QED Background: Comparison of Data and Monte Carlo

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- Expected Background at Belle II
- QED expectations based on different MC generators
- Performed QED experiments at KEK
- Comparison between data and MC
- Summary and Conclusion

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Expected Background at Belle II

expected increase by a factor ***20***

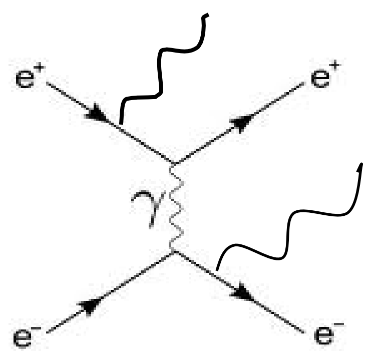
Machine background

- Beam – gas scattering (bremstrahlung and Coulomb scattering)
- Touschek effect (intra – bunch scattering) ← *this is main reason*
- Synchrotron Radiation

increase by a factor of ***40***
(due to luminosity)

Luminosity – related background

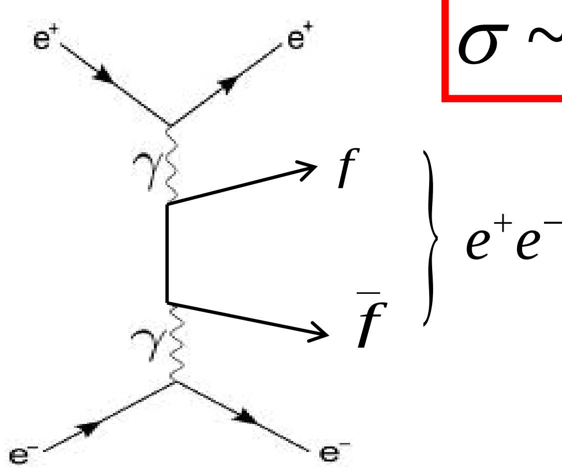
- Radiative Bhabha scattering



$\sigma \sim 50nb$

$\gamma\gamma$ reactions

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



2 photon (QED) processes

- to predict the situation for Belle II we need MC
- we have a set of three "standard" MCs
  - Berends – Daverfeldt – Kleiss (BDK)
  - S.Jadach et al. (KW)
  - J.Fujimoto et al. (Grace)

The answers from these three MCs are consistent amongst themselves

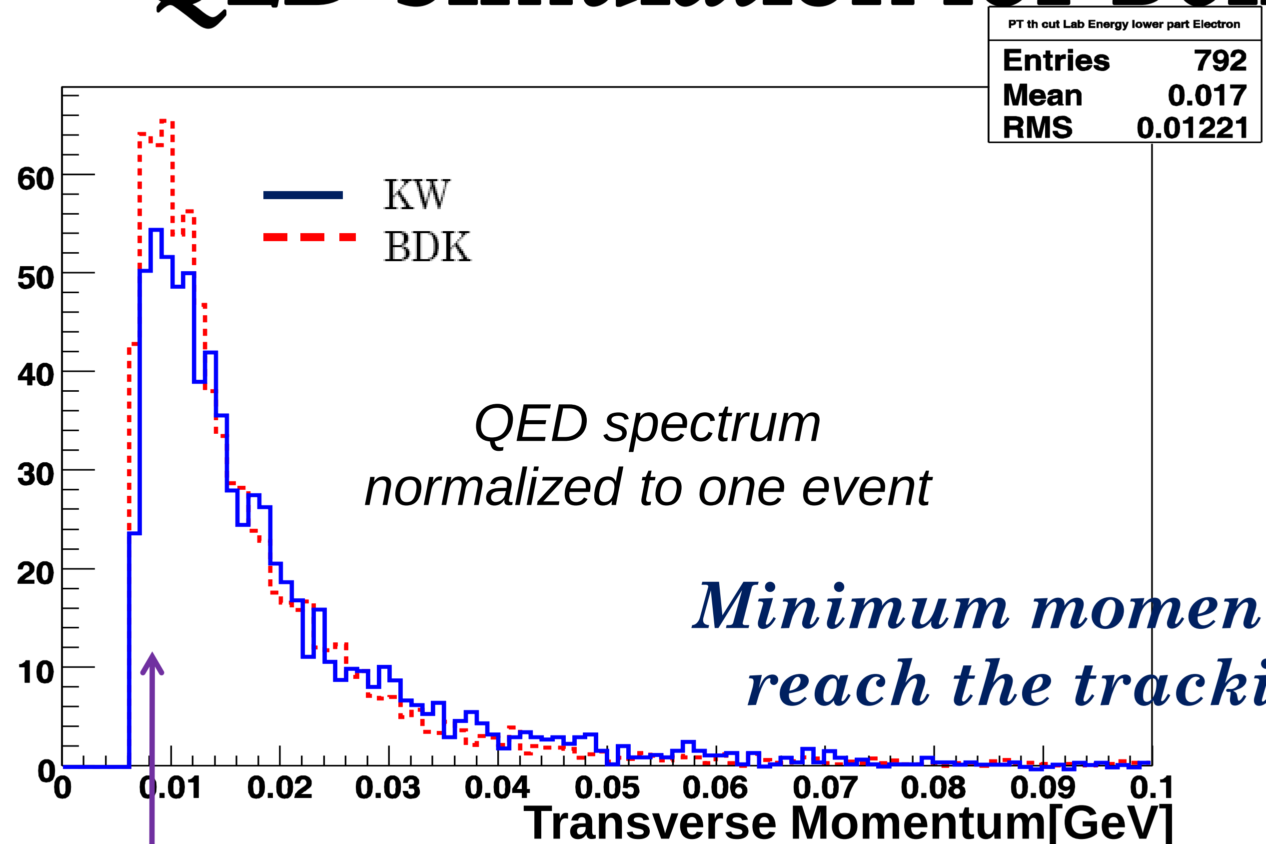
- BUT: there is also a prediction from SUPERB which deviates strongly

MC generator	**SuperB (BDK)**	**BDK**	**KoralW**
Tracks	13800	~ 710	~ 800
Occupancy	**1.3%**	0.07%	**0.1%**

a factor of 15 difference

Question: Who is right?

QED Simulation for Belle II



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

Minimum momentum needed to reach the tracking detectors

PXD : e^- with energy > 5.8MeV

SVD : > 40MeV

CDC : > 100MeV

Expected number of tracks from the consistent MCs is ~ 800

What do we expect?

DEPFET
Active Pixel Detector

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

- L ~ 1000 /nbs
- Integration time = $20\,\mu s$ **(PXD)**

Scale to **KEKB**:

Factor 1000 less

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

Assumption that 1 track makes only 1 cluster:
3 hits/track

Belle

0.8 tracks/SVD frame

SuperB MC : **13 tracks/frame on average**

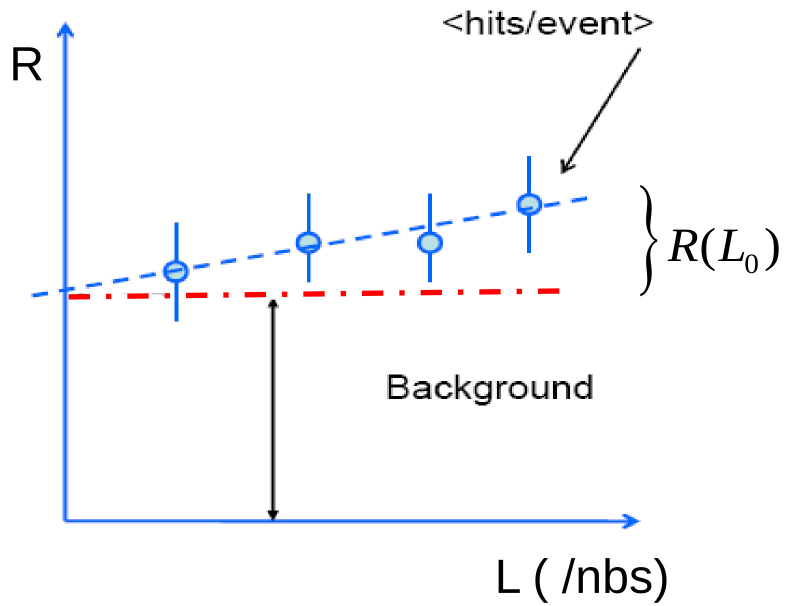
(radius correction included)

QED Background Runs

Real data to solve the MC puzzle

- ➢ A few MeV cannot be triggered at Belle

Random Triggers (unbiased background)



IDEA:

- ➢ vary luminosity
- ➢ look at change in # hits in SVD
- ➢ extrapolate to L = 0 to estimate non – QED machine background

Background events generated by 3 sources:

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

depends only on luminosity and not on the particular beam setting

Performed QED experiments

DEPFET Active Pixel Detector

Random Trigger Runs and Data Sample :

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

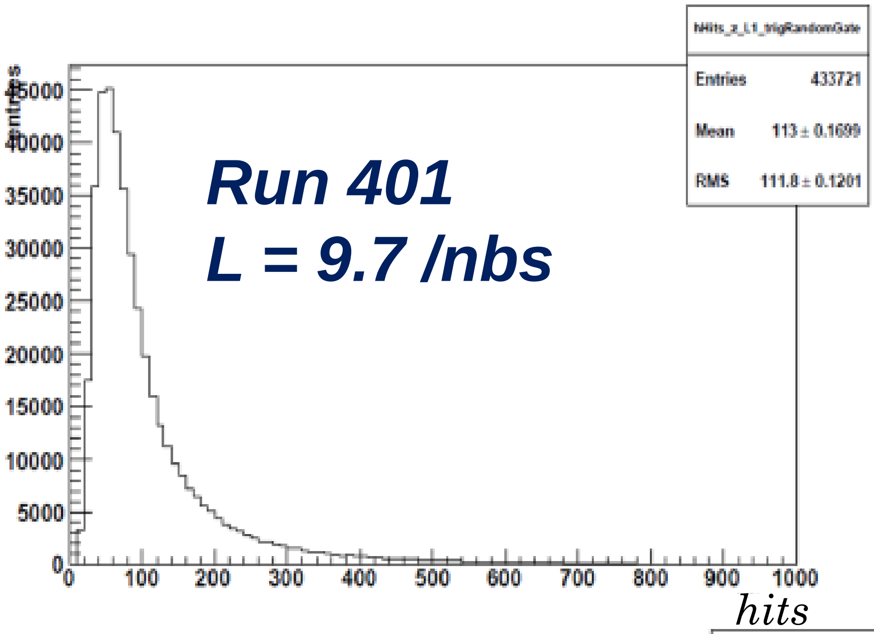
Exp. B (**increase vertical beam size in HER**)
Run (401 – 411) each run 500 k trigger

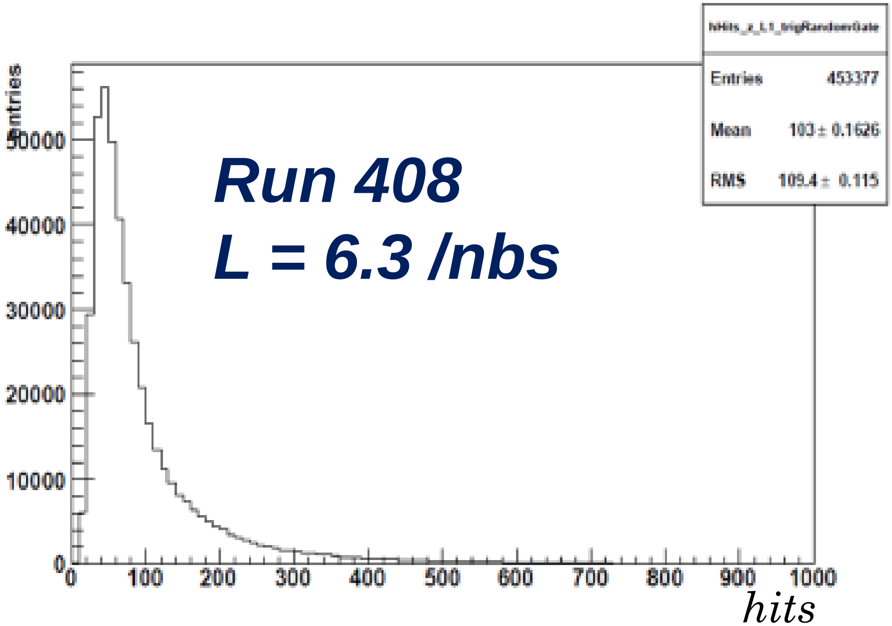
Exp. C (**change beam currents by stopping injection**)
Run (421 – 427) each run 10 min

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

Luminosity Change





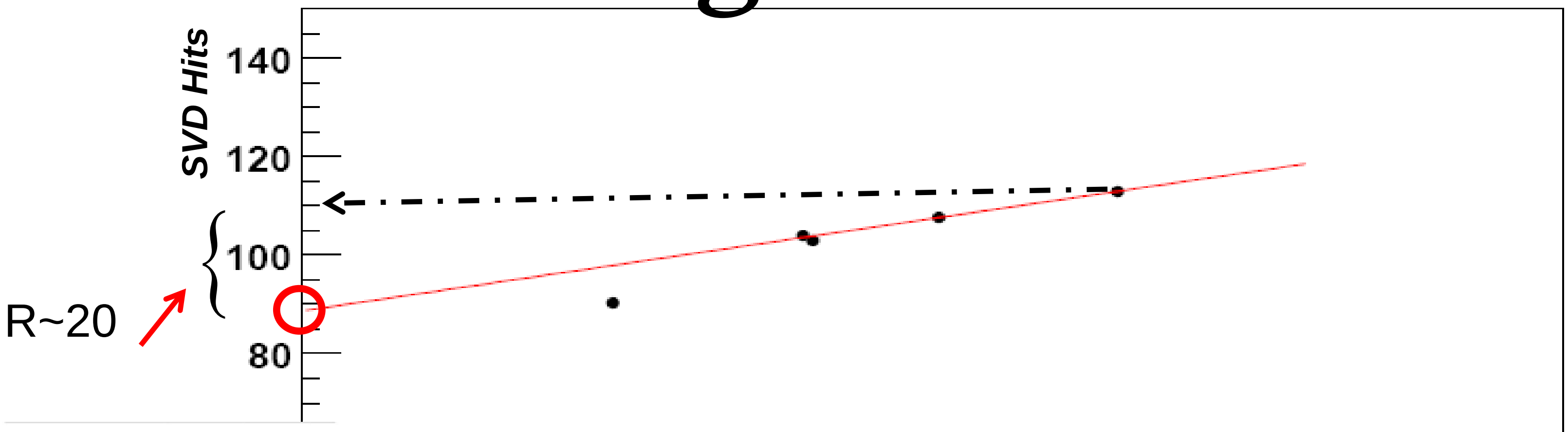
SVD hit multiplicity in the 1st SVD layer

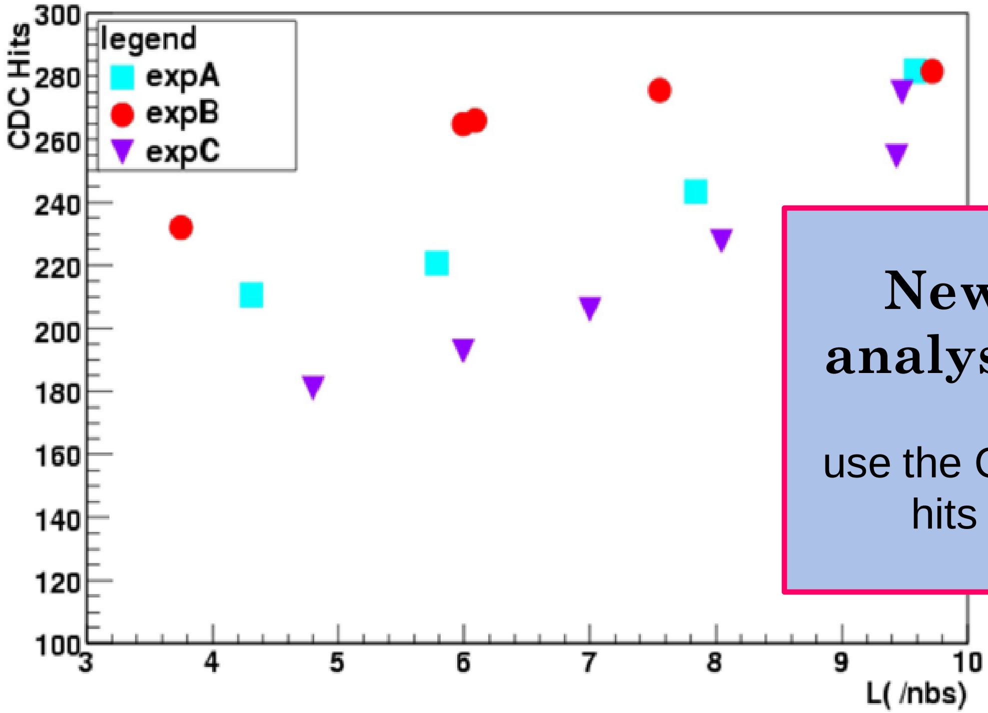
$$R = < N_{hits} > = 113$$

Hit Rate decreases

$$R = < N_{hits} > = 103$$

Luminosity Of Observed Background Hits



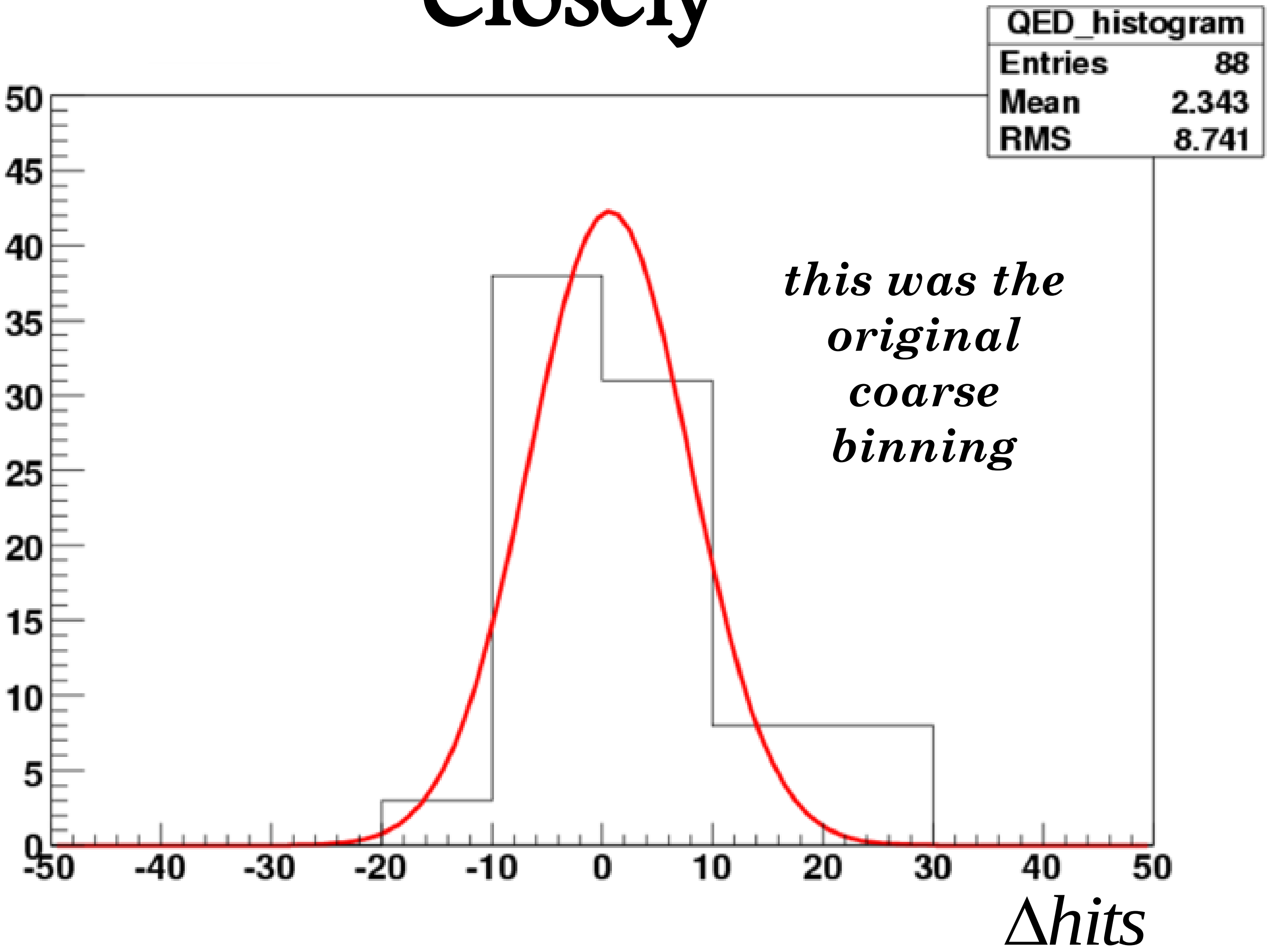


New analysis:

use the CDC hits

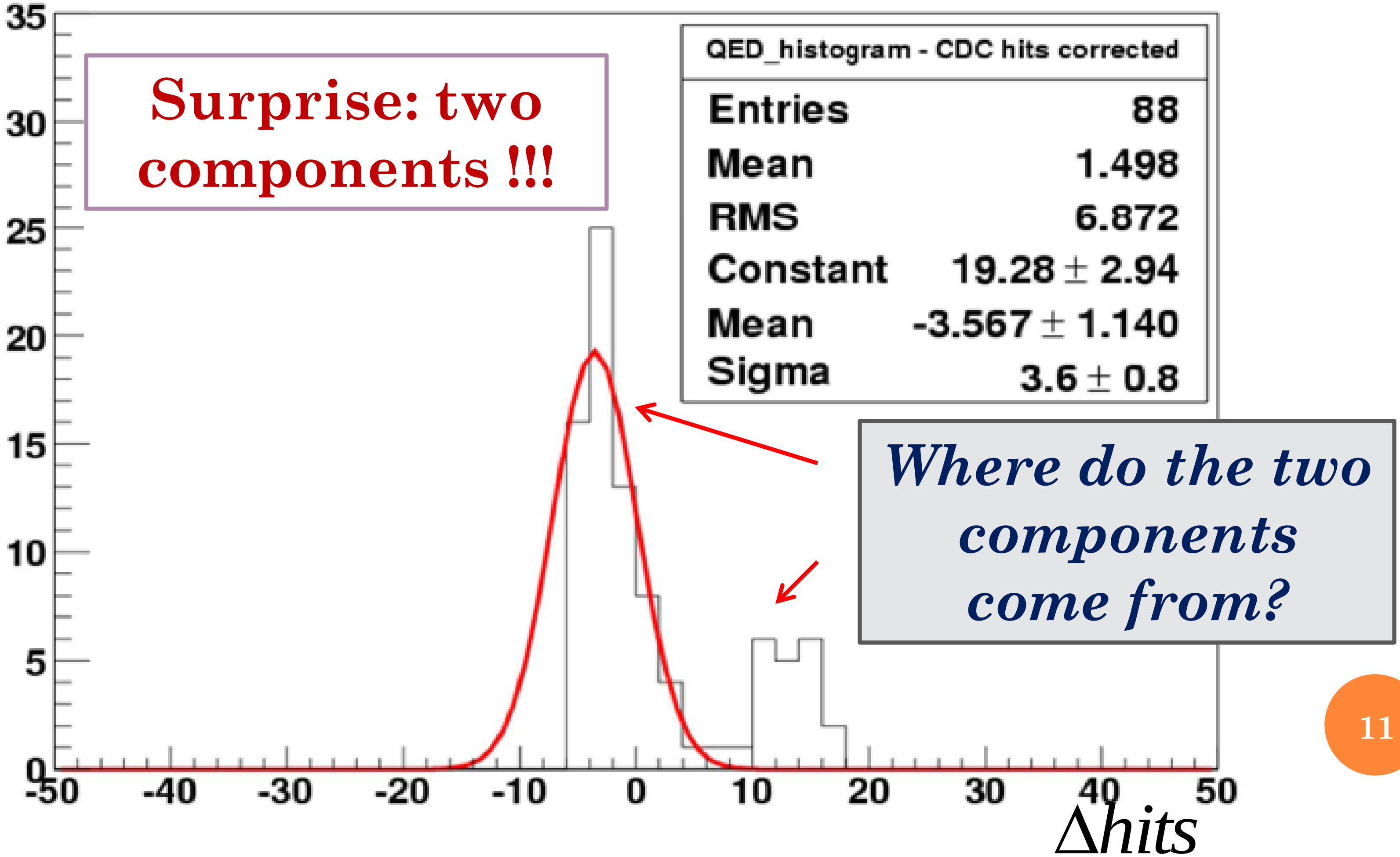
old analysis :
correct by the CDC current

Look Into SVD Hits More Closely



Observed Increase In Number Of Hits For All Measurements

- *All Layers and All Experiments included*



Origin Of The Big Peak

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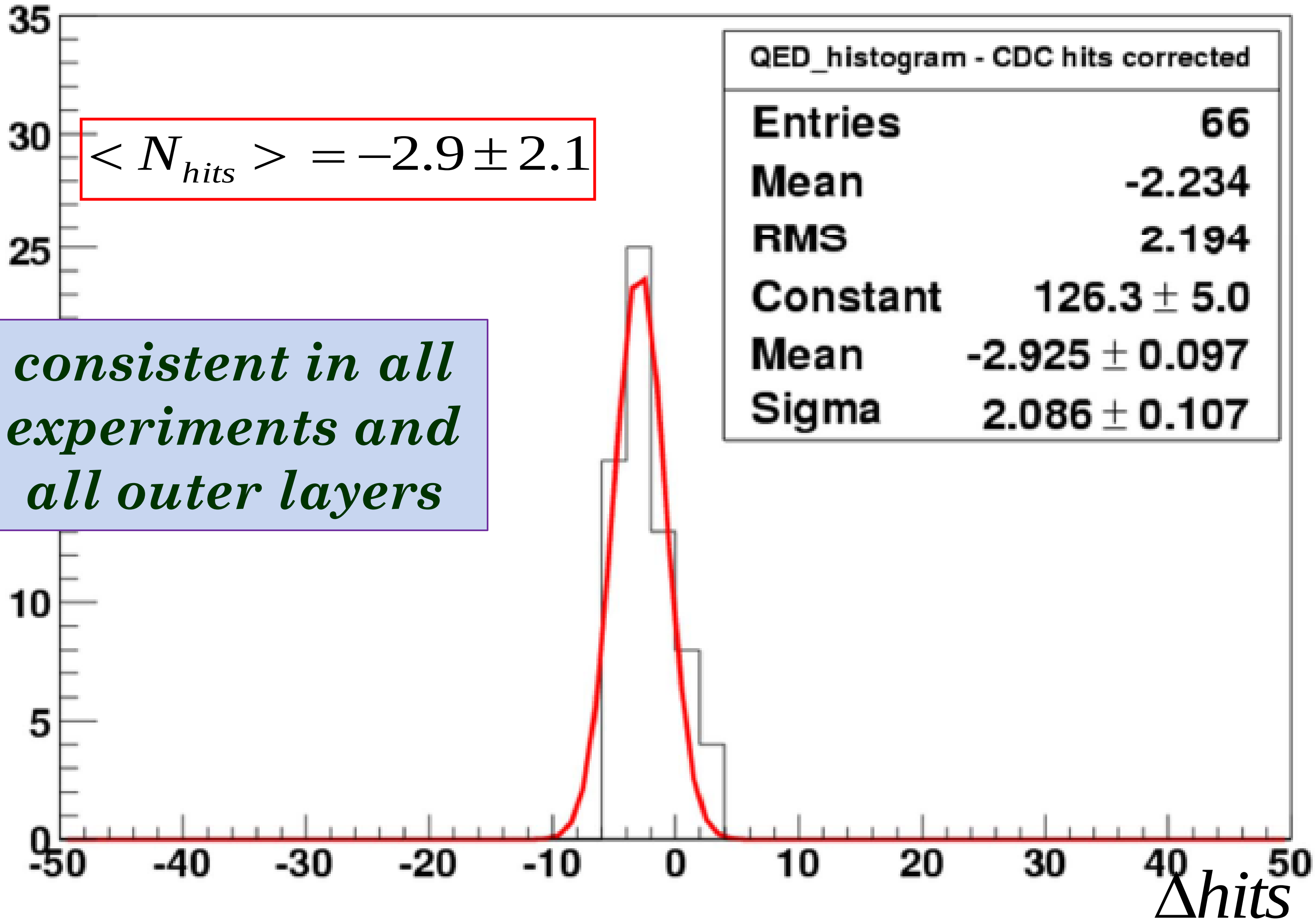
2^{nd} - 4^{th} SVD layer - all experiments included

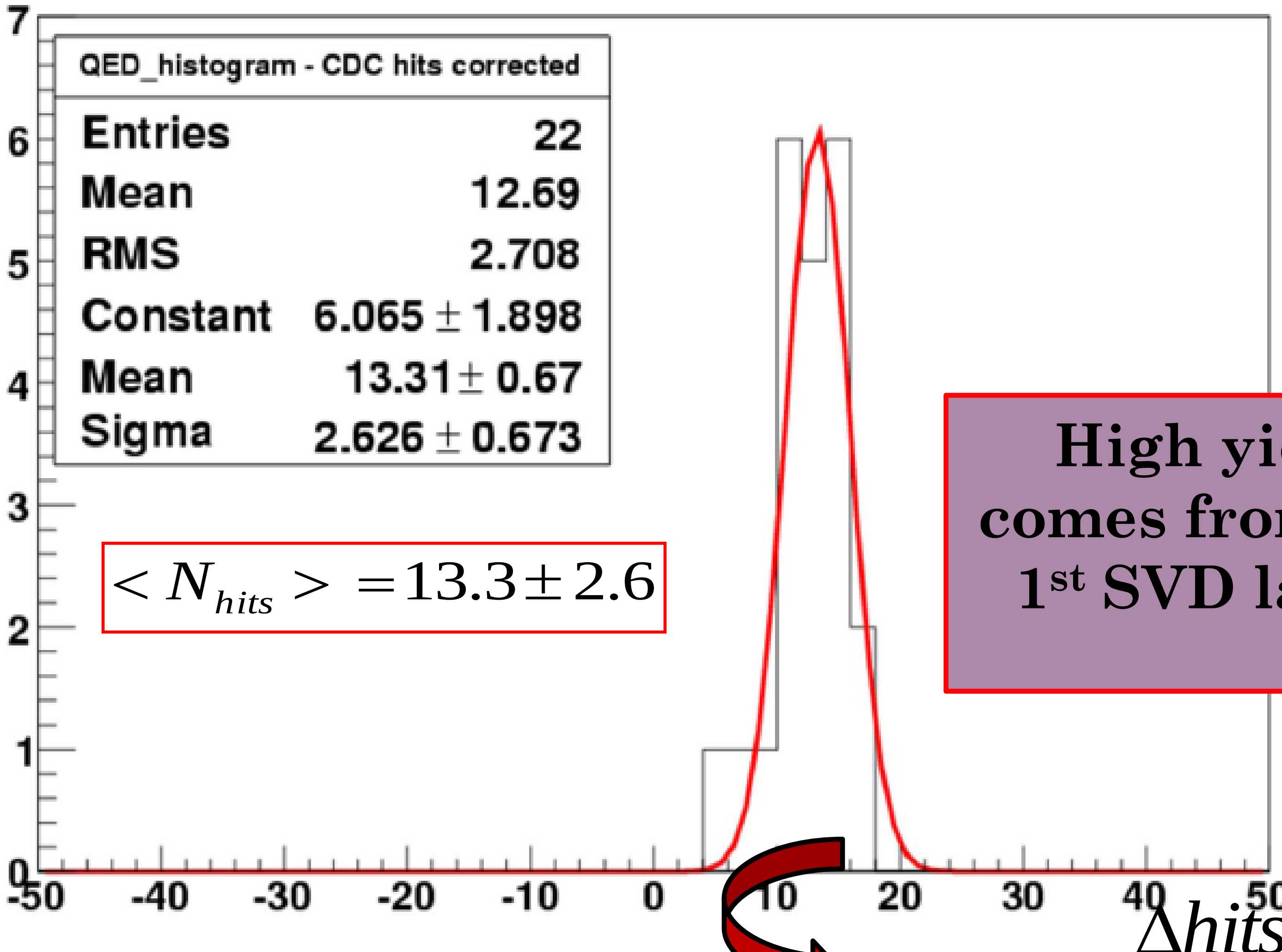
$< N_{hits} > = -2.9 \pm 2.1$

consistent in all experiments and all outer layers



Origin Of The Small Peak

1st SVD layer - all experiments included



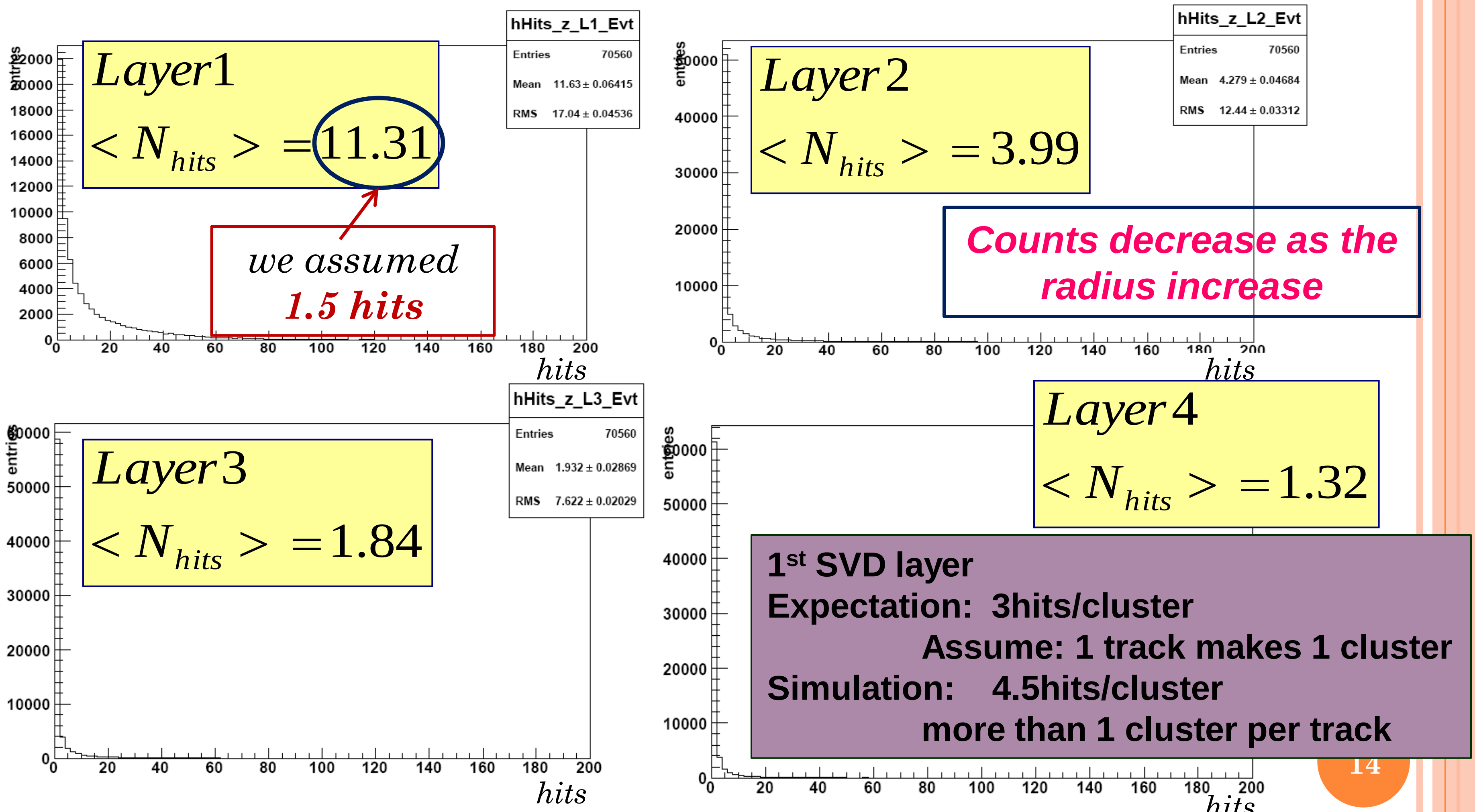
High yield comes from the 1st SVD layer

Can Layer 1 peak come from QED?

Use Full Detector Simulation

DEPFET Active Pixel Detector

- *to determine how many hits a track produces in each SVD layer*
  - SVD hit multiplicity – z strips (similar for φ strips)



1st SVD layer
Expectation: 3hits/cluster
Assume: 1 track makes 1 cluster
Simulation: 4.5hits/cluster
more than 1 cluster per track

Simulation shows discrepancy from naive expectation

Summary Of The Performed Measurements

In layer 1 measured : $< \Delta hits > = 13.3 \pm 2.6$
In layer 2-4 measured : $< \Delta hits > = -2.9 \pm 2.1$

Observation can be explained when looking at the full detector simulation:

- predicts in layer 1 < #hits > = **11.31** per QED event
- predicts in layer 2-4 < #hits > = **2.38** per QED event

Conclusion:
the observation for layer 1 and layer 2 – 4 are consistent and in agreement with the full MC Simulation

Comparison Between Data And Monte Carlo

DEPFET
Active Pixel Detector

Naive Expectation

Assume :

1 track makes 1 cluster

MC generator	SuperB (BDK)	BDK	KoralW
Tracks	13800	~ 710	~ 800
Occupancy	**1.3%**	0.07%	**0.1%**
Hits	**24**	**1.1**	**1.5**

MC vs. Data	SuperB (BDK)	KoralW	Data	
			average	delta
Hits (1st SVD layer)	181	11.31	~ 100	13.3
Hits (2nd – 4th SVD layer)	38.1	2.38	~ 45	~ 0
Occupancy (1st SVD layer)	**5.5%**	**0.3%**	**0.4%**	

1 QED track makes more than 1 "curlers"

Still far away from the limit of 2 %

The expectation form SuperB is completely excluded

Summary and Conclusion

- Strong discrepancies in MC predictions for QED Background between Belle II and SuperB

- Use measurements with different beam tunings to extract QED background hits in SVD2

- Measurements show additional luminosity – depended background which is also seen in CDC

- Δhits for layer 1 of SVD2 very different from naive expectation (outer layers in agreement)

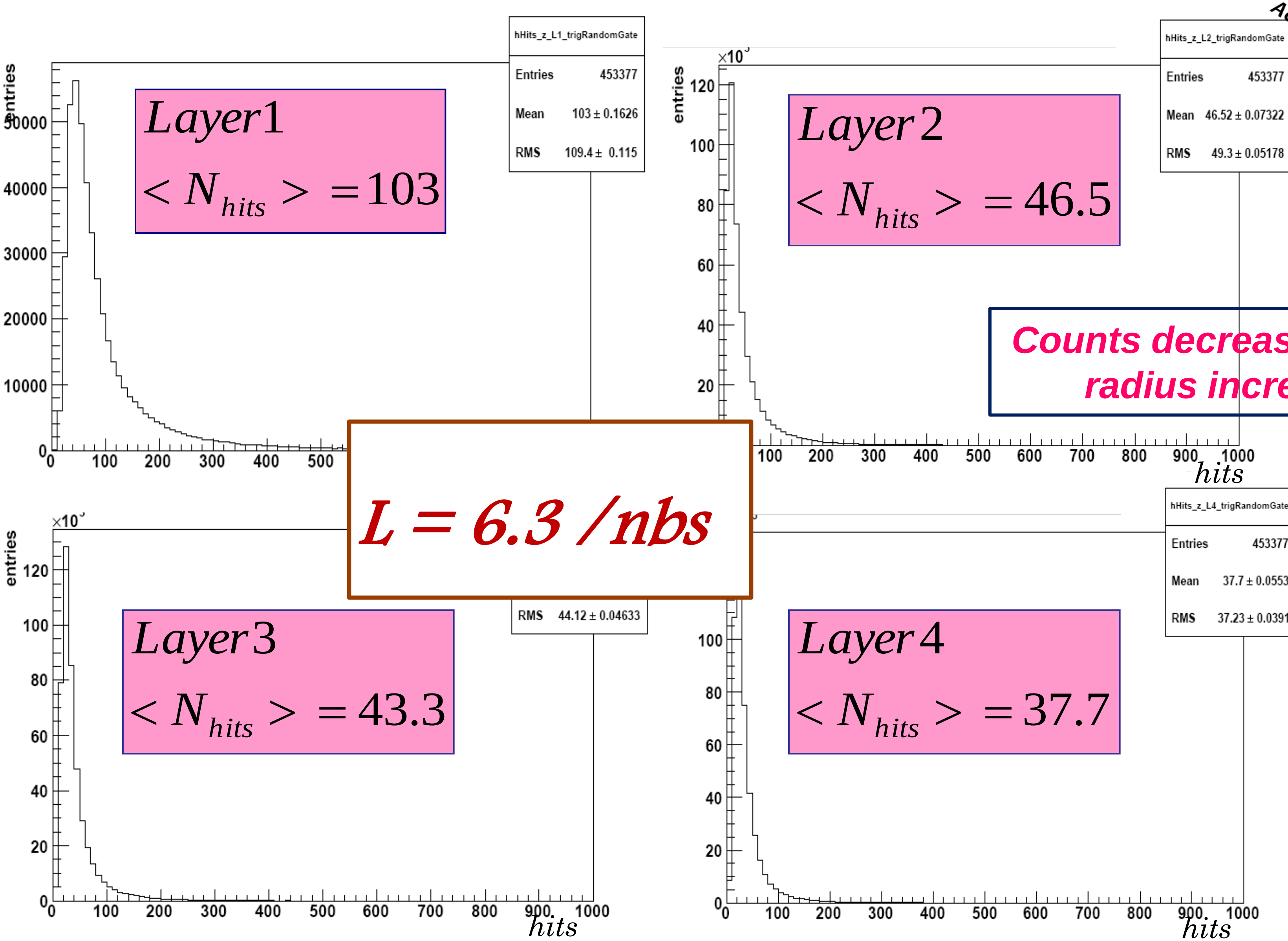
- Full MC simulation explains this observation and gives consistent picture of measurements

- expected occupancy for layer 1 rises to 0.3 %

- Comparison of measured Δhits with predictions of different MC generators again allows complete exclusion of SuperB prediction

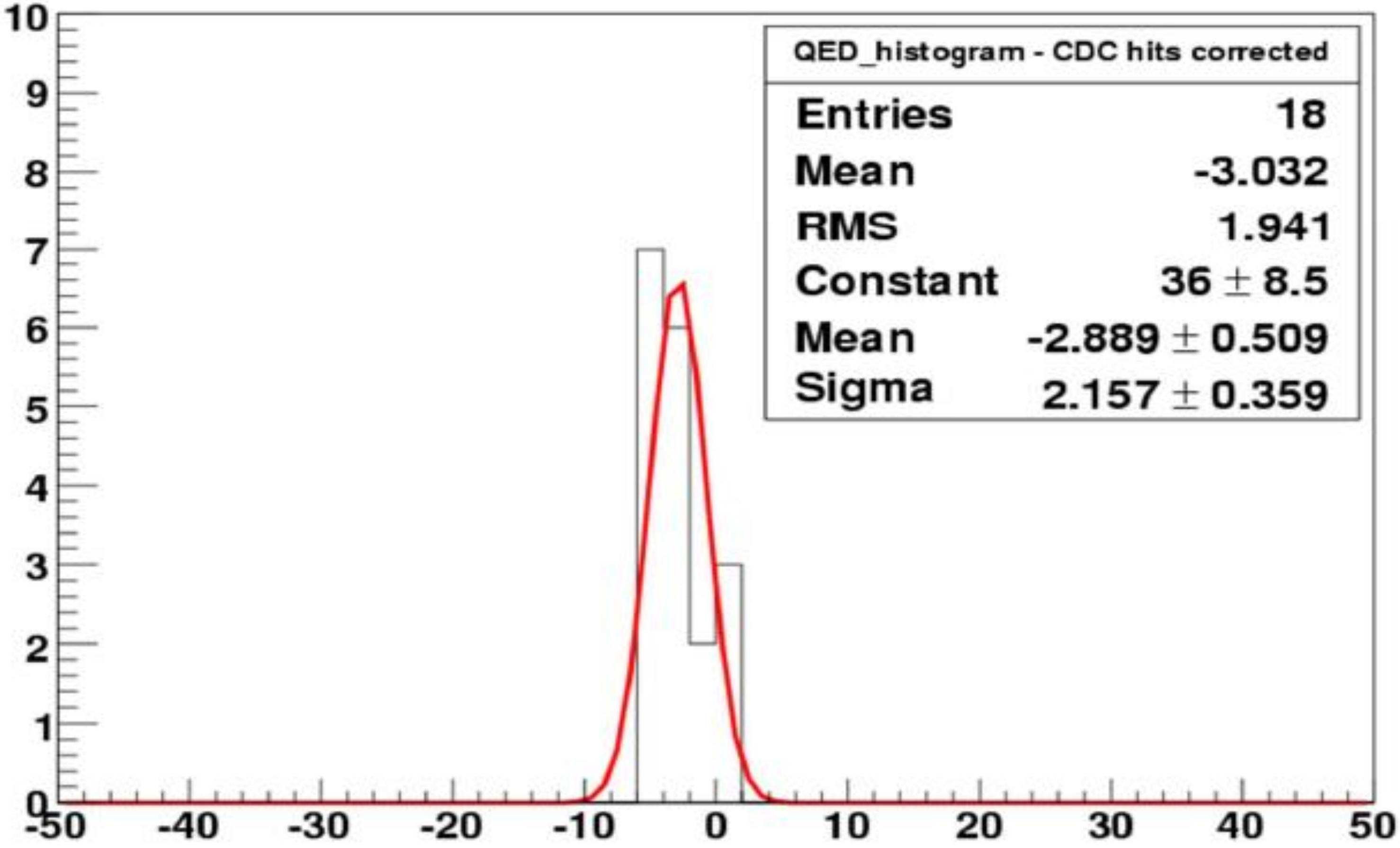
Experiment B – Run 408

- SVD hit multiplicity – z strips (similar for φ strips)



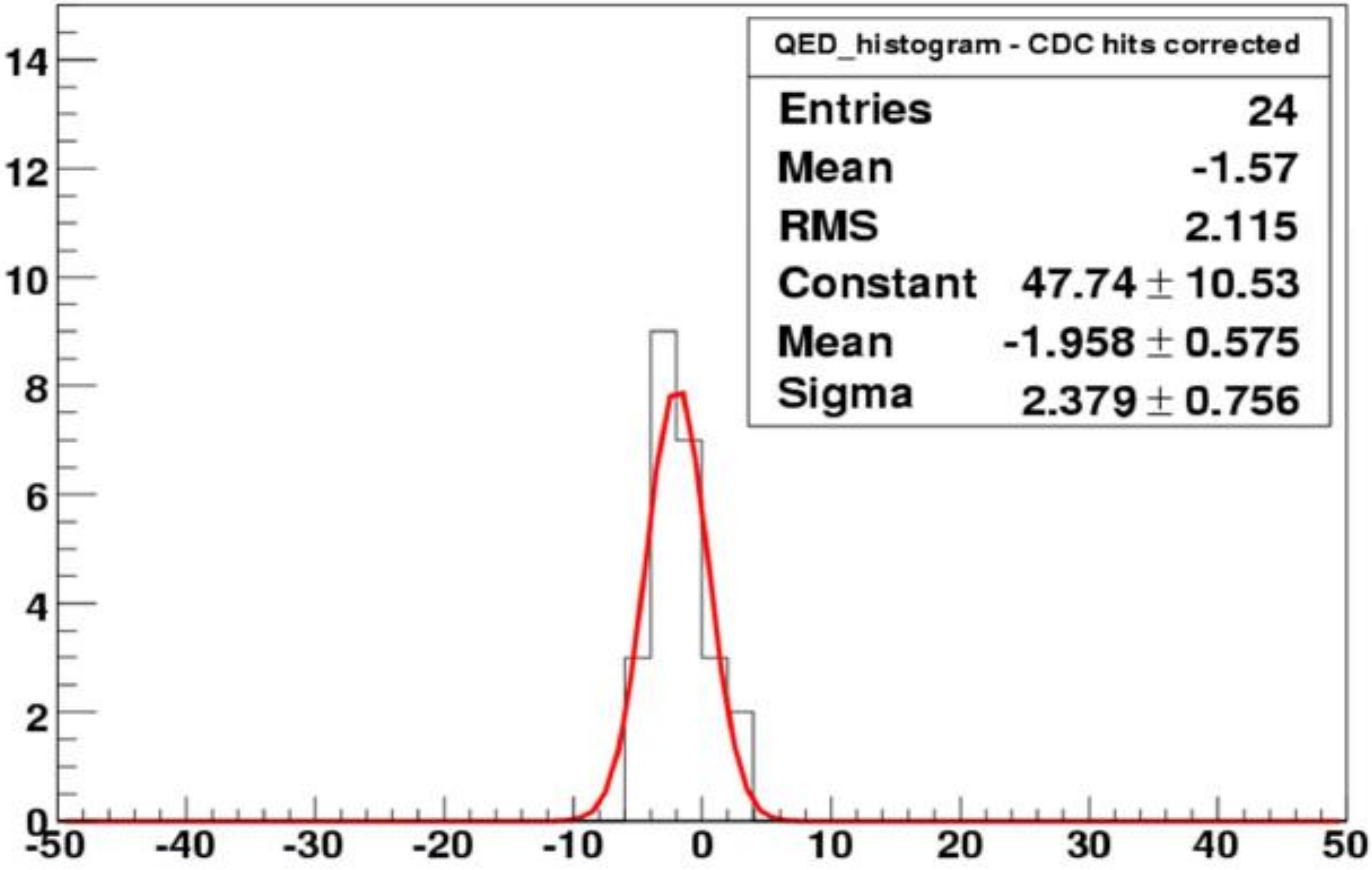
CDC Hits Corrected SVD Hits

➢ 2^{nd} – 4^{th} SVD layer – Experiment A



CDC Hits Corrected SVD Hits

- 2^{nd} – 4^{th} SVD layer – Experiment B



CDC Hits Corrected SVD Hits

- $2^{nd} - 4^{th}$ SVD layer – Experiment C