QED Background at Belle experiment

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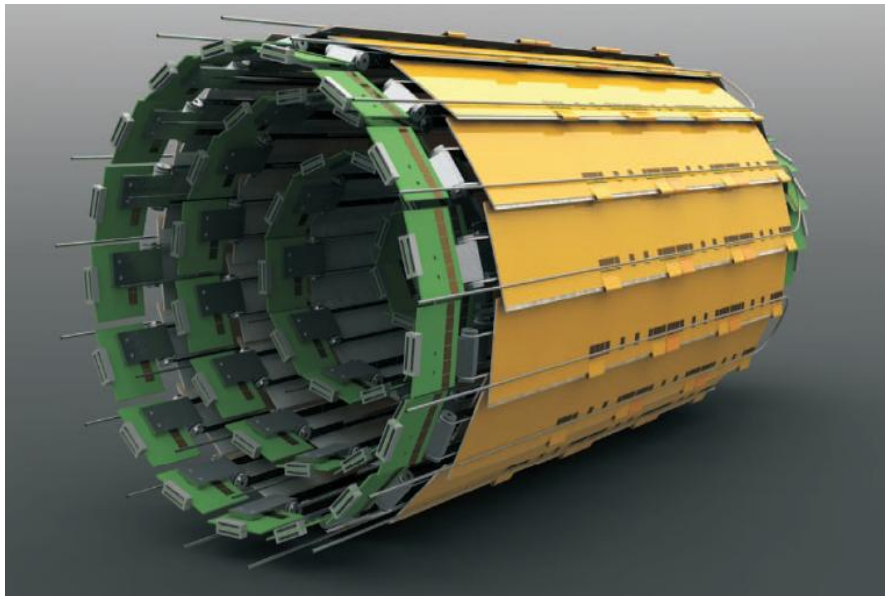
- Expected background at BELLE II
- QED Background Experiments
- Background analysis
- Next steps
- Conclusions

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Si ~ Detectors

Strips vs Pixels

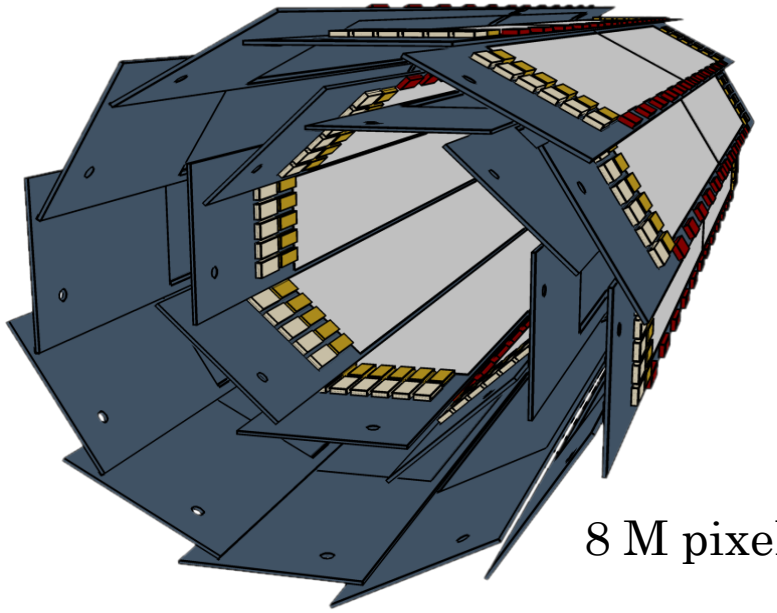


Silicon Vertex Detector at Belle II

- **4 layers**
- **DSSDs**
  - **z strips**
  - **phi strips**

4 cm

Pixel Vertex Detector (PXD)



8 M pixels

2 layers

- **1.4 cm**
- **2.2 cm**

has to handle harsh background at Belle II

Expected Background at Belle II

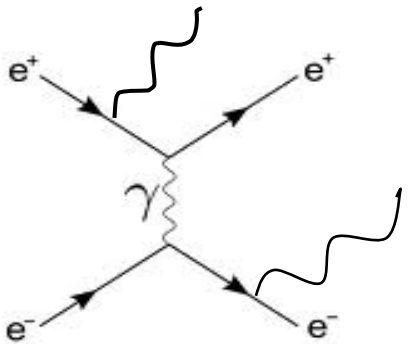
expected increase by a factor of 2 (due to current)

Machine background

- Beam – gas scattering (bremstrahlung and Coulomb scattering)
- Touschek effect (intra – bunch scattering)
- Synchrotron Radiation

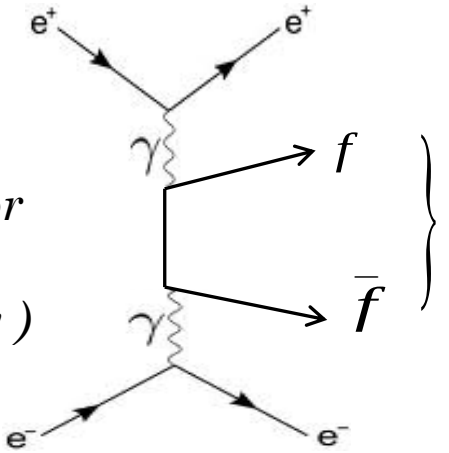
Luminosity – related background

- Radiative Bhabha scattering
- $\gamma\gamma$ reactions



$\sigma \sim 50nb$

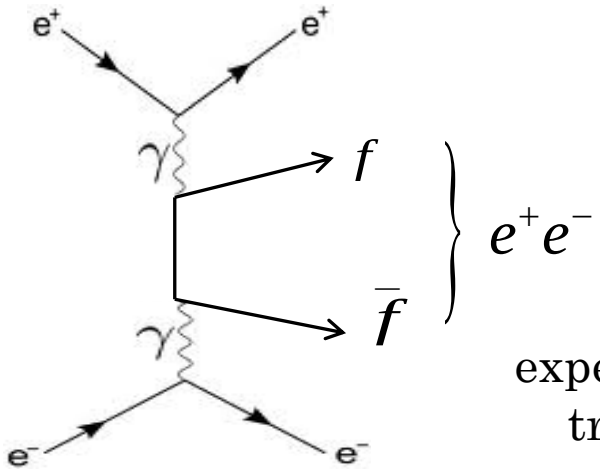
increase by a factor of 40 (due to luminosity)



$\sigma \sim O(10^7 nb)$

QED Processes – 2 photon processes

t – channel processes



- Berends – Daverfeldt – Kleiss (BDK)
- S.Jadach et al. (KW)
- J.Fujimoto et al. (Grace)

Occupancy (inner layer):

expected background tracks per event

BDK: 0.07%
KW: 0.1%

in strong disagreement with the number form SuperB (a factor of 15 difference)

SuperB, Italy
$rate \rightarrow 10 MHz/cm^2$

PXD:

per event

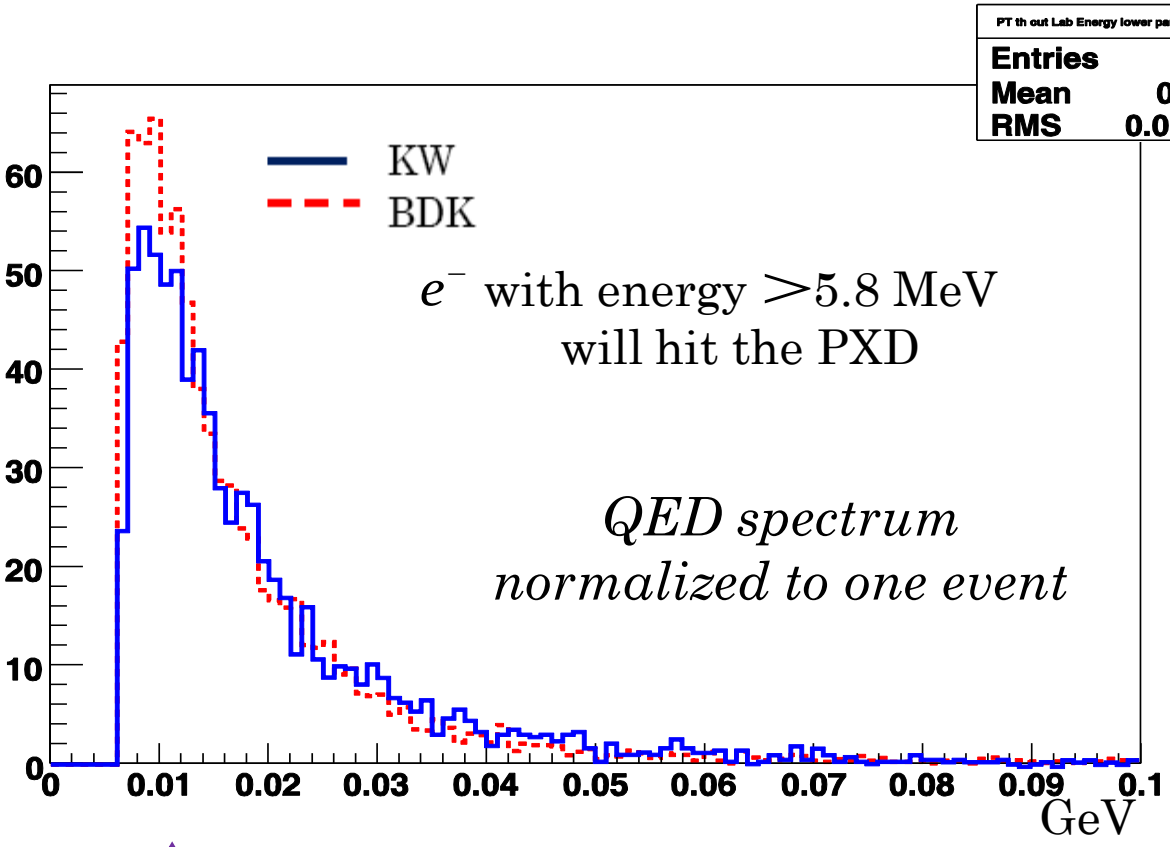
$tracks \rightarrow 13800$

$occupancy \rightarrow 1.3\%$

would be a problem

our three MCs are consistent

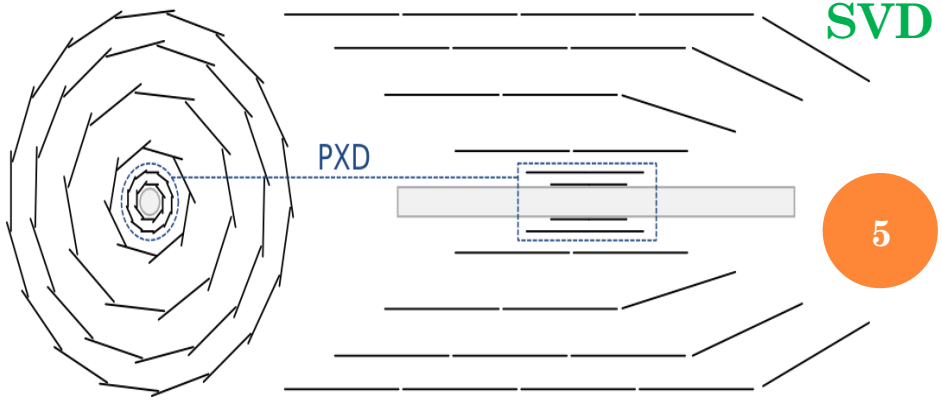
QED Processes – 2 photon processes



SVD : > 40 MeV
CDC : > 100 MeV

our MC gives ~ 800 tracks per event

high rate at very low momentum
(~ 5 – 20 MeV)



→ Look at real data from Belle to decide between MC's

↓

- A few MeV cannot be triggered at Belle

Therefore:

Random Triggers (unbiased background)

Assumption : the "non – physics" hits in the SVD

- beam background (expected to be ~ beam current)
- QED processes (~ luminosity)

Idea:

separation of the two components and thus determine the QED cross section

QED Expectations

SuperKEKB Simulation: ~ 800 tracks per PXD frame
(~ 13 000 tracks, SuperB Simulation)

- L ~ 1000 /nbs
- Integration time = 20 μs **(PXD)**

Scale to **KEKB**:

Factor 1000 less: 0.8 tracks per SVD frame

- L ~ 10 /nbs ($10^{32} cm^{-2} s^{-1}$)
- Integration time = 2 μs **(SVD)**

Belle **Belle II**

SuperB MC : 3 hits/track

22 hits ← expected hits in layer 1 SVD

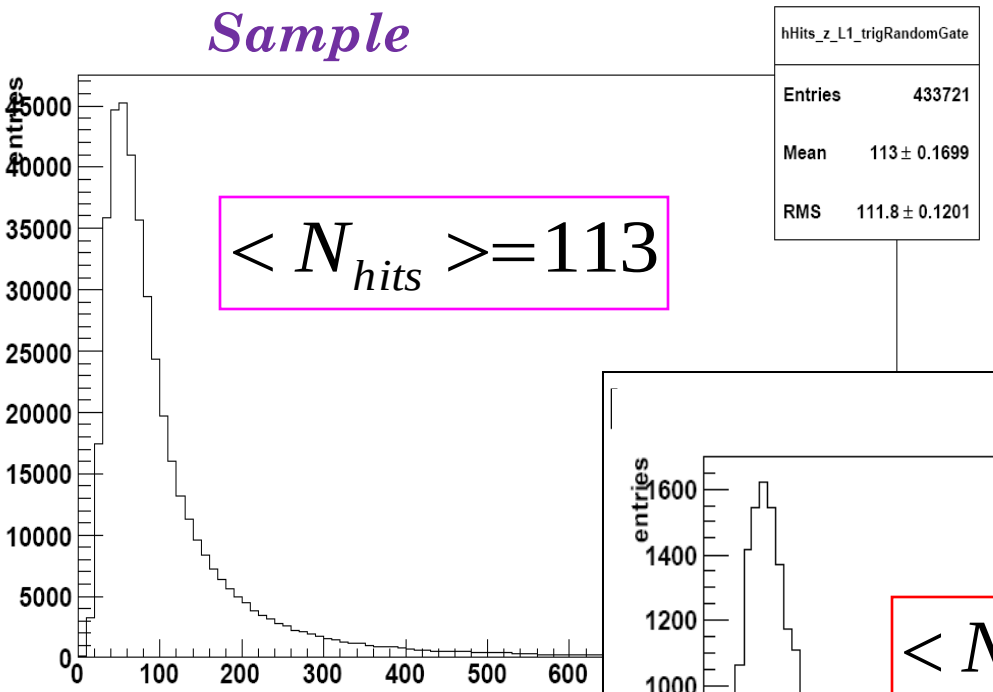
Our MC :

1.5 hits ← expected hits in layer 1 SVD

SVD Hit Multiplicity

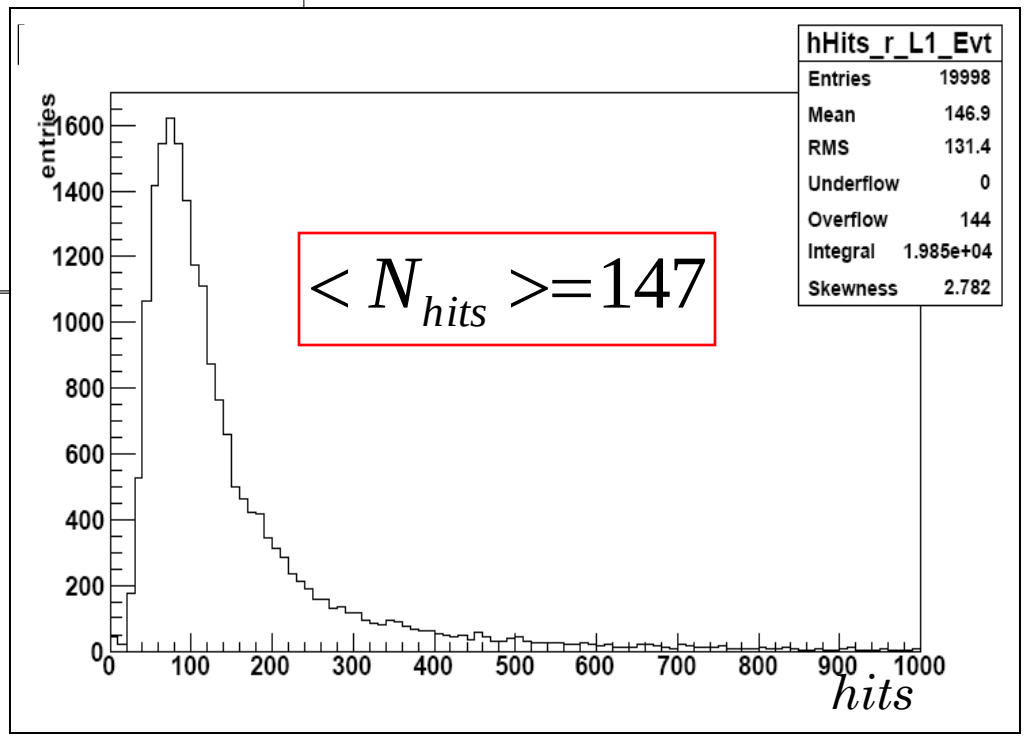
Random Trigger Sample

Control sample study



$< N_{hits} >= 113$

Hadron Control Sample

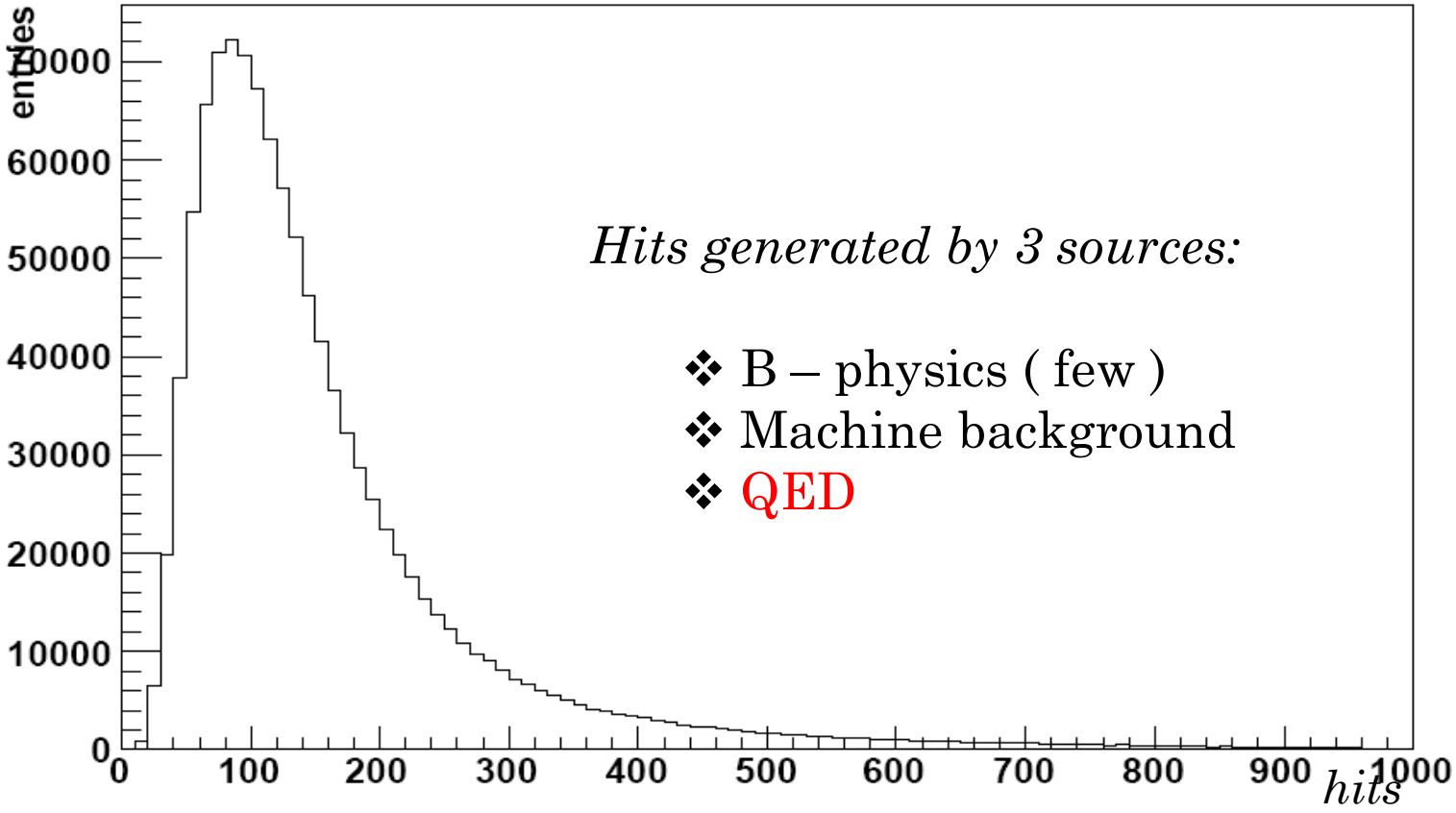


$< N_{hits} >= 147$

additional
11 tracks
~ 33 hits

QED "Measurement"

Hit multiplicity in the SVD per **randomly triggered** event



Hits generated by 3 sources:

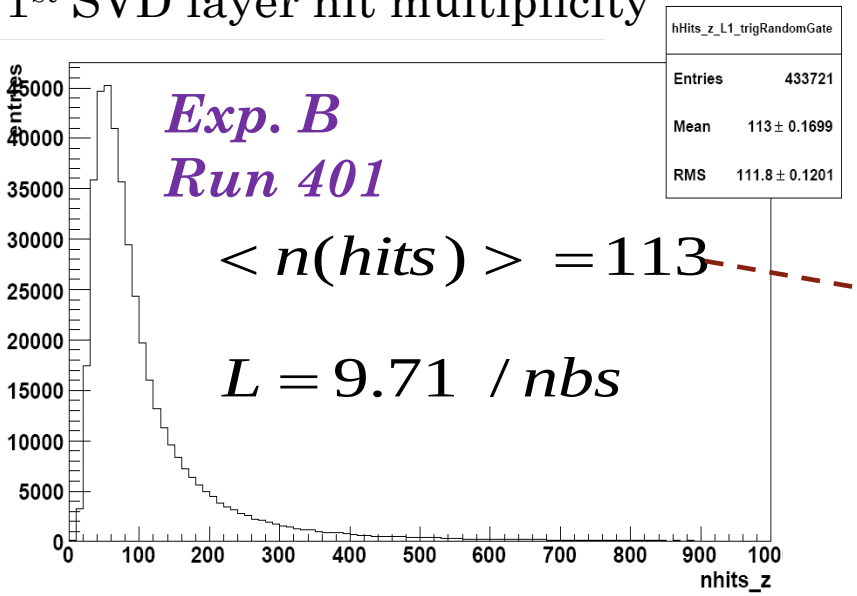
- B – physics (few)
- Machine background
- QED

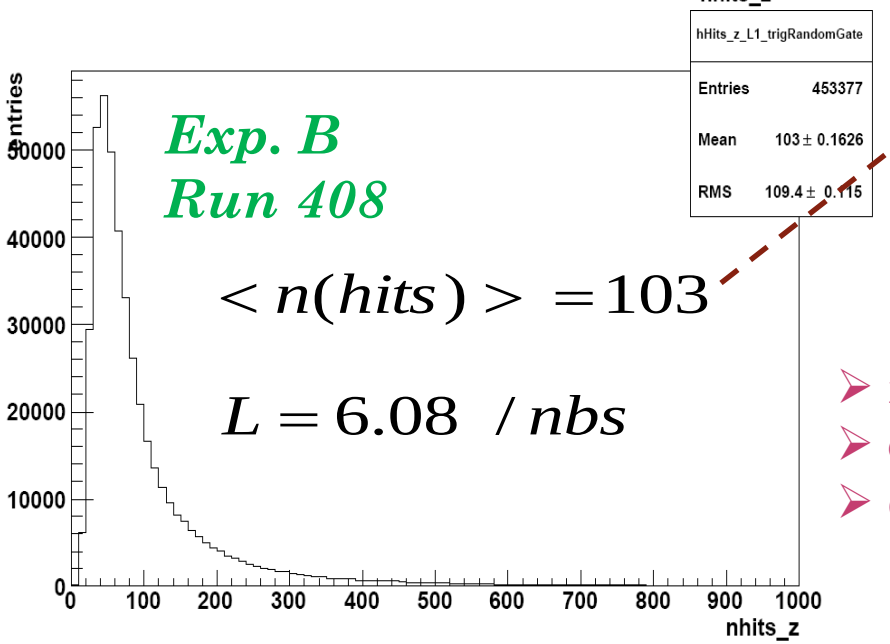
To do:

Try to separate the three sources by measuring
< hit/event > as function of luminosity

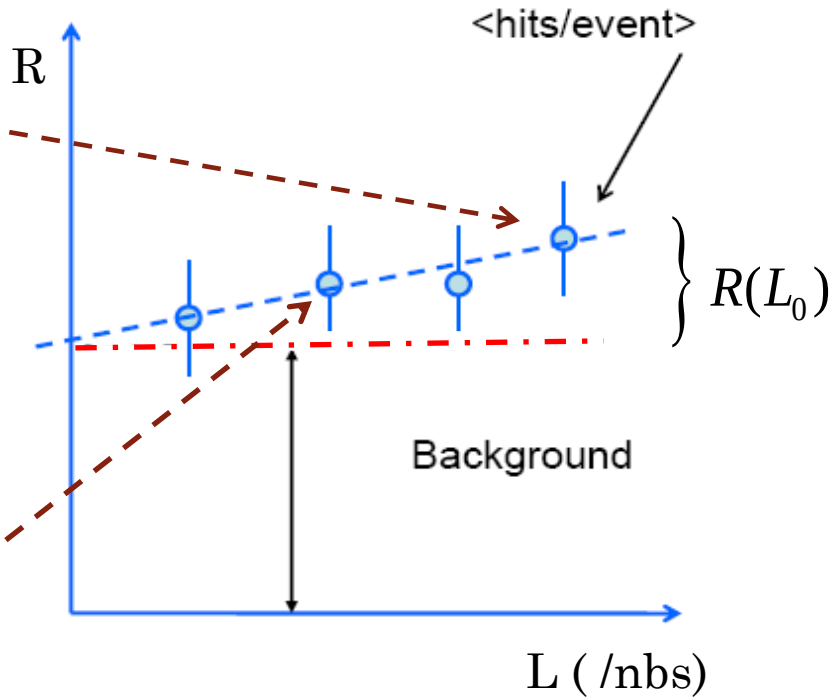
QED "Measurement"

1st SVD layer hit multiplicity





$R = < hits / event >$



- measure R as function of L
- extrapolate to L = 0 ("non – QED" BG)
- difference → QED rate

Random Trigger Runs and Data Sample

Exp. A (**separate the beams vertically**)
Run (415 – 420) each run 500 k triggers

Exp. B (**increase vertical beam size in HER**)
Run (401 – 411) each run 500 k trigger

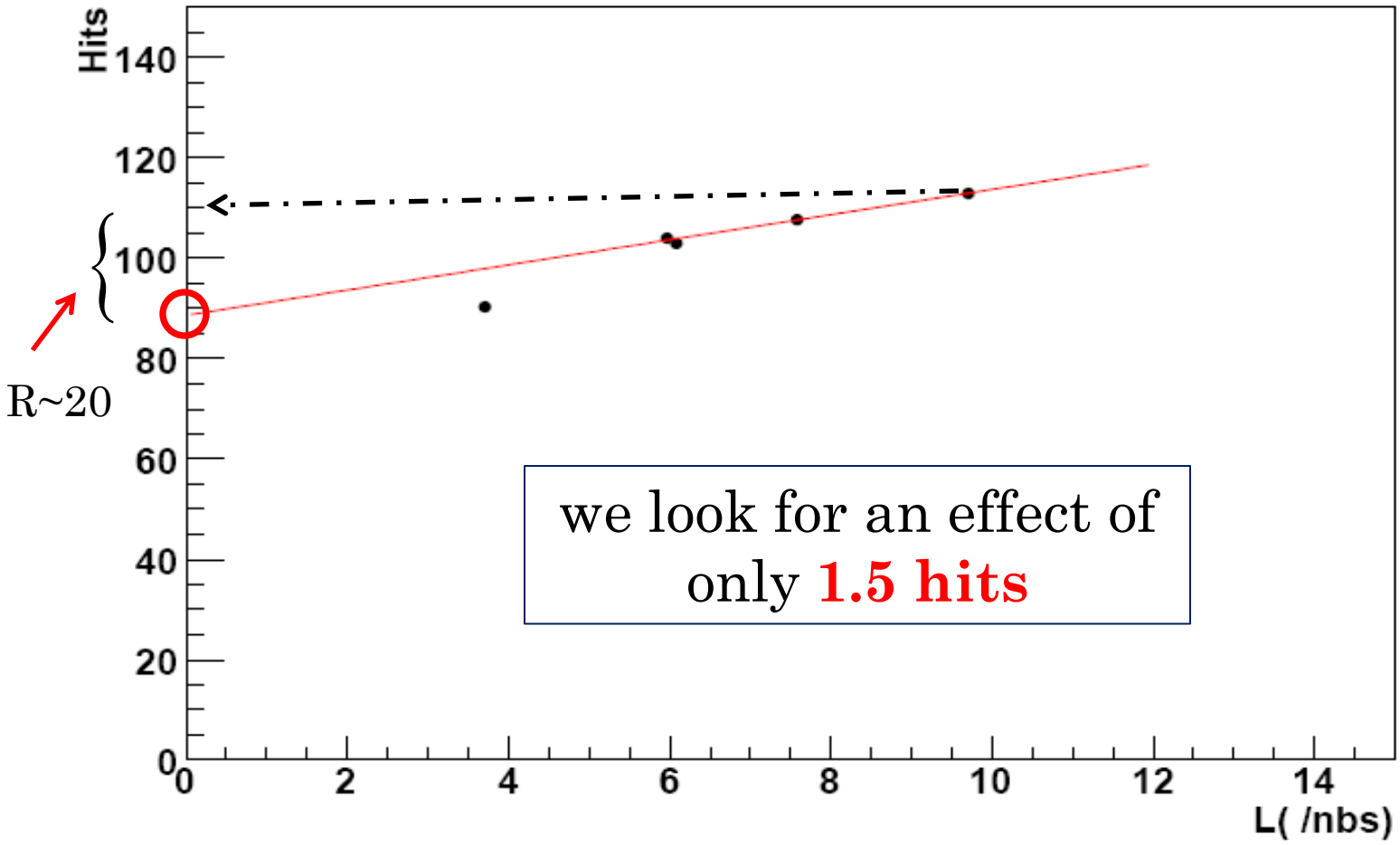
Exp. C (**change beam currents by stopping injection**)
Run (421 – 427) each run 10 min

Random trigger rate: 400Hz
Bhabha trigger rate: 50Hz moderate start luminosity (~ 10/nbs)

Each experiment started with a run ~ 10 /nbs (" default ")
500 k triggers at 400Hz = 30 min (including beam setup)
vary luminosity steps of 2 /nbs
10, 8, 6, 4 /nbs

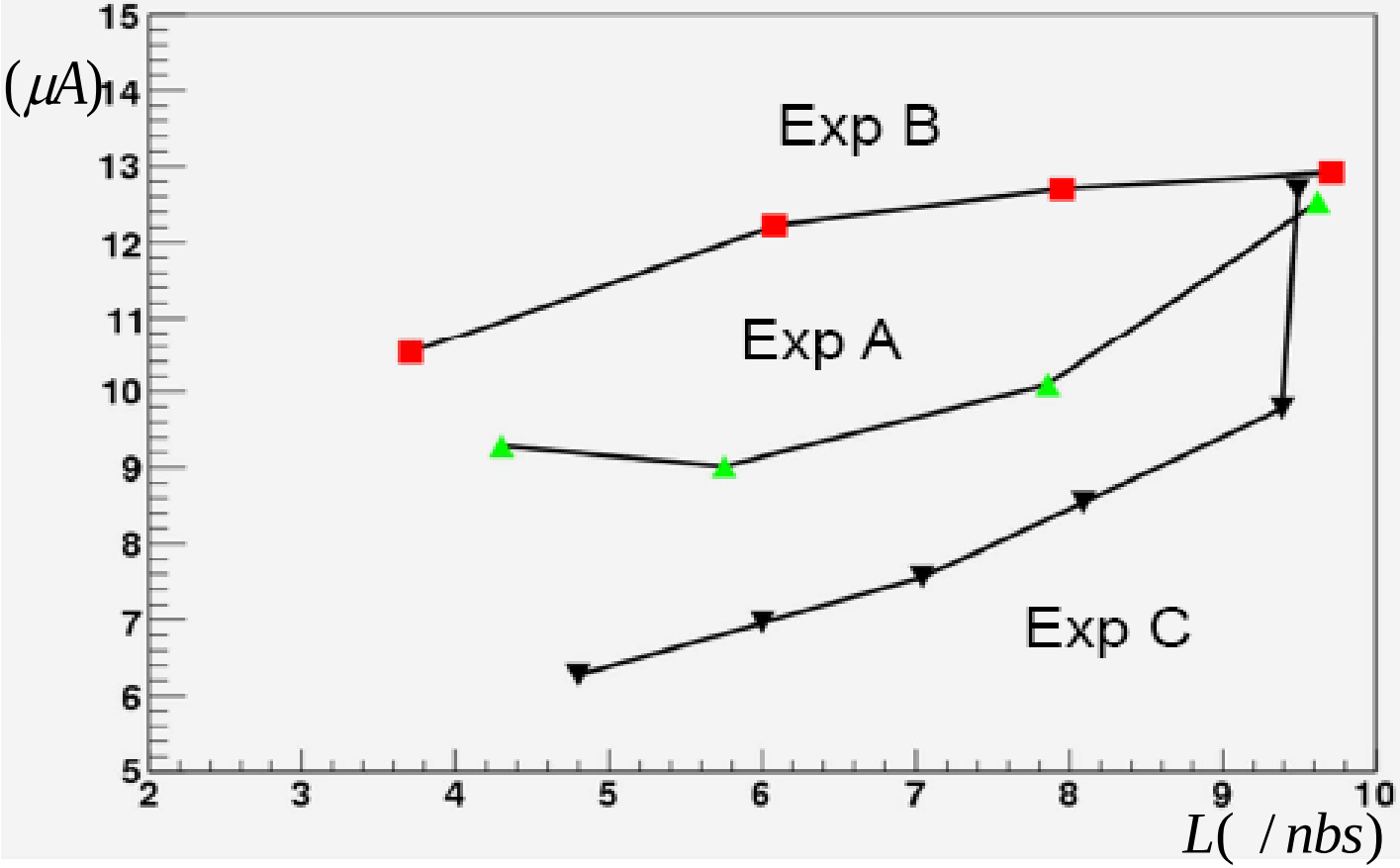
Exp. B

Hit multiplicity in the 1st layer of the SVD for Z strips as function of luminosity



Beam Background Monitoring

CDC (Central Drift Chamber) currents as function of luminosity



Exp. A and Exp. B - **no current change**

Only for Exp. C - **current change**

The different behavior of A, B (and C) is unexpected and unexplained

Development of analysis strategies

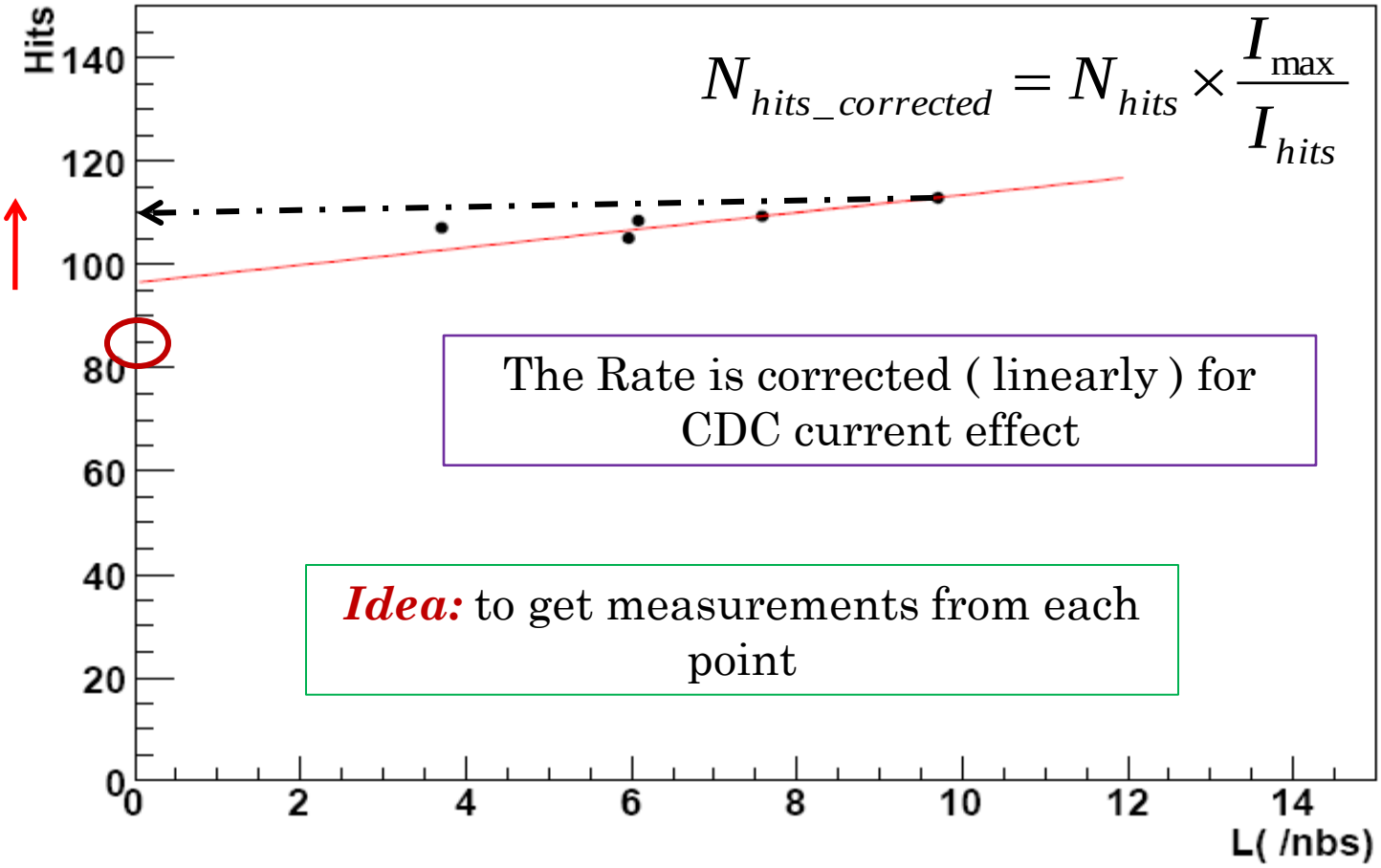
- Background is not independent of luminosity (in all exp.)
- More refined strategies are needed to limit QED
- CDC current varies with Luminosity

→ ***There is luminosity – related background other than 2 photon QED***

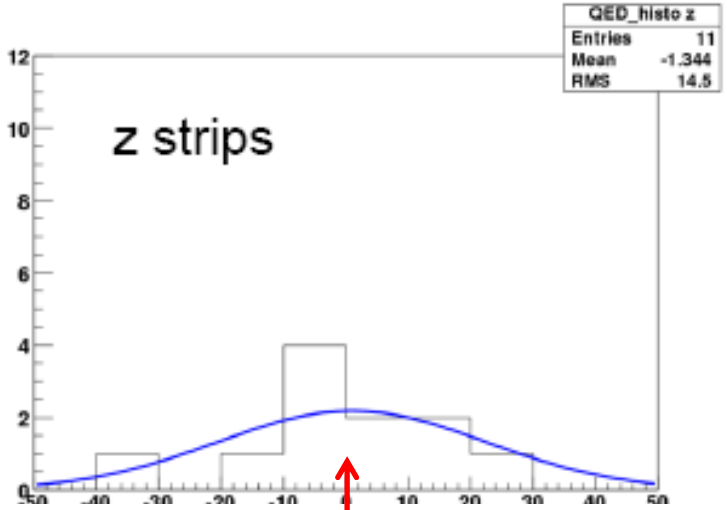
- This luminosity – related variation must be interpreted as background
- Correction due to CDC current variation will " flatten " the background

CDC correction analysis strategy

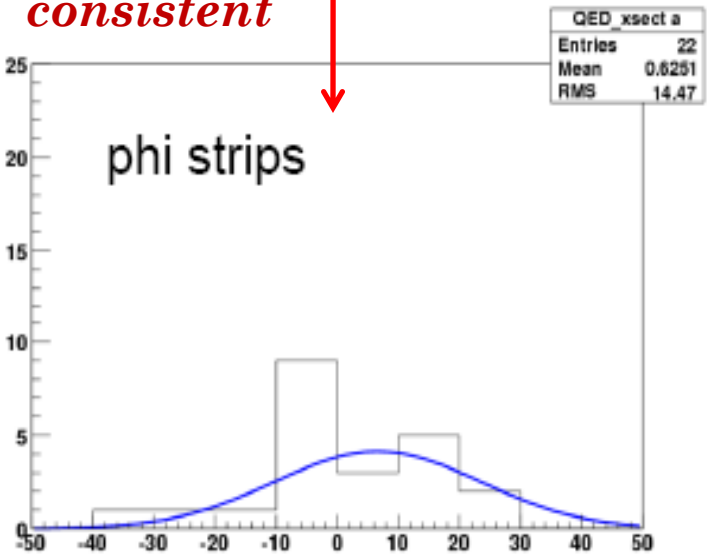
Hit multiplicity in the 1st layer of the SVD for Z strips with CDC correction included



Analysis strategy outcome



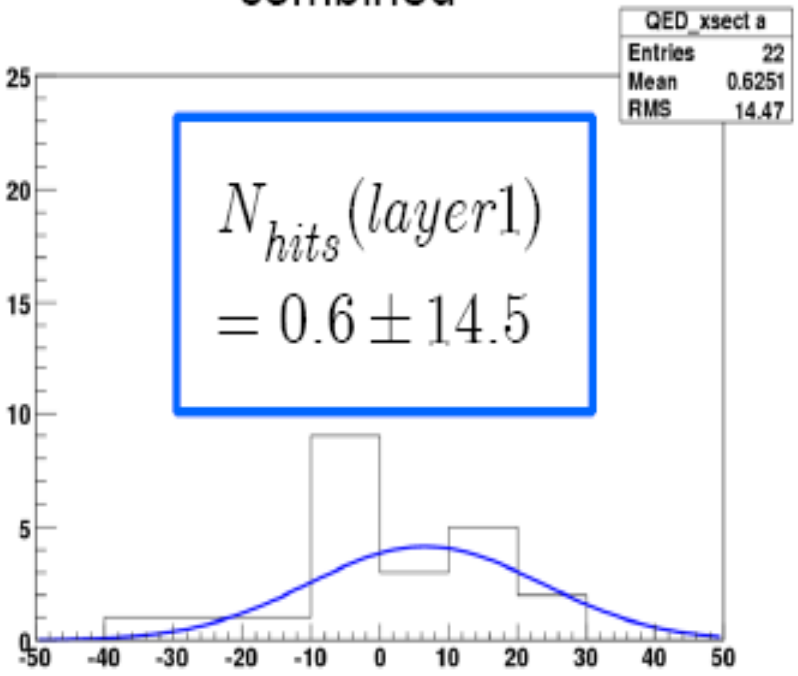
consistent



1st layer:

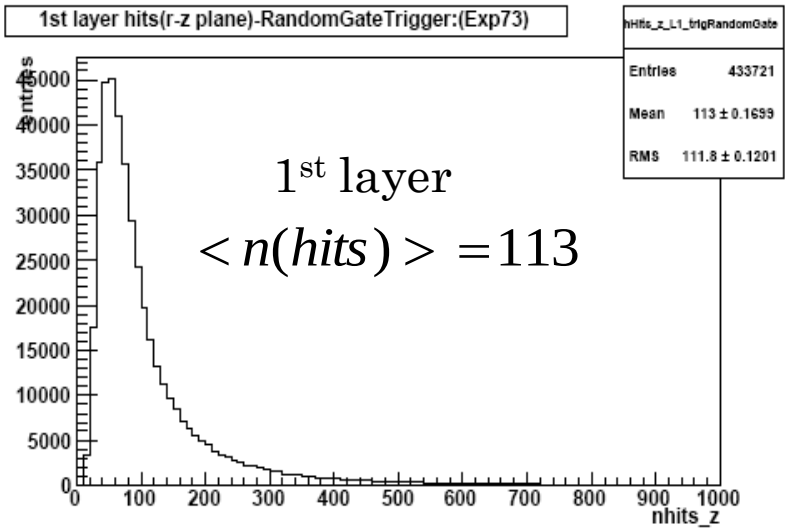
$$N_{KW}(Layer1) = 1.49$$

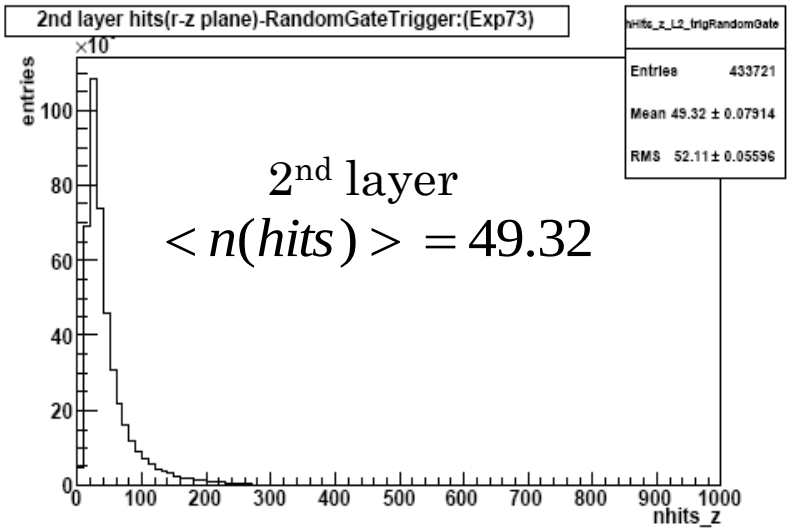
combined

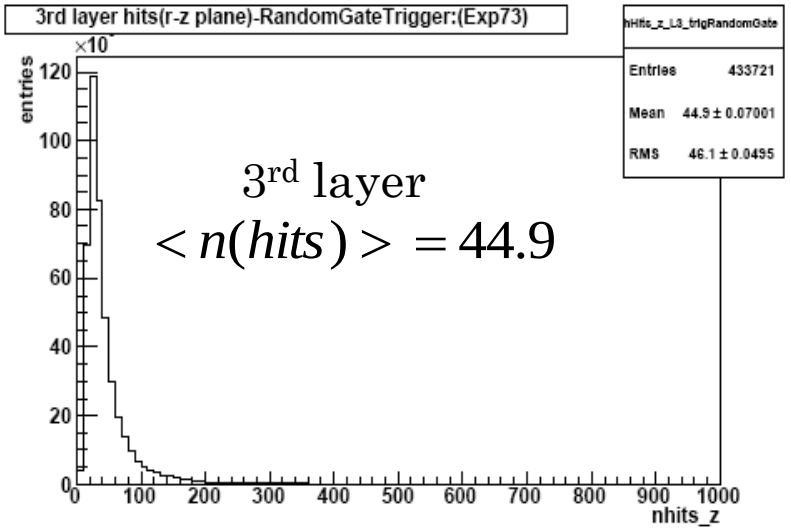


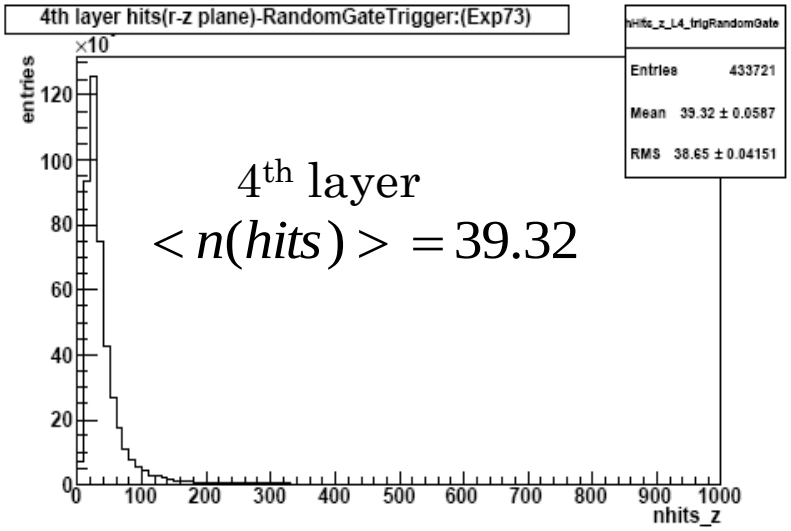
Use also the higher layers

Z strips



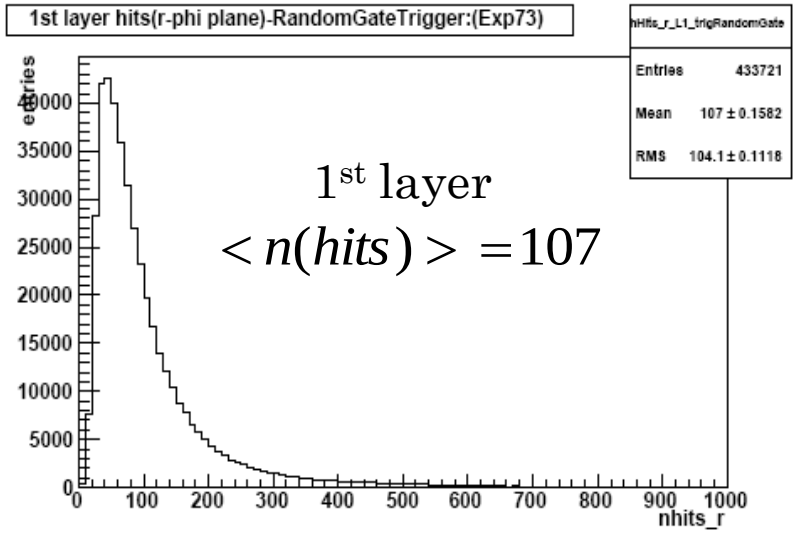


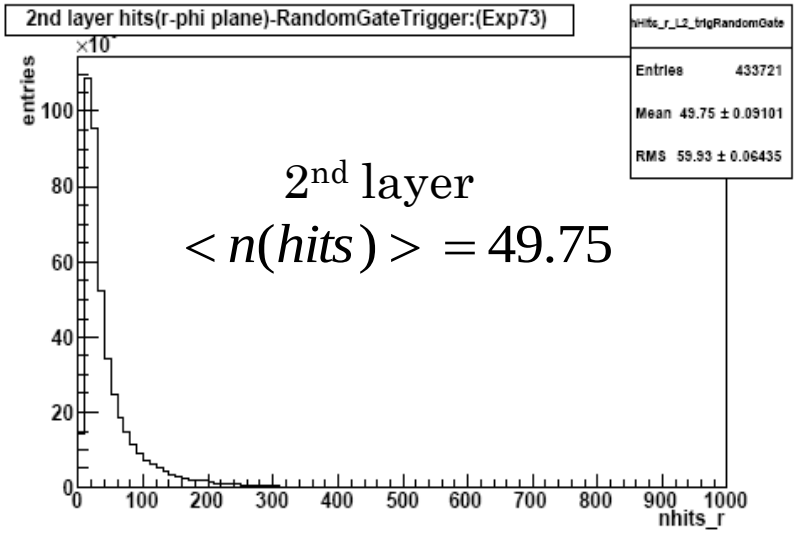


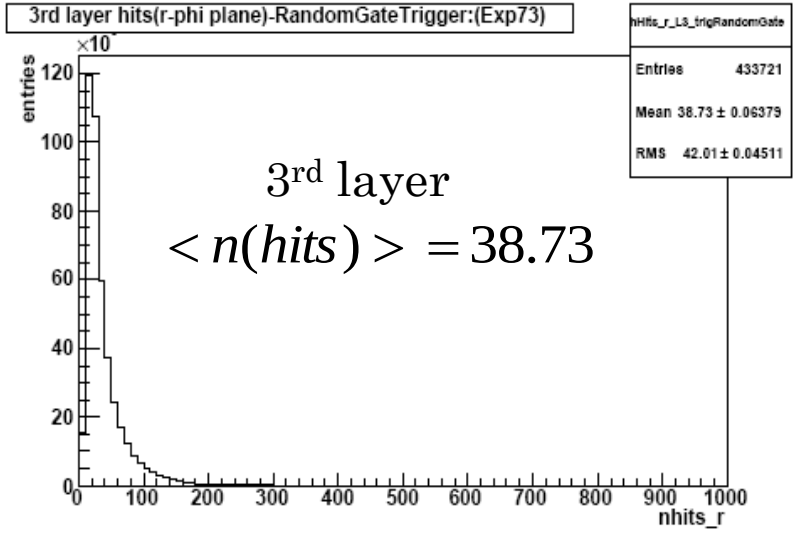


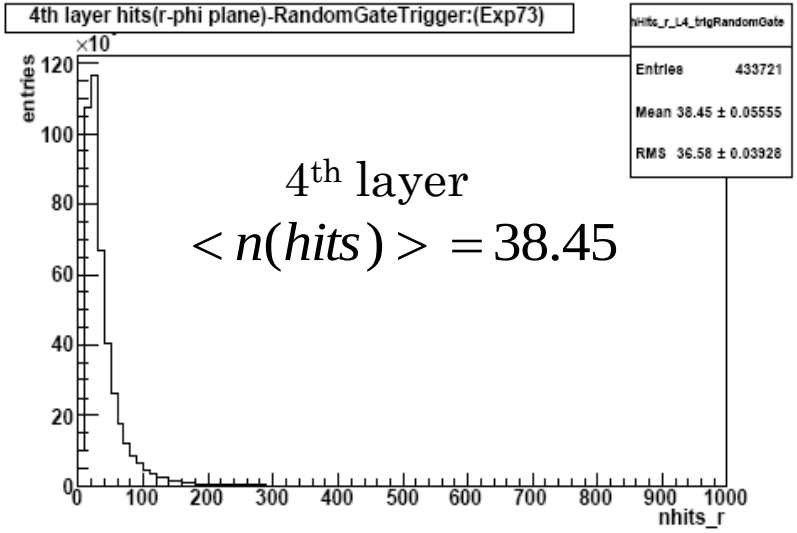
And the phi strips

Phi strips



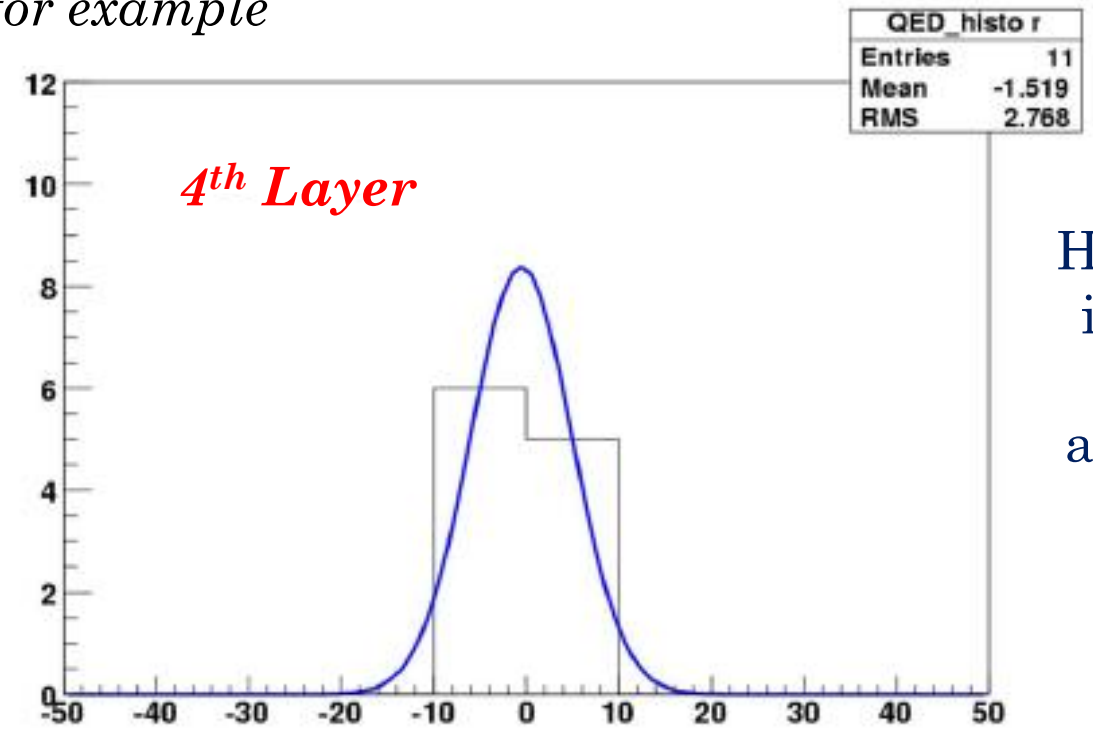






Analysis strategy outcome – Higher Layers

for example



Higher layers can also be included but then QED expectation has to be averaged over the layers

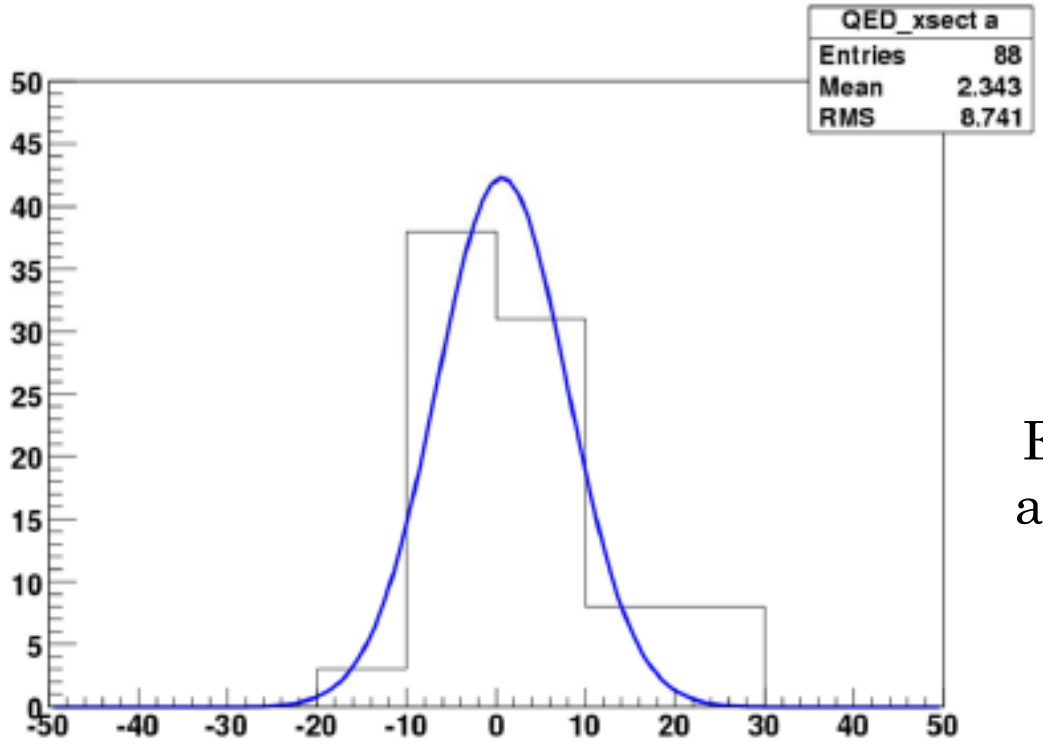
expected number of hits

From KW MC

SVD

- Layer 1: 1.49
- Layer 2: 0.52
- Layer 3: 0.33
- Layer 4: 0.26

All Layers Combined



Combined all layers for both phi and z strips

Gauss – Fit including all layers:

$$N_{hits} = 0.7 \pm 7.3$$

Expected hits from KW averaged over all layers in the SVD

$$< N_{hits} >= 0.65$$

SuperB MC:

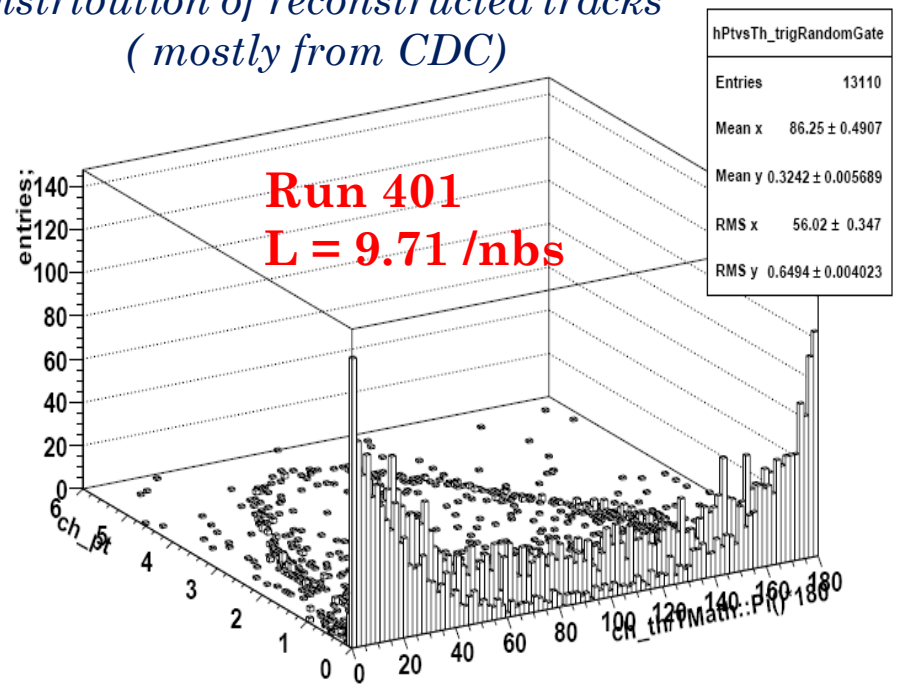
$$< N_{hits} >= 10.4$$

Next Steps

Try to improve CDC correction:

- exclude regions with unstable CDC current
- look at hit maps per wire layer
- improve the radial dependence to extrapolate into SVD region

Polar angle vs Pt
Distribution of reconstructed tracks
(mostly from CDC)



Later:

- use the track information to explicitly reconstruct QED events
- use full reconstruction:
  (analyze 2 – track events with vertex in random triggers)

Conclusions

- MCs give us very different answer for the QED background
- Three QED experiments were done at KEK to resolve the MC puzzle

  - Exp. B – increase vertical beam size in HER
  - Exp. A – separate the beams vertically
  - Exp. C – change bunch currents

- Background variation much more complicated
- Special correction in CDC current was applied
- Preliminary results points to a small contribution of QED consistent with our calculation
- Next steps are defined (we hope to exclude the SuperB's number better than 80%)