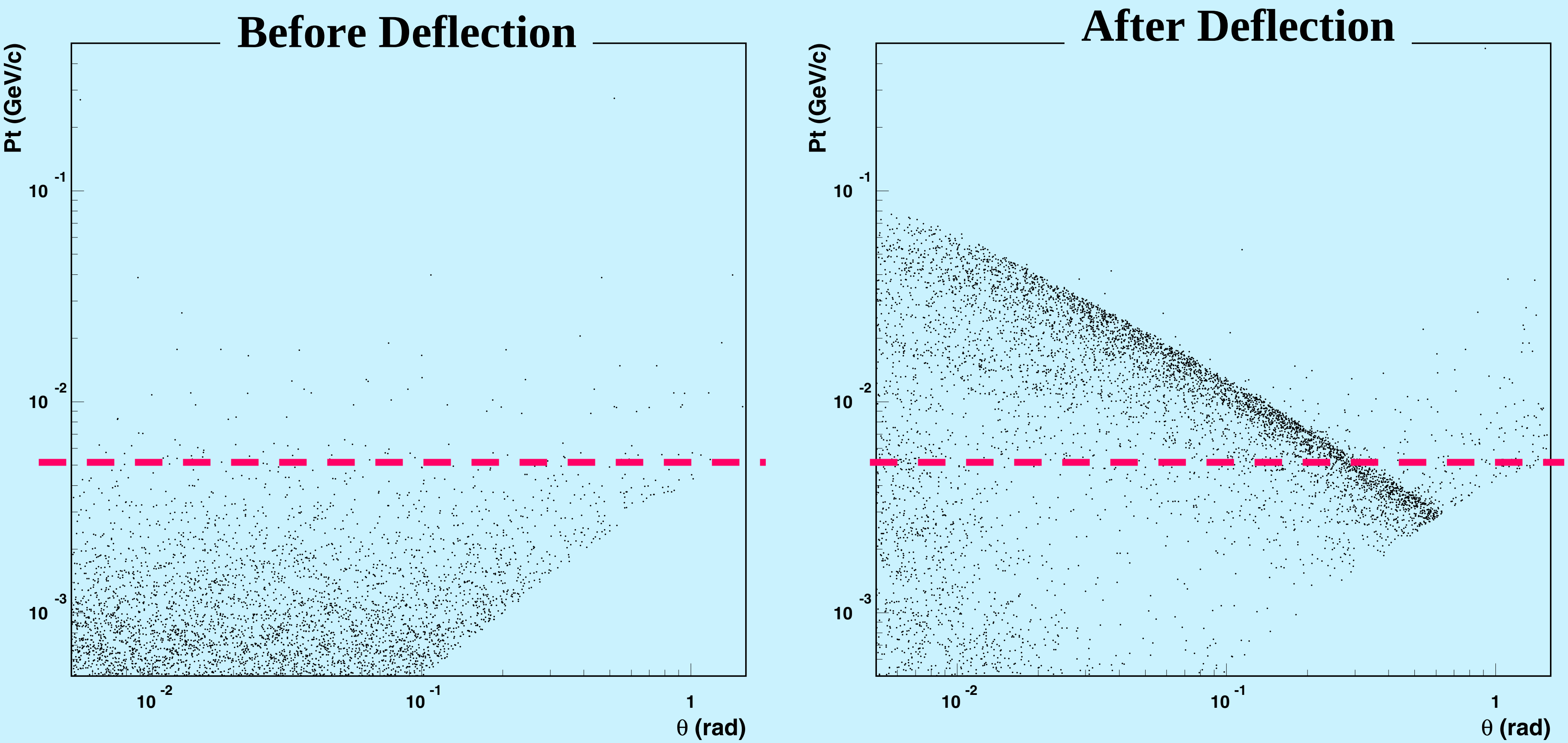
BDK: **$e^+e^- \rightarrow e^+e^-e^+e^-$, $s_{min}= 4m_e^2$ used as a reference for the LL process**

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

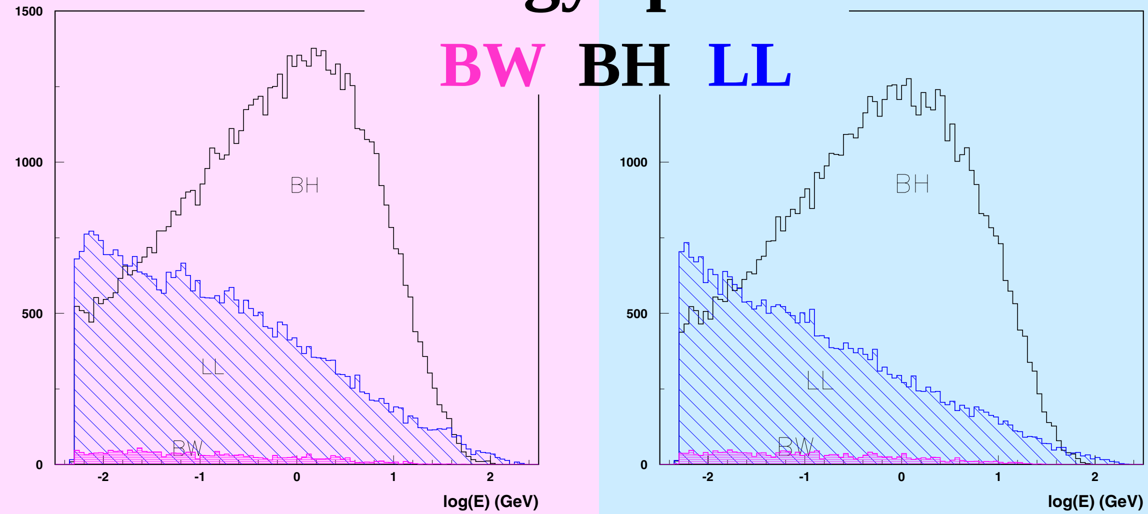
GuineaPig



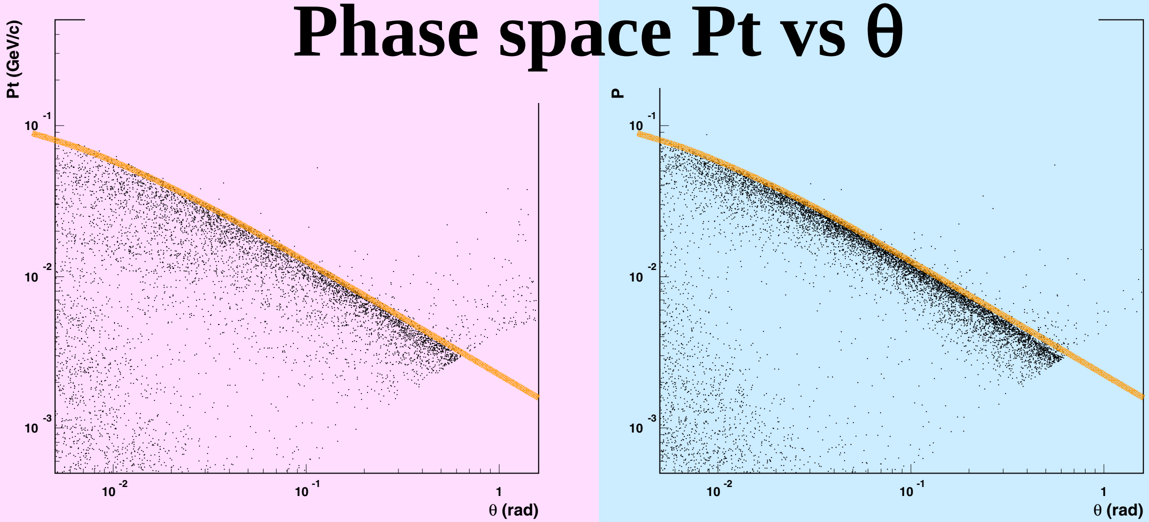
Pt > 5 MeV/c mostly due to electromagnetic deflections

GuineaPig / CAIN

Energy spectra

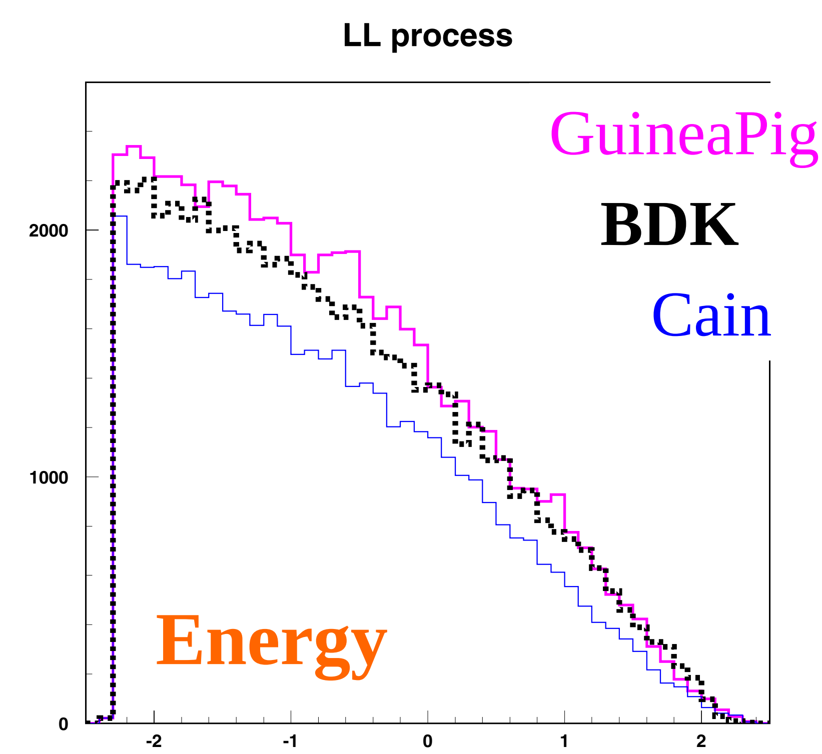


Phase space Pt vs θ

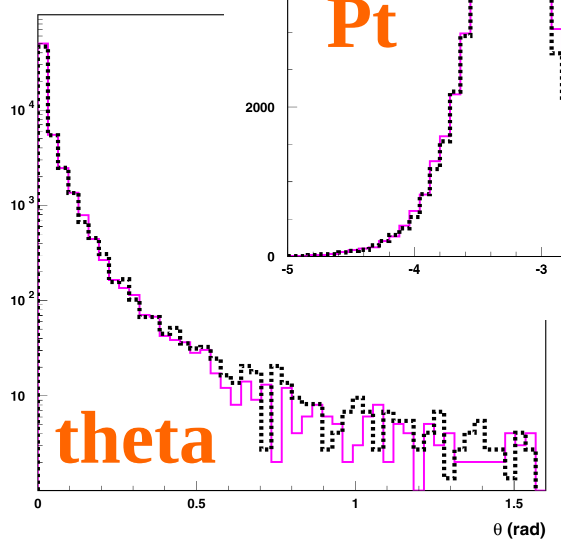


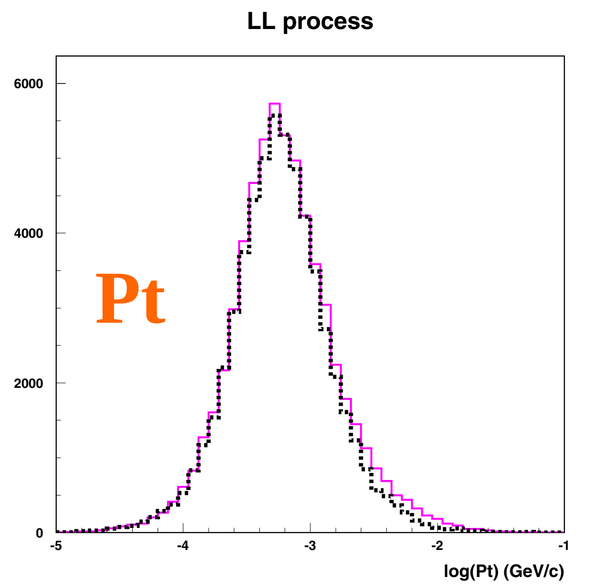
Qualitative agreement between Guinea-Pig and CAIN

Landau-Lifshitz : Comparison with BDK



No Beam Size Effect, No Deflection





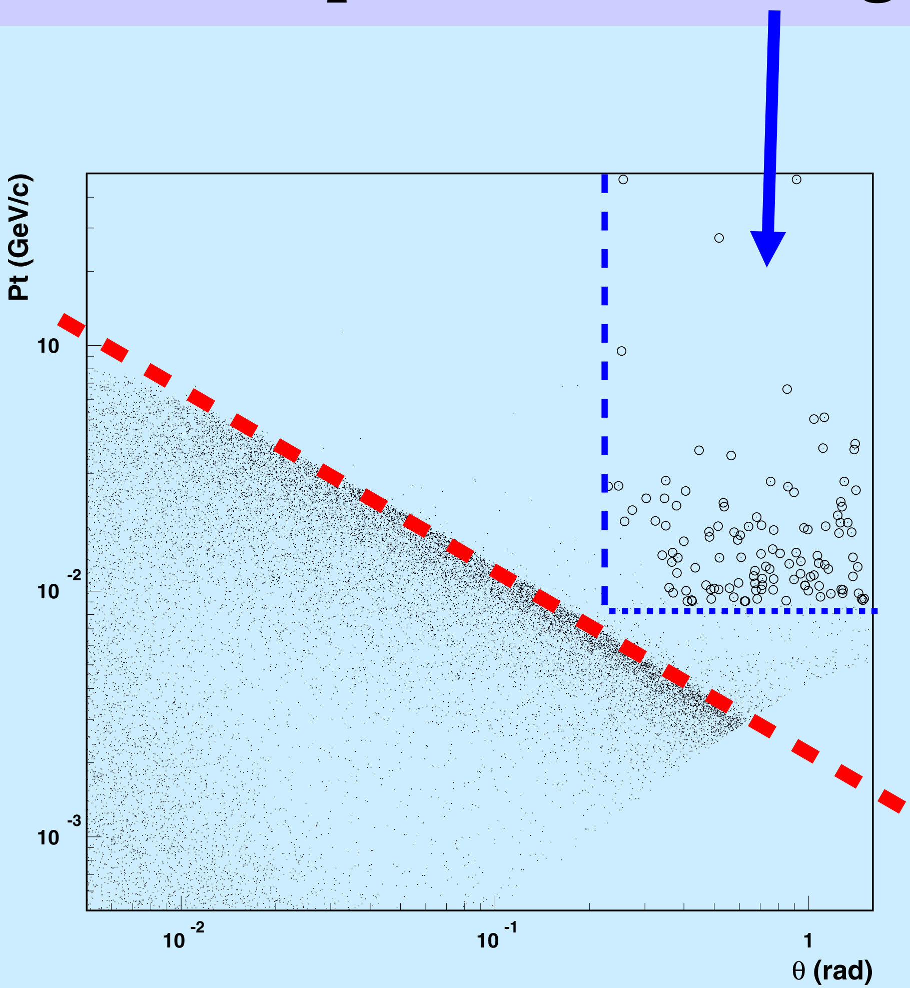
Very good agreement for Guinea-Pig and BDK

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

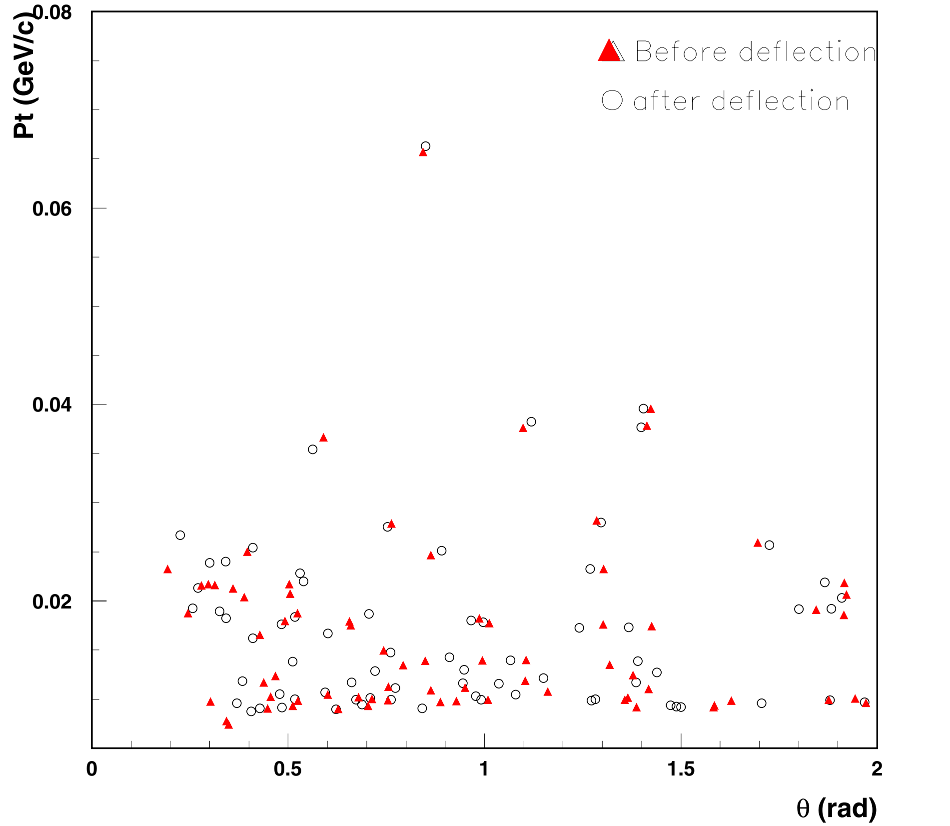
σ (mb)	**Guinea-Pig $Q^2_{max}=s/4$**	**CAIN $Q^2_{max}=m_e^2$**	**BDK**	(GP-CAIN)/GP
All IPC particles	**101** / ***58.0***	**89.5** / ***50.7***	**-**	**0.12**
Breit-Wheeler	**1.01** / ***1.05***	**1.11** / ***1.04***	**-**	**0.01**
Bethe-Heitler	**66.3** / ***37.7***	**61.7** / ***34.5***	**-**	**0.07**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

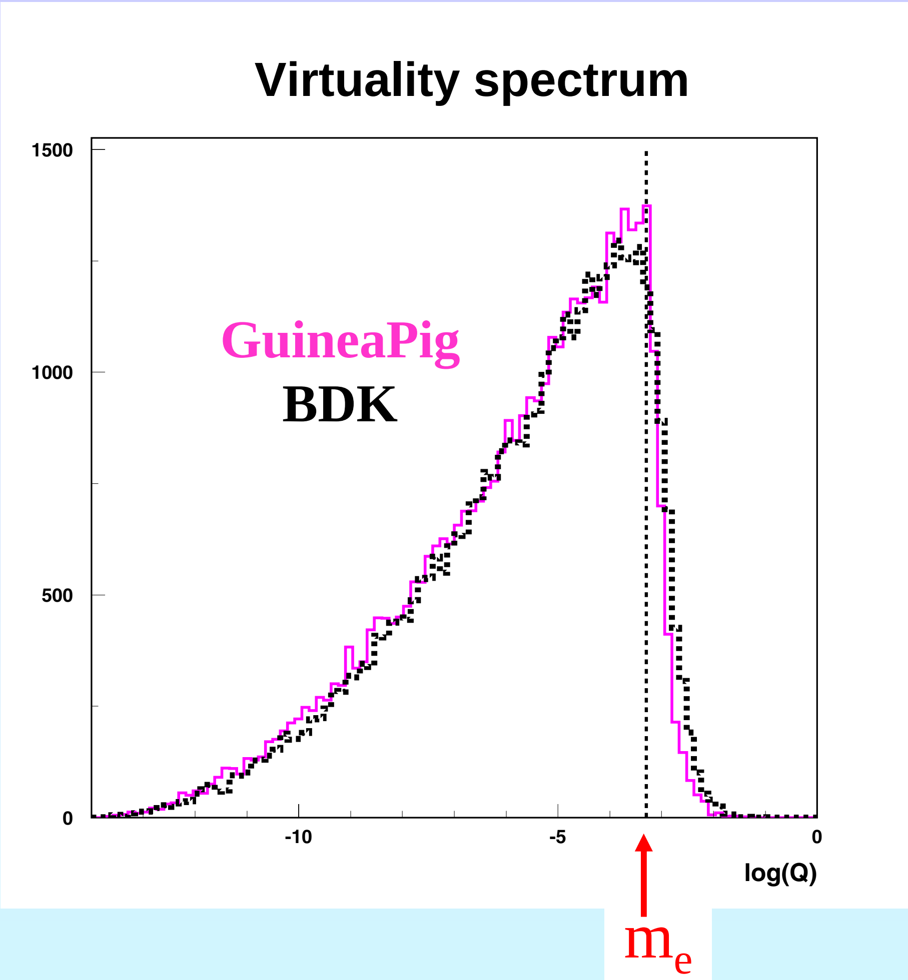
without & *with* Beam Size Effect

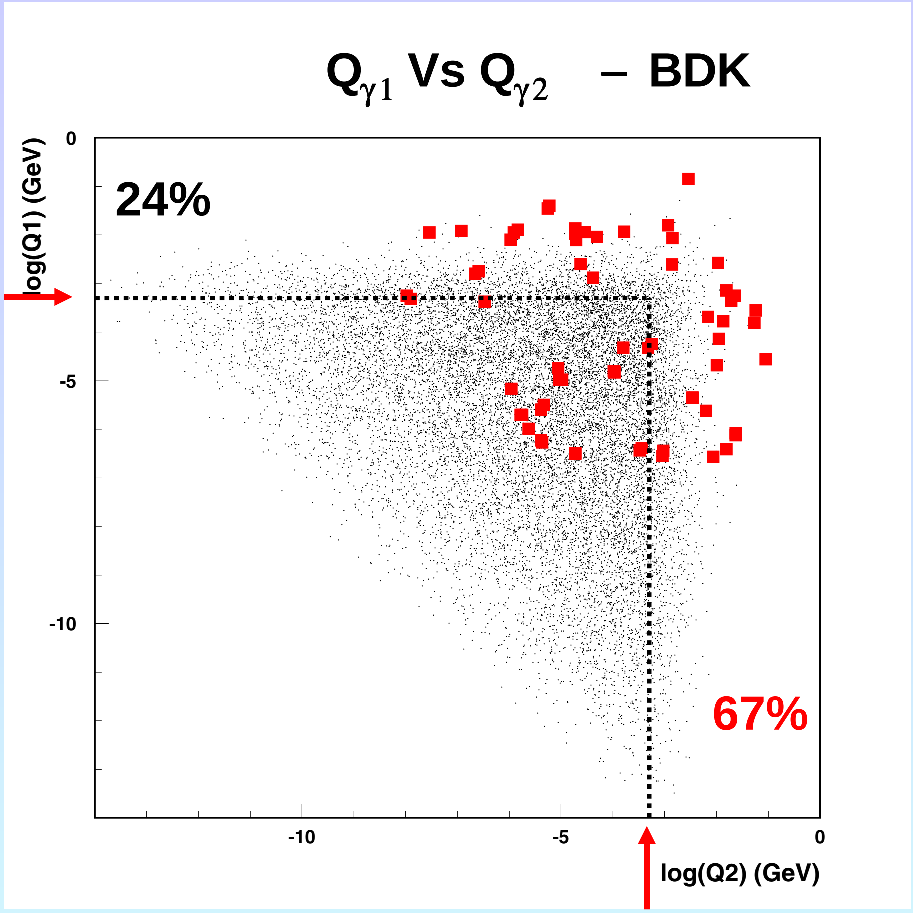
Origin of the difference GuineaPig / CAIN : Q^2_{max}

$Q^2_{max} = m_e^2$	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

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

Main results on IPC GuineaPig/CAIN/BDK comparison

• Relative difference between GuineaPig & CAIN:

All IPCe : 12%	LL IPCe : 21%
All VD : 41%	LL VD : 60%

due to the difference in photon virtuality upper limit.

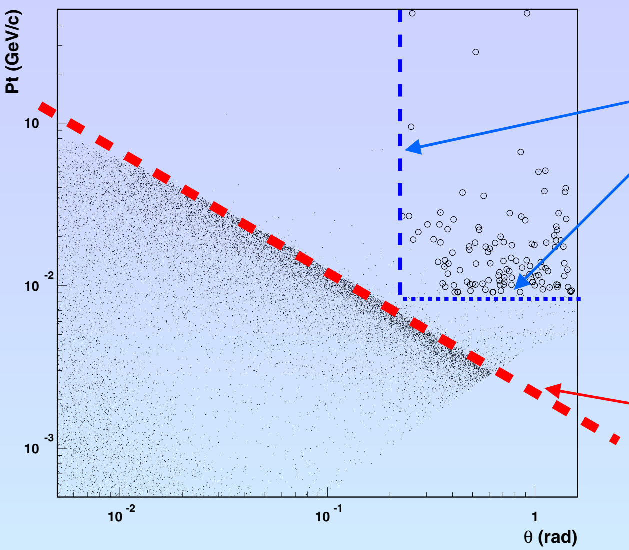
• At low virtuality (Q<me) : agreement between GuineaPig & CAIN and BDK for LL process

• Very good agreement between GuineaPig and BDK

• m_e as a upper virtuality limit is too small

➔ **GuineaPig prediction is the better one**

Impact of beam parameter sets on IPC VD background



- microVertex Detector: 5 cylindrical layers

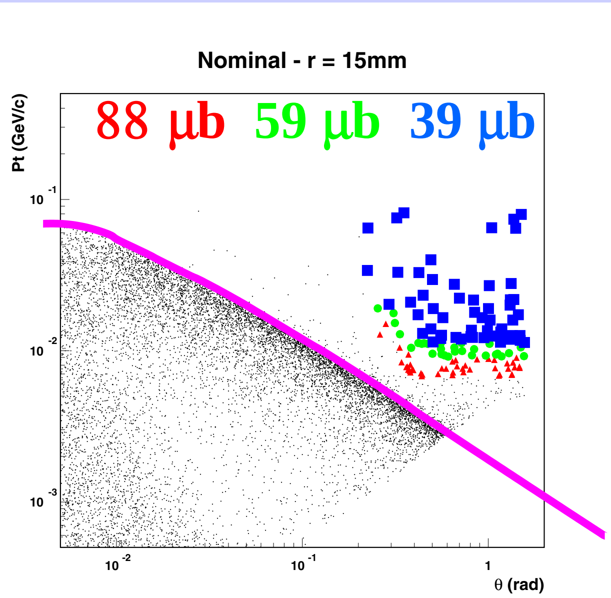
  l_1 = 10 cm , $l_{2,5}$ = 25 cm

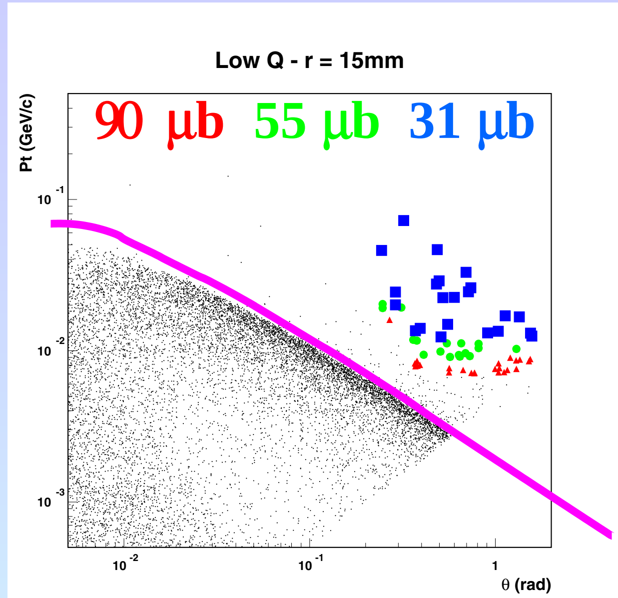
  r_1 = 14, 15, 20 mm, r_2 = 26 mm, r_3 = 37 mm, r_4 = 48 mm, r_5 = 60 mm
- B = 3, 4, 5T (GLD, LDC, SiD)
- 5 beam param. sets : ***Nominal, Low Q, Large Y, Low P, High Lum***

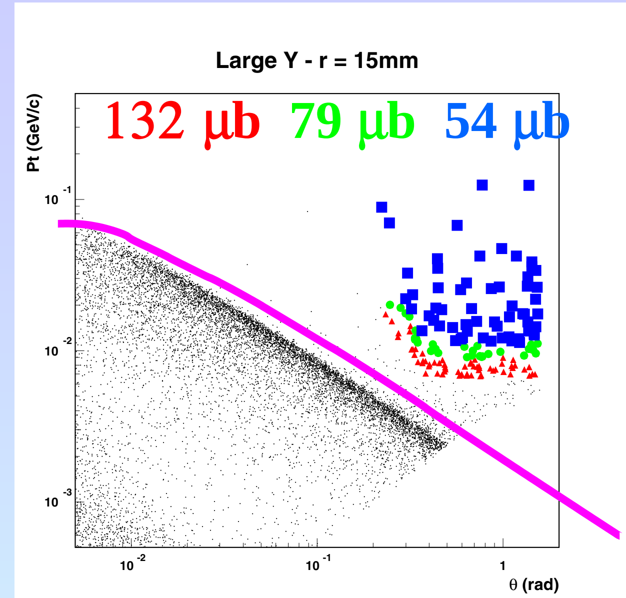
  (ILC WG1, T. Raubenheimer, D. Schulte, K. Yokoya**)**
- GuineaPig

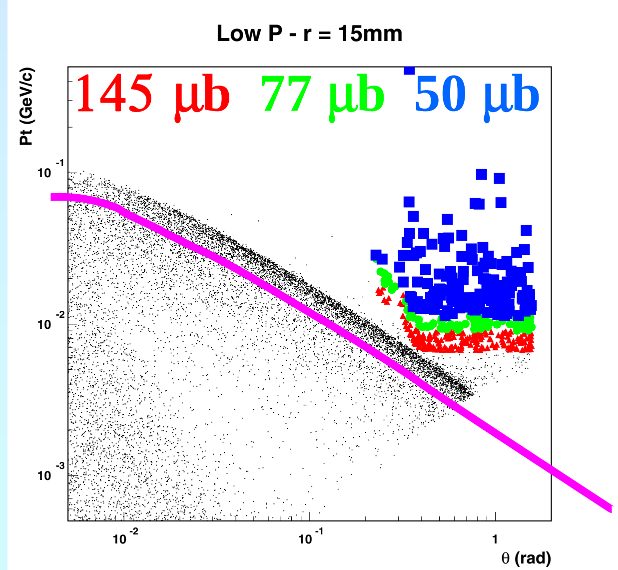
Impact of beam parameter sets on VD background

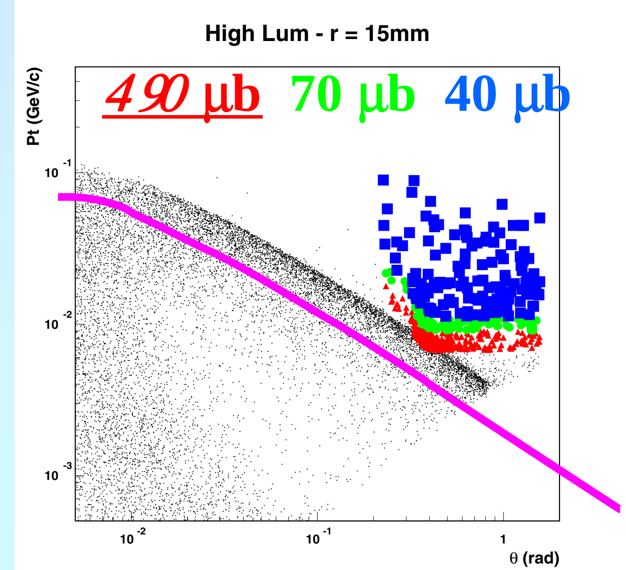
for r_1 = 15 mm











B=3T

B = 4T ~ 3T, 20mm

B = 5T

Impact of beam parameter sets on VD background

	B ; r (T;mm)	tesla	nominal	lowQ	largeY	lowP	highLum
L_{bx} [μb^{-1}]		1.9	1.5	0.7	1.1	2.8	3.4
N_{incVD}/train [10^3]	3; 14	560	420	440	480	770	19400
	3; 15	460	360	370	430	550	4800
	3; 20	250	240	210	250	290	650
	4; 14	300	270	250	280	350	920
	4; 15	270	240	220	250	290	680
	4; 20	150	150	120	160	170	340
	5; 14	190	190	160	200	220	490
	5; 15	160	160	120	170	190	390
	5; 20	90	90	80	100	110	230

highlum Bkg = 2.7 nominal Bkg

Impact of beam parameter sets on VD background

	B; r (T;mm)	tesla	nominal	lowQ	largeY	lowP	highLum
L_{bx} [μb^{-1}]		1.9	1.5	0.7	1.1	2.8	3.4
N_{incVD}/train [10^3]	3; 14	560	420	440	480	770	19400
	3; 15	460	360	370	430	550	4800
	GLD	250	240	210	250	290	650
	4, 14	300	270	250	280	350	920
	LDC	270	240	220	250	290	680
	4; 20	150	150	120	160	170	340
	SiD	190	190	160	200	220	490
	5; 15	160	160	120	170	190	390
	5; 20	90	90	80	100	110	230

GLD ~ LDC

SiD ~ 25 % less than LCD/GLD

Comparison with GLD occupancy tolerance

Tolerance : 10^4 hits/cm^2/train

Using : $\overline{\mathrm{Nb}}$ hits/particle = 3 rough estimate

Surface L1 = 2cm* 10cm*2pi = 126 cm^2

GLD	tesla	nominal	lowQ	largeY	lowP	highLum
N_{incVD}/train [10^3]	**250**	**240**	**210**	**250**	**290**	**650**
N_{hits}/cm^2/ train	**5950**	**5700**	**5000**	**5950**	**6900**	**15500**

- high Lum is beyond the occupancy tolerance

Comparison with LDC occupancy tolerance

Tolerance : 3 hits/cm^2/bx (TDR)

Using : $\overline{\text{Nb}}$ hits/particle = 3 rough estimate

Surface L1 = 1.5cm* 10cm*2pi = 94 cm^2

LDC	tesla	nominal	lowQ	largeY	lowP	highLum
N_{incVD}/bx	94	86	39	90	220	240
N_{hits}/cm^2/ bx	3.0	2.7	1.2	2.9	7.0	7.7

- high Lum & lowP are beyond the occupancy tolerance

Comparison with SiD occupancy tolerance

Tolerance : ? hits/cm^2/train   not communicate

Using : $\overline{\text{Nb}}$ hits/particle = 3   rough estimate

Surface L1 = 1.4cm* 10cm*2pi = 89 cm^2

SiD	tesla	nominal	lowQ	largeY	lowP	highLum
N_{incVD}/train [10^3]	190	190	160	200	220	490
N_{hits}/cm^2/ train	6400	6400	5400	6700	7400	16500

Summary

• Incoherent pair VD background : CAIN prediction is 40% less than GuineaPig one

GuineaPig prediction is the better one

• Be careful with pair accumulation region after deflection

• Incoherent VD bkg : GLD ~ LDC, SiD ~ 25% less

• HighLum ➔ constraints on VD design (B, radius, readout)

Incompatible with present GLD & LDC concepts

• New proposed HighLum option (A. Seryi) → potentially better
➔to be studied...

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