Physics Studies for the PXD Optimisation

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Content

- Master plan for optimization study
- Reminder: Physics channel
- Establish baseline for optimization study
- Optimization study: Physics
- Optimization study: Physics + Background
- Summary and Conclusions

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Master Plan for Optimization Study

as presented in Barcelona

A.) Establish analysis chain in Belle framework: BASF

well-proven tool box for Physics analysis in Belle

1. Generate events (EvtGen)
2. Simulate events (Belle Geometry)
3. Analyze events (BASF / ROOT) *established for Barcelona*

B.) Implement analysis in ILC framework: Mokka/Marlin = LCIO

tool box for detector optimization studies

1. Interface EvtGen output
2. Simulate events with ILC framework setup for Belle geometry
3. Reconstruct decays (LCIO/ROOT)

Comparison of A and B establishes baseline for optimization study

C.) Rerun B.) for various Belle II detector (and beam) scenarios

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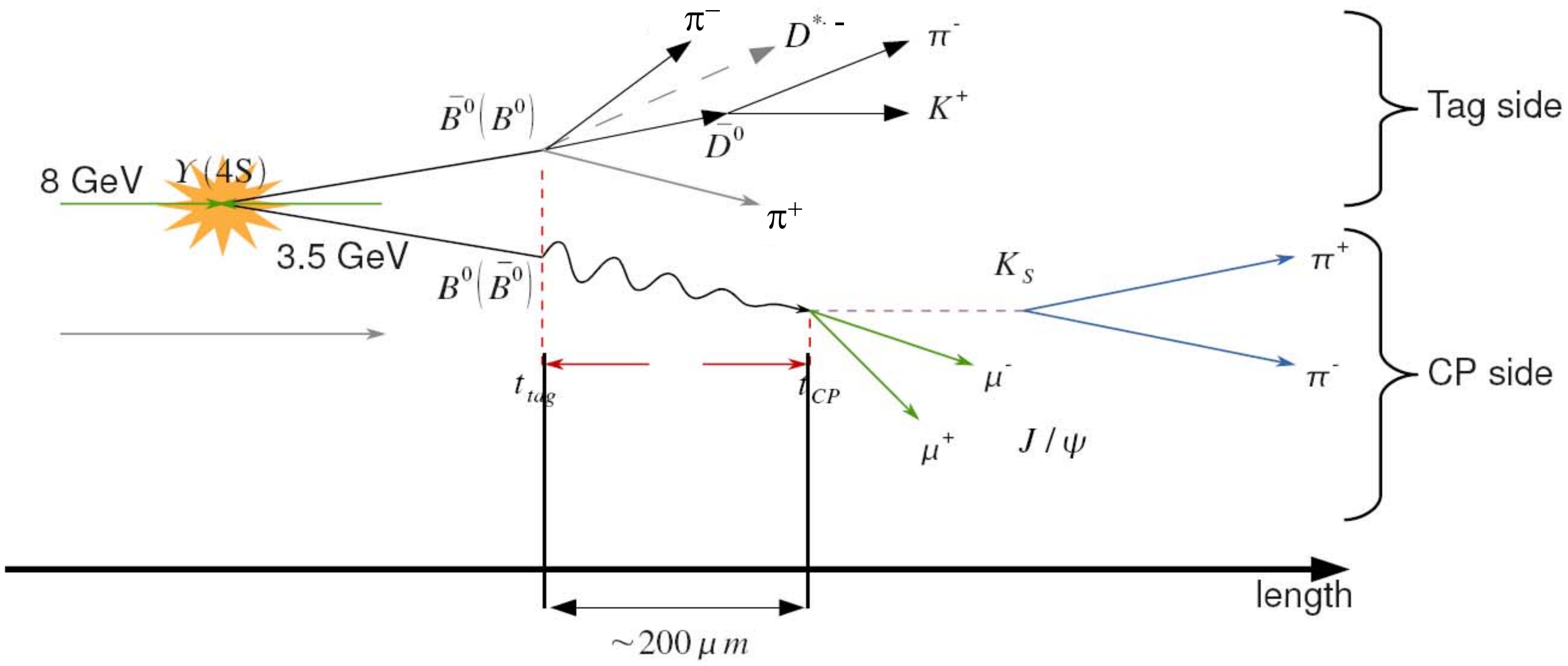
Introduction

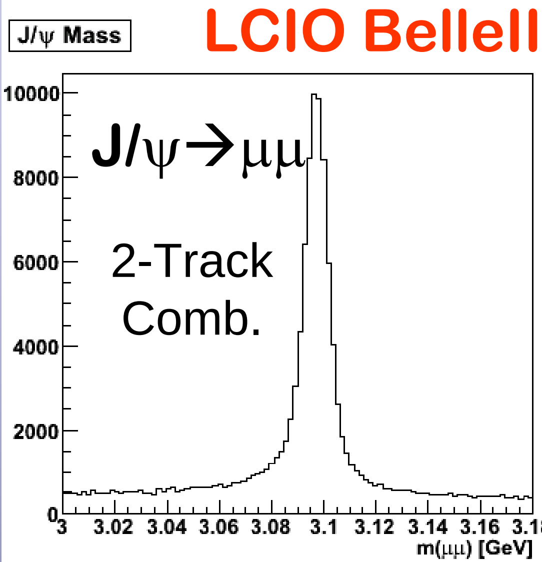
- Aim: Evaluate PXD options with realistic physics benchmark process
- Vertex resolution key to all CP violation measurements

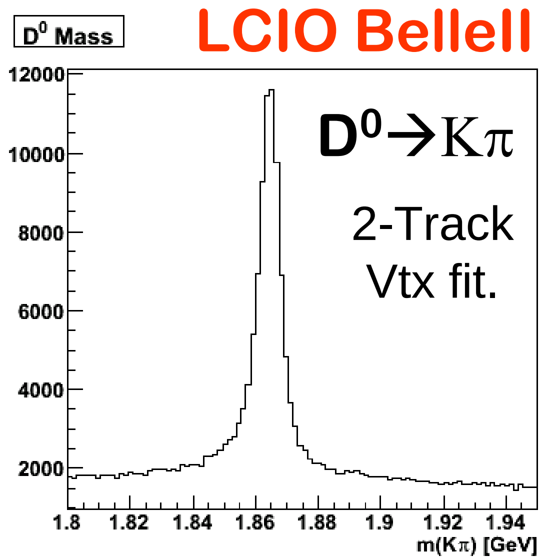
  ➔ Study “Golden Channel”:

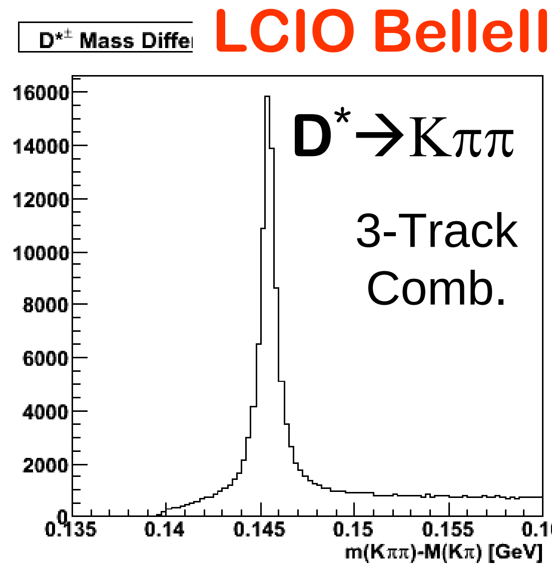


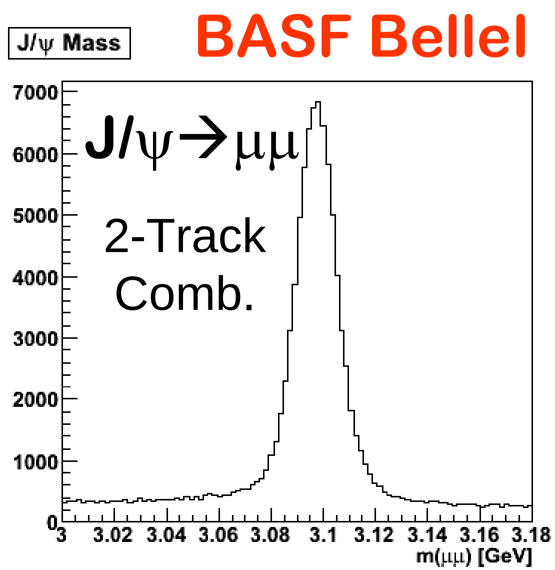
High precision vertexing essential for this type of measurements

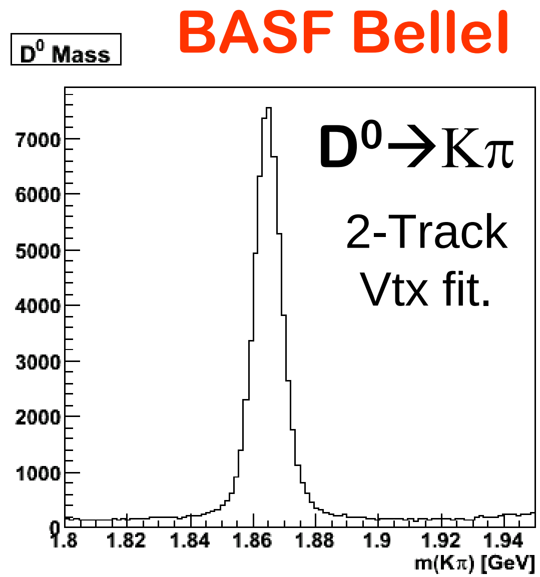
Reconstructed Decays

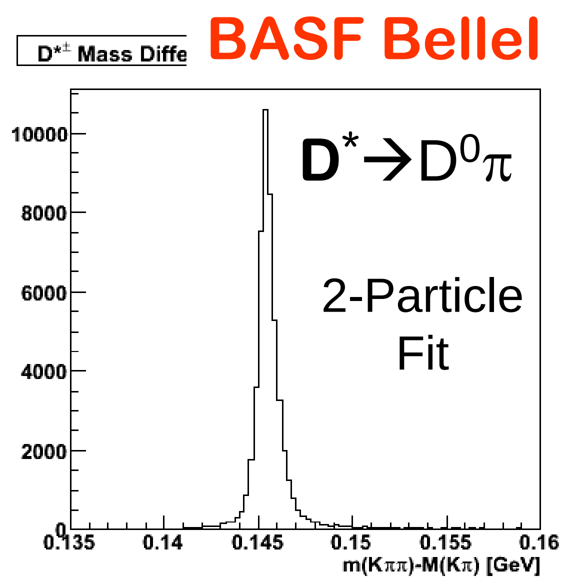












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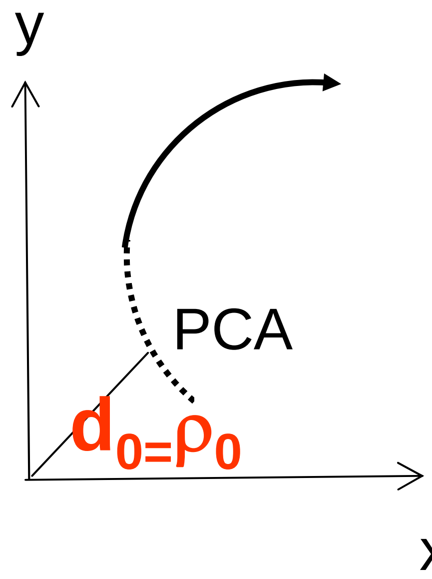
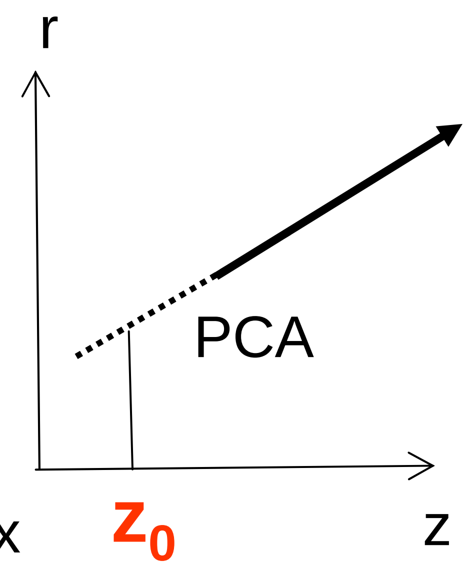
Track Impact Parameter Resolution

- Definition of impact parameters d_0 & z_0

PCA = point of closest approach
defined in x-y plane



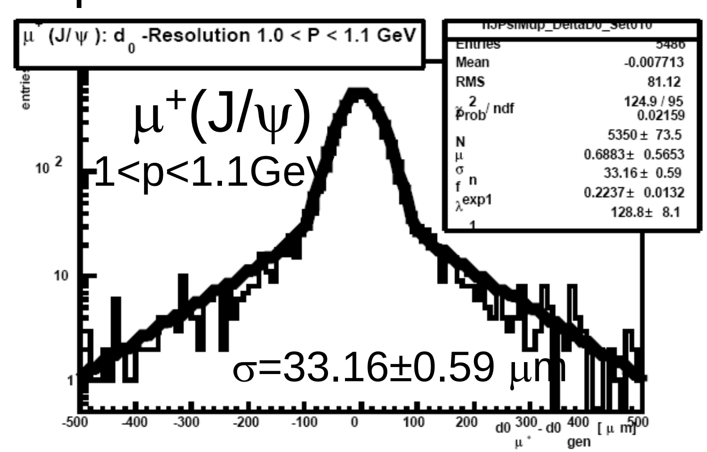


- Quantifying the resolution

$$\sigma_{vtx} = N\left\{\frac{(1-f)}{\sqrt{2\pi\sigma^2}}\exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)+\frac{f}{2\lambda}\exp-\frac{|x-\mu|}{\lambda}\right\}$$

Gaussian core — exponential tails

Example:



- Study resolutions of μ tracks from J/Psi decays

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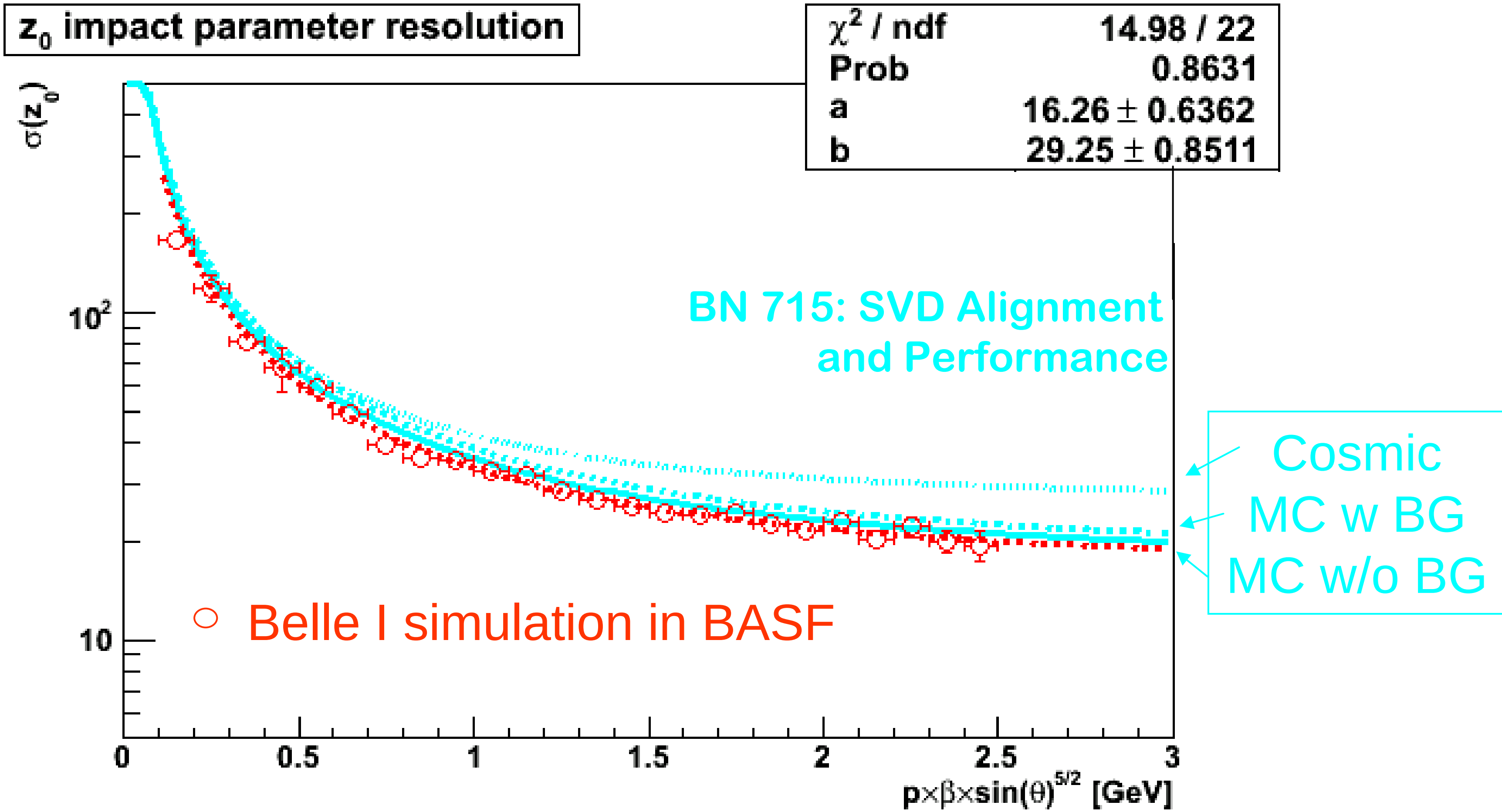
Z_0 Resolution within BASF



μ^+ from J/Psi decays

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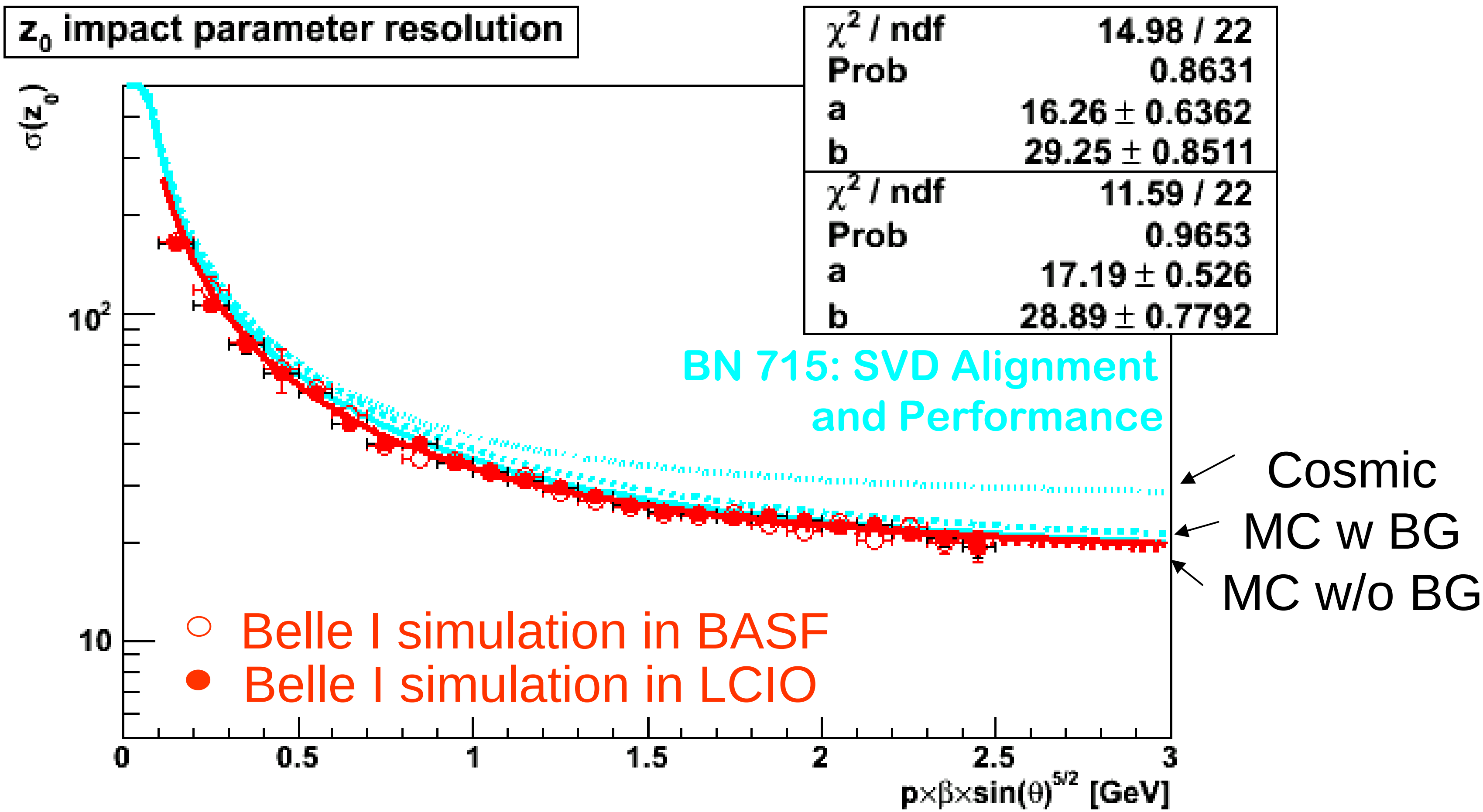
Z_0 Resolution within BASF & LCIO



μ^+ from J/Psi decays

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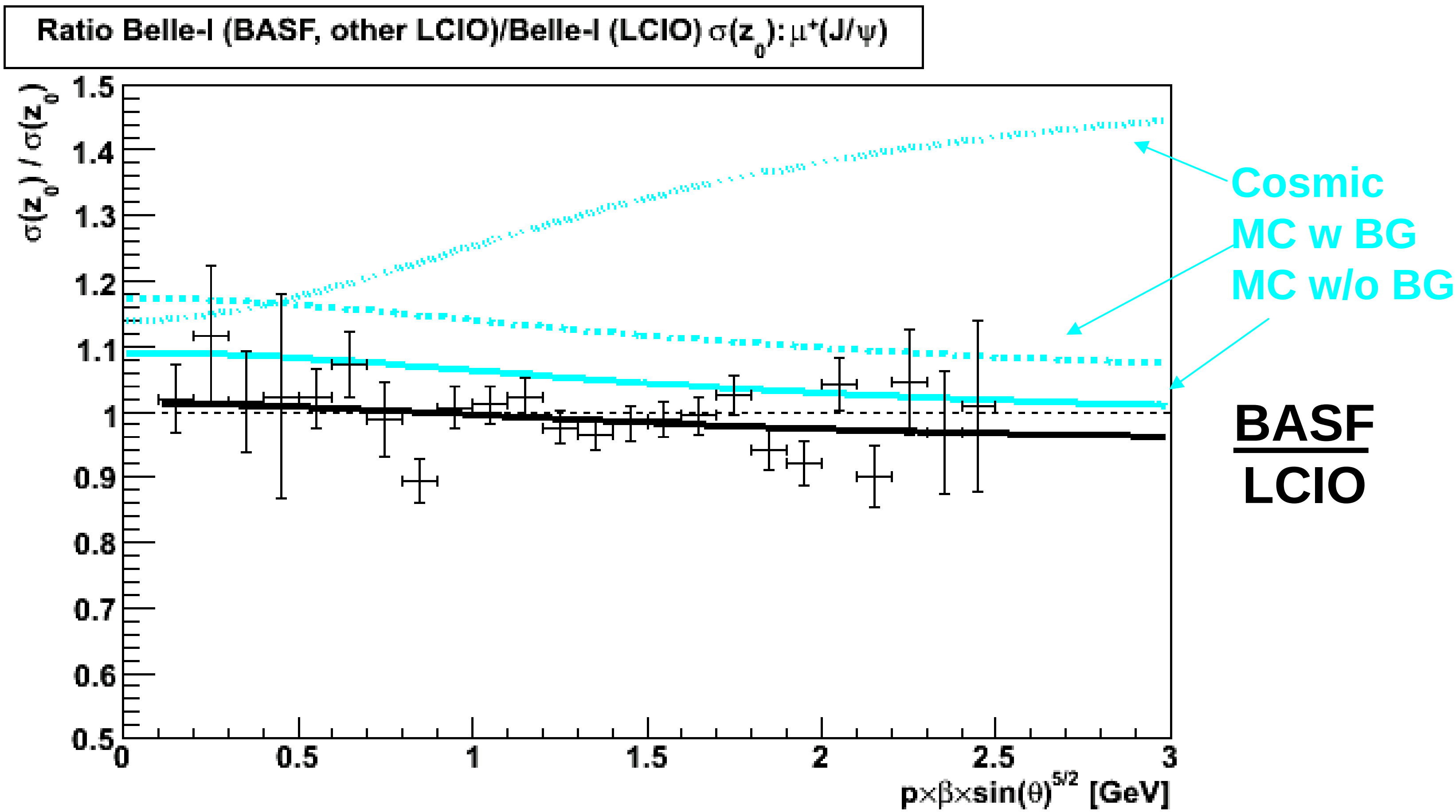
Comparison of Belle-I Simulations



almost perfect agreement between two independent simulations in completely different frameworks

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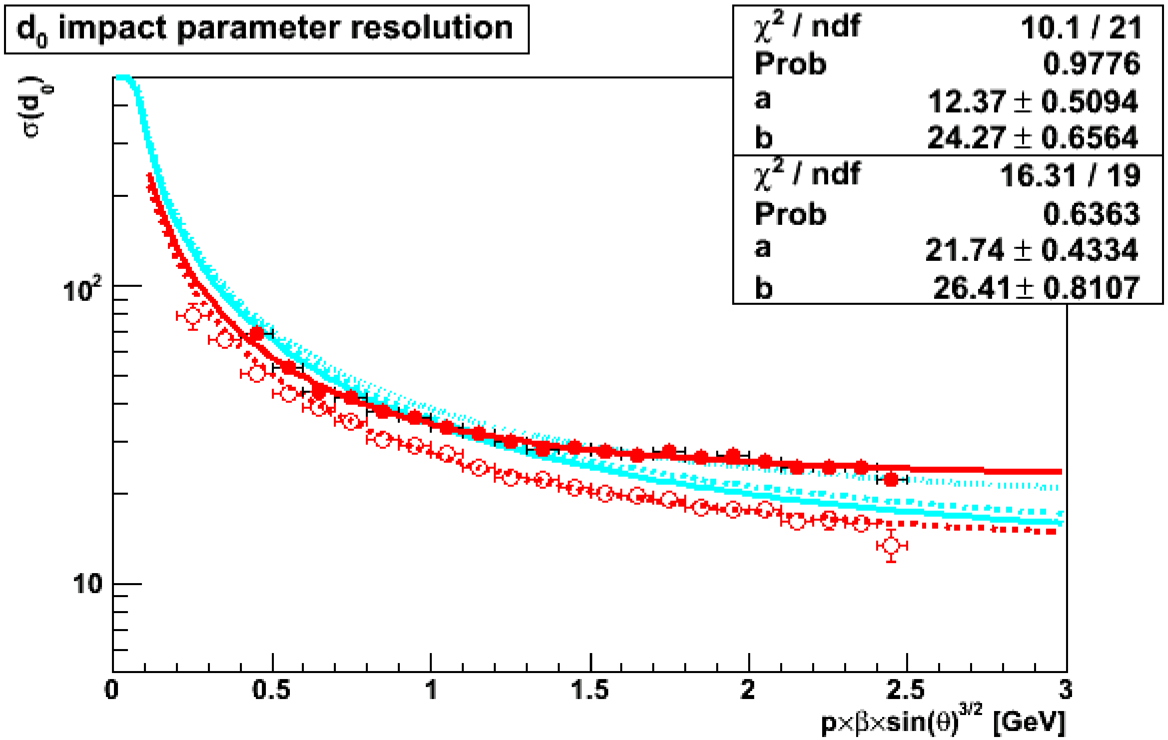
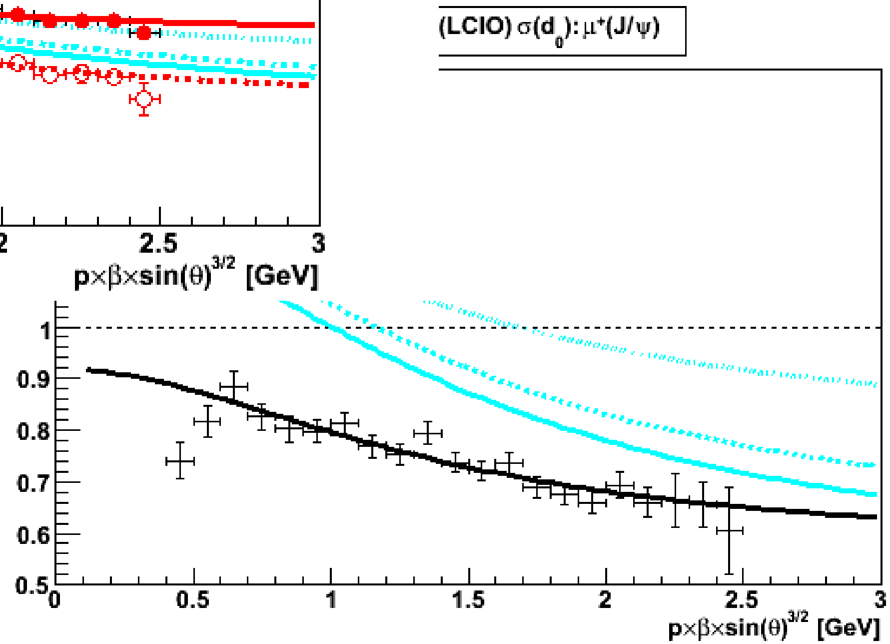
Comparison of Belle-I Simulations





d_0 impact parameter

d_0 resolution in LCIO not as good as in BASF

Conclusion at the B2GM 11/2009: still good enough for Optimization studies

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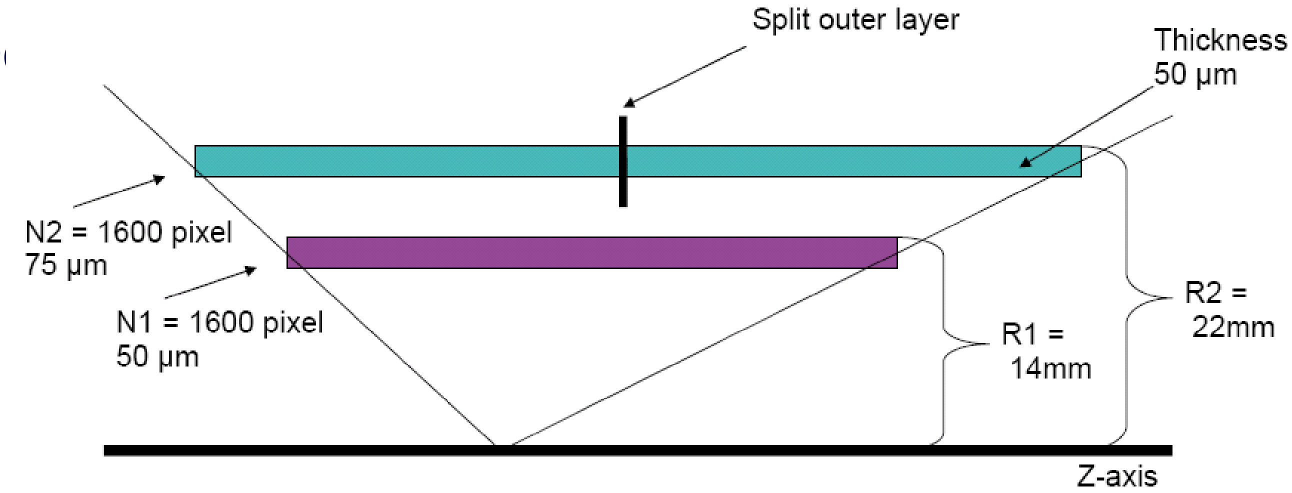
Baseline Setup

Beam: SuperKEKB nano-beam option:

4GeV e^+ on 7GeV e^-, crossing angle 83mrad, angle LER B-field 15.55mrad

Detector axis parallel to B- field

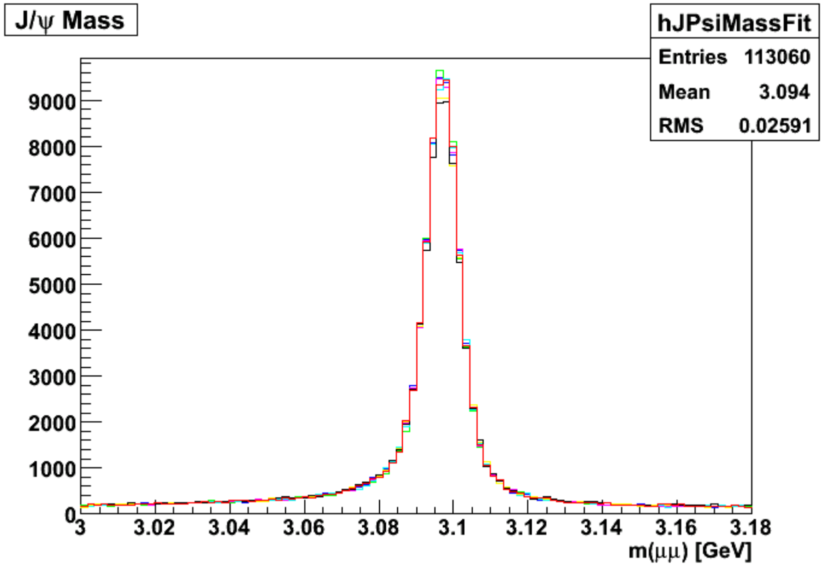
Baseline D

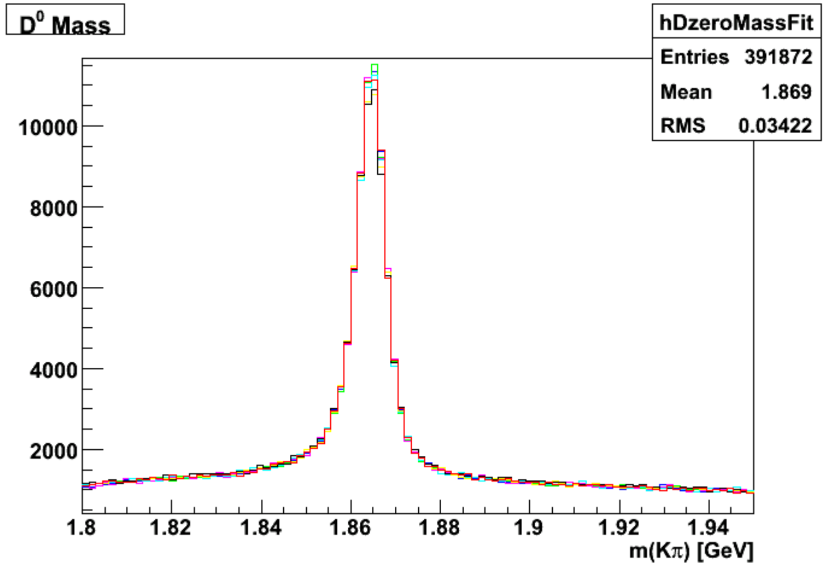


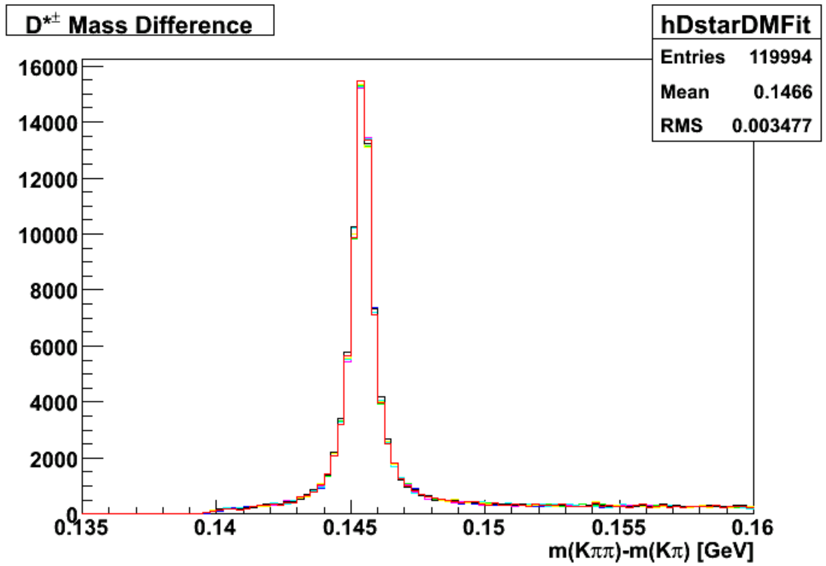
Detector Variations:

- Study 1: variation of inner radius R1 = 13 mm
- Study 2: variation of sensor thickness d = 75 um
- Study 3a: variation of number of pixels and readout speed N1 = 800 pixel
- Study 3b: variation of number of pixels and readout speed N1 = N2 = 800 pixel
- Study 4: break the inner layer
- Study 5: Optimal but still conceivable PXD) R1 = 13mm; N1 = N2 = 2000 pixel

Mass Plots







- J/ψ and D^0 Masses and D^{*+} mass differences quite similar signal yields and background levels for all detector models
- Very loose track quality criteria

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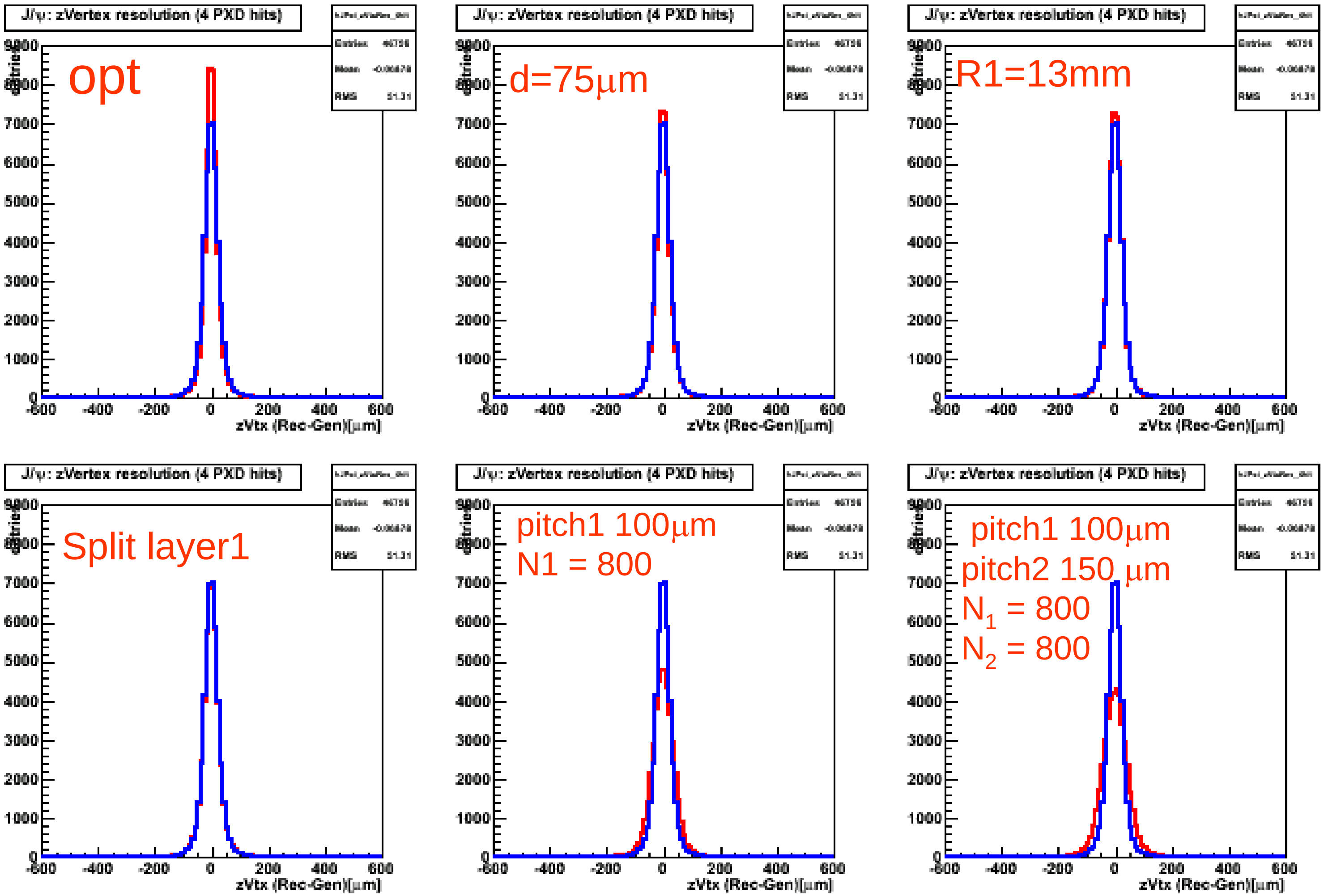
J/Psi z-Vertex resolution



Baseline
Variations

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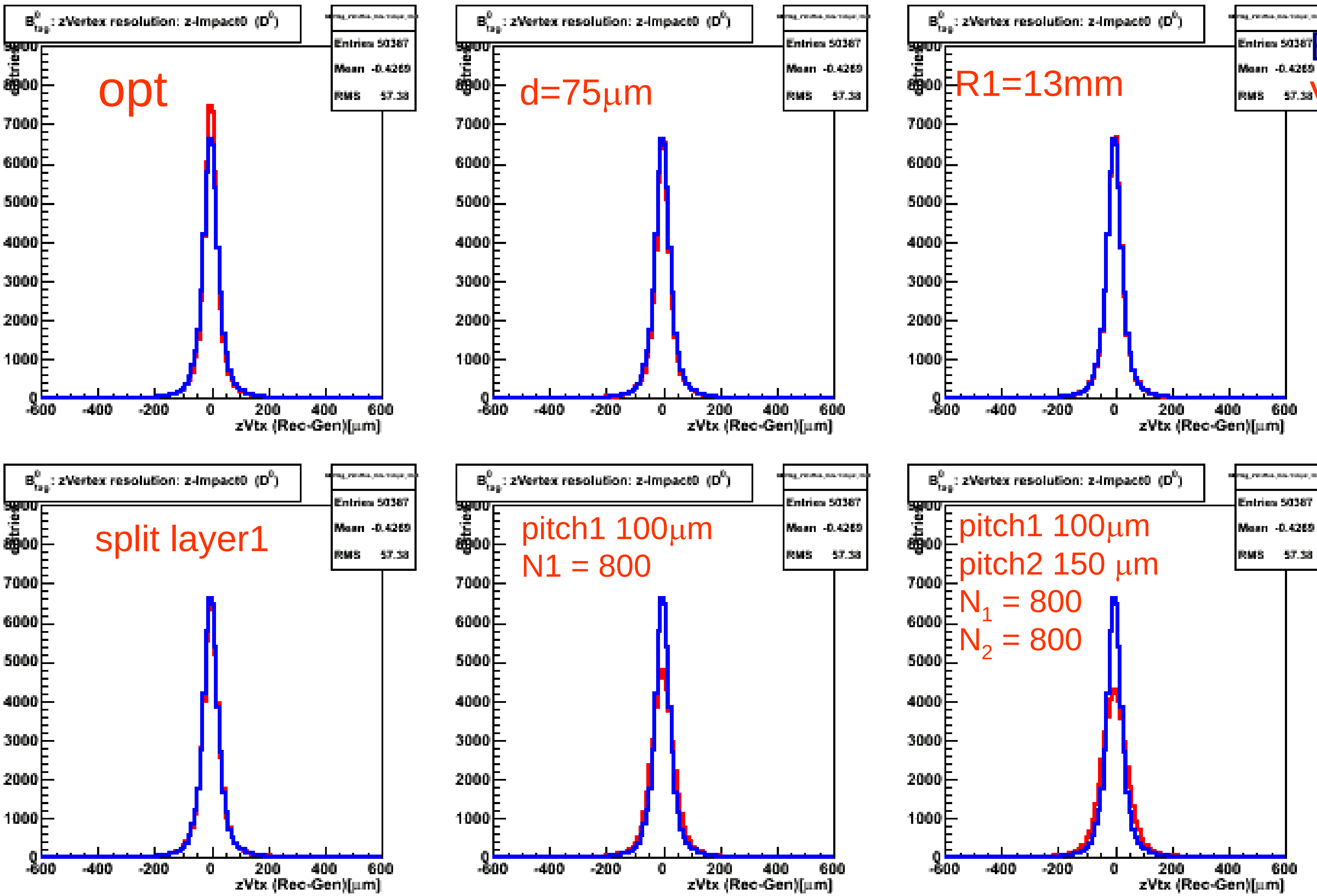
B^0_{tag} z-Vertex: resolution extrapolate D^0 back to beam line

Baseline Variations



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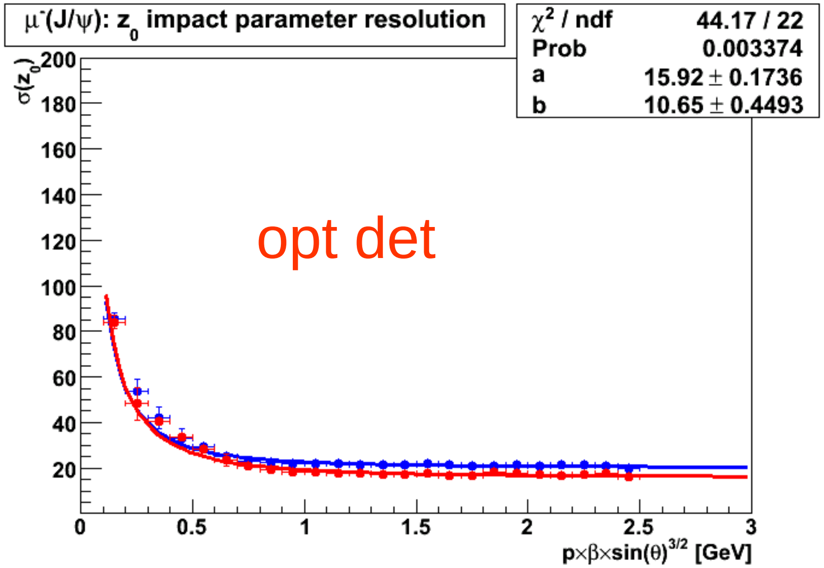
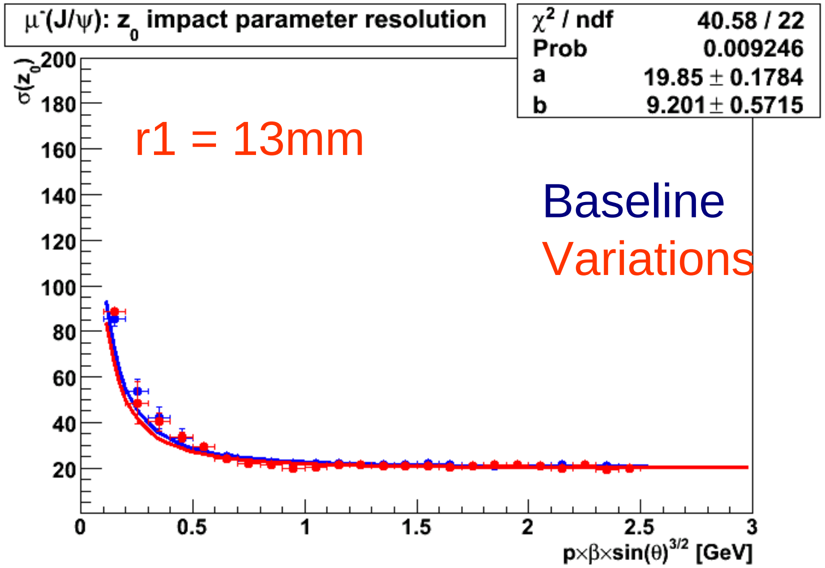
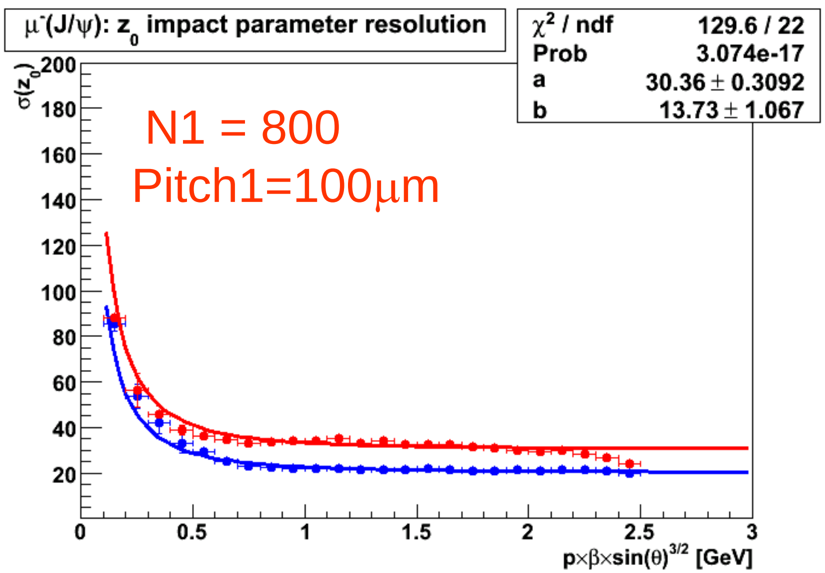
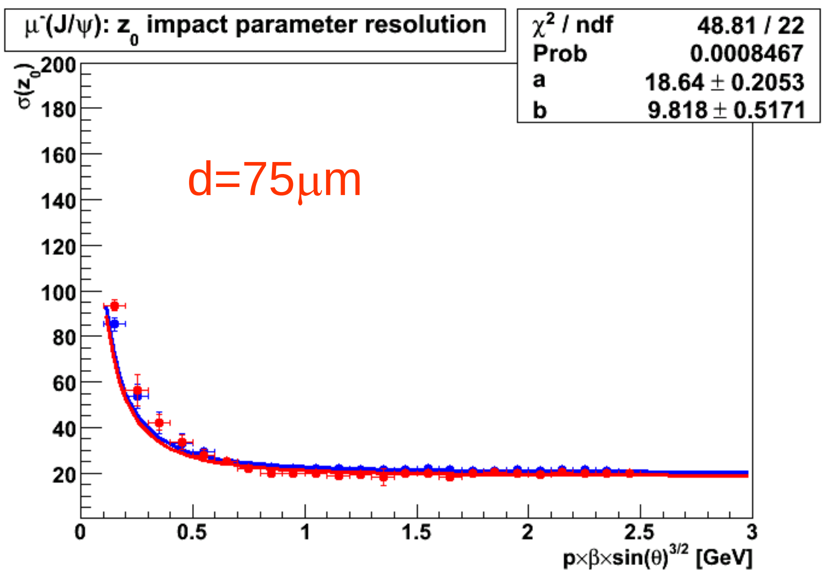
Track Impact Parameter of μ(J/ψ)









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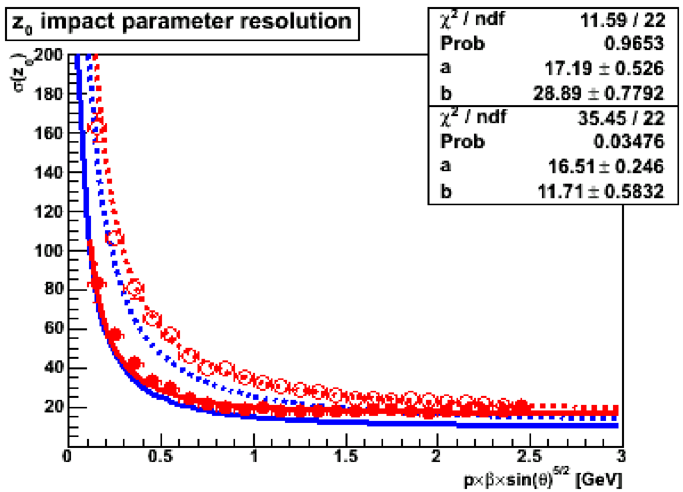
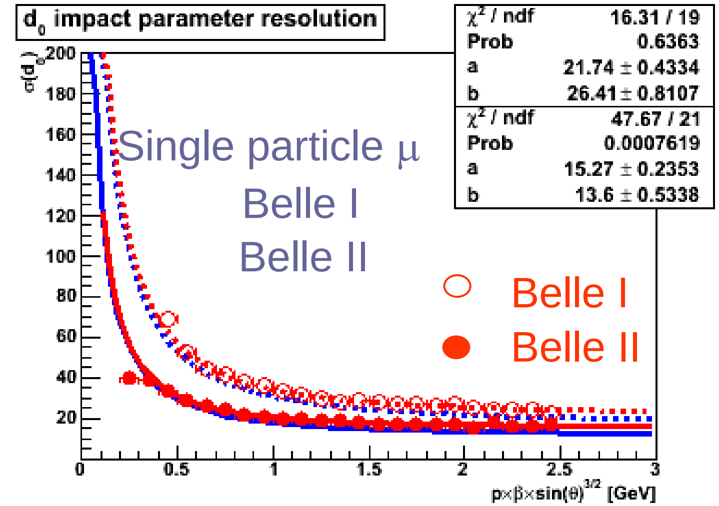
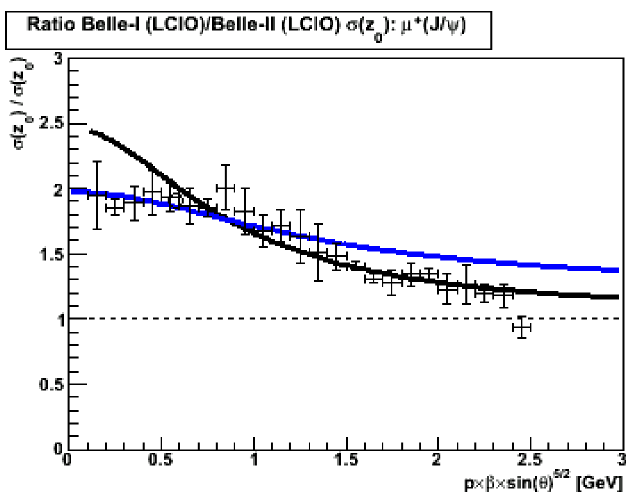
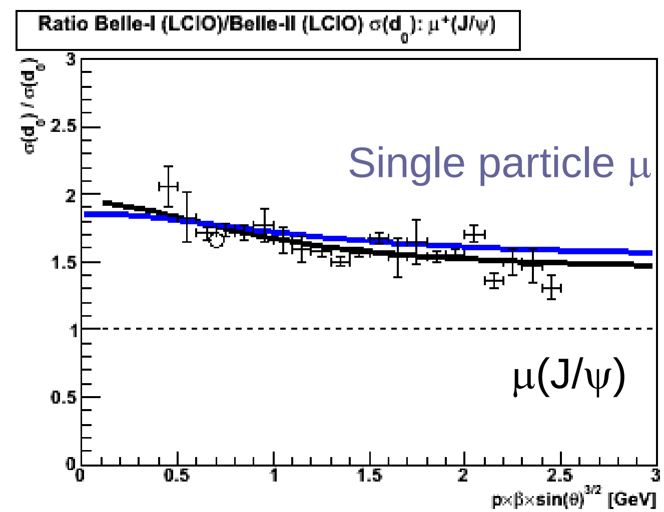
Belle I vs. Belle II in LCIO









Belle II:
pixel sizes: layer1: 50x50x48μm^3, layer 2: 50x50x73μm^3 (i.e. 1600 pixel rows); R_1 = 14mm,
expected improvement by Factor ~2 seen for low momentum tracks

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Physics + QED Background

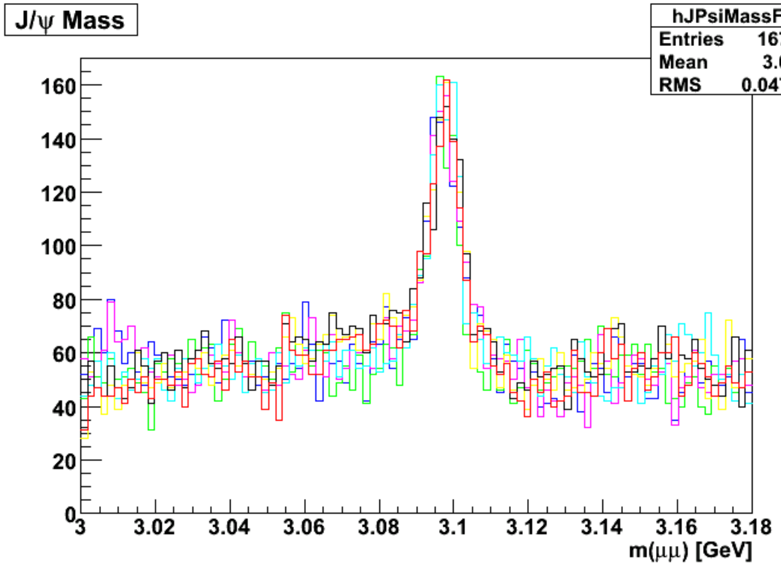
- QED generator issues

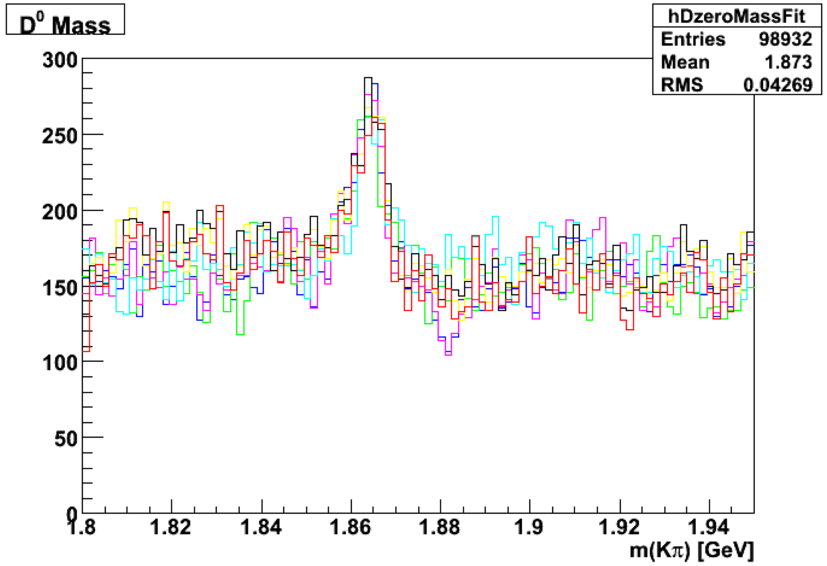
  → See talk by Christian Kiesling
- Merging Y(4S) Physics and QED background

  → See talk by Kolja Prothmann
- 1000 events for each PXD variation

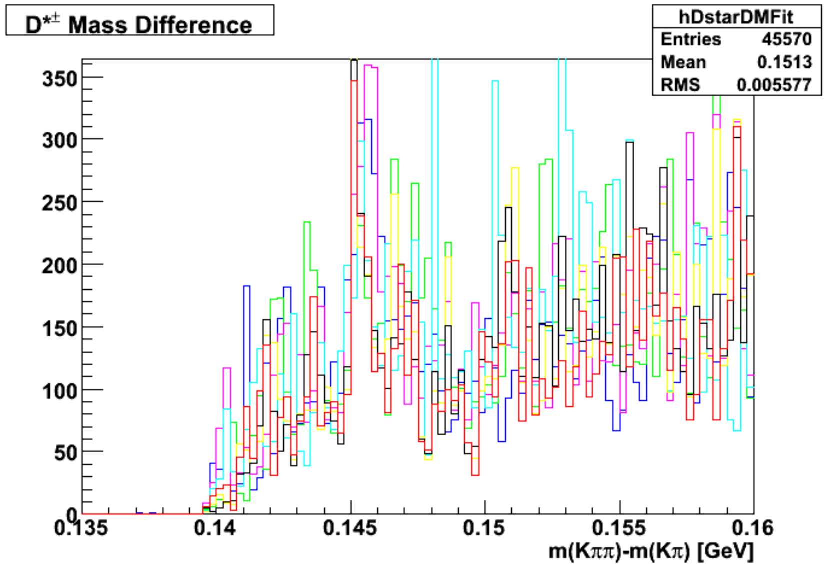
  →hot from the queues

Mass Plots





- J/ψ and D^0 Masses and D^{*+} mass differences quite similar for all detector models
- Much higher combinatorial BG
- D* reveals issues with low momentum tracks
- Need to study track quality criteria



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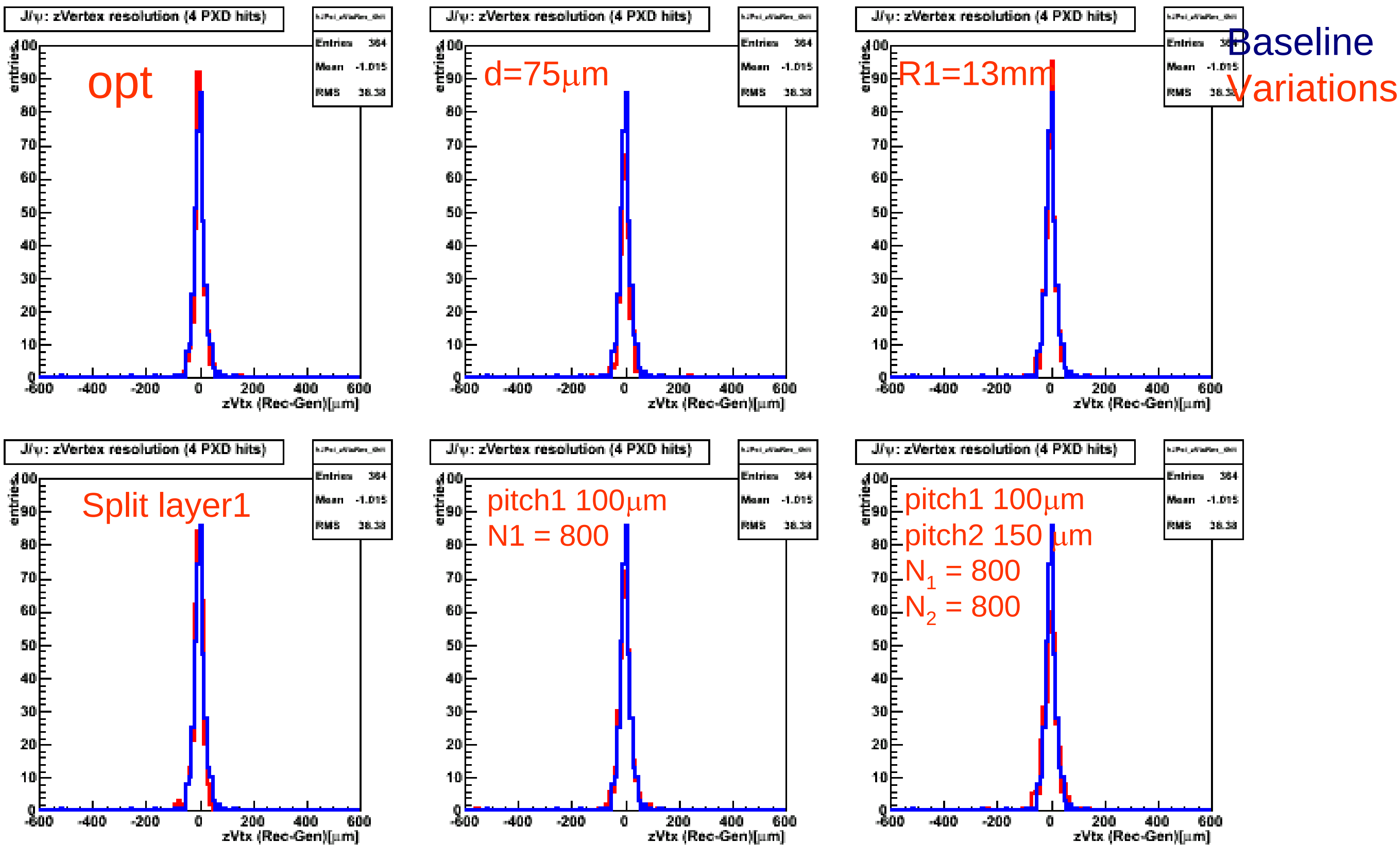
Vertex Resolutions



Physics + QED-BG: Same trends as for physics only

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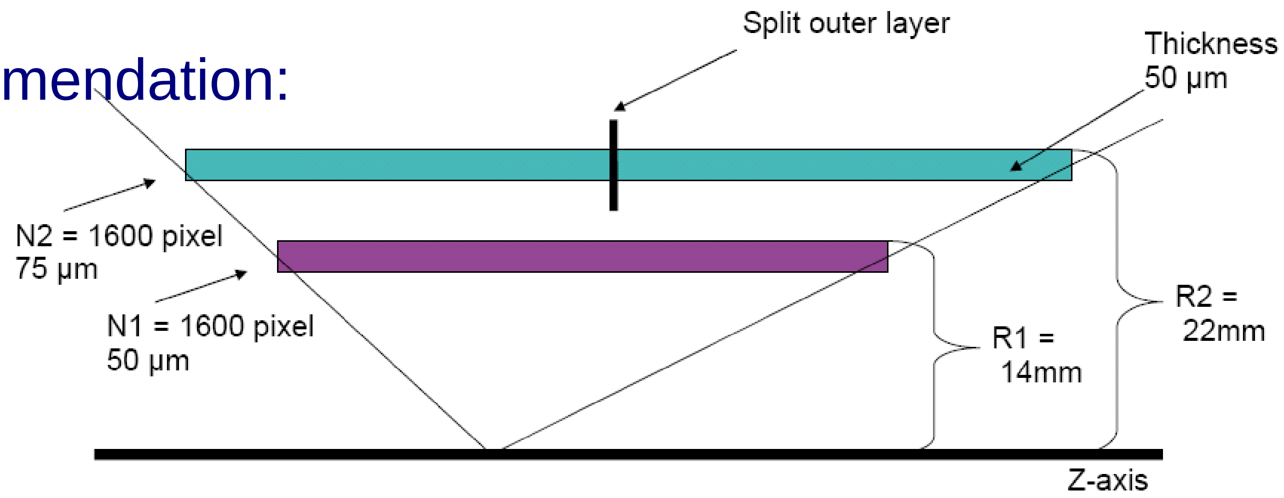
Summary & Conclusions

- Detector simulation software chain validated: reasonable level of agreement for Belle I detector simulation in BASF and Mokka/Marlin

- Detector baseline layout and variations studied
  - Physics only
  - First look at Physics + QED background

- Belle II baseline close to optimum

- Recommendation:



Backup Slides

- Event Reconstruction
- Software chain
- J/Psi and B0 zVertex resolution in log
- Soft pion track impact parameter
- J/Psi vertex resolution fits

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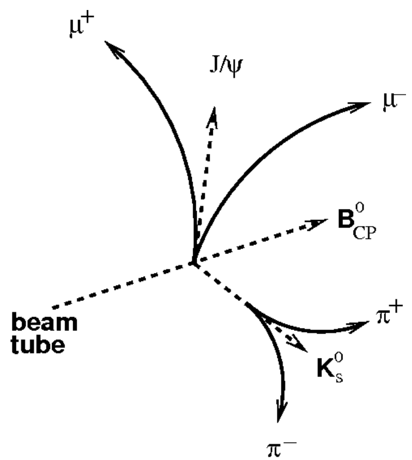
Event Reconstruction

- EvtGen: Generate 100 000 entangled $B^0 \bar{B}^0$ pairs
- Force “golden” decay modes:

CP side:

$\overset{(-)}{B^0} \to J/\psi K^0_s \to \mu^+\mu^- \pi^+\pi^-$

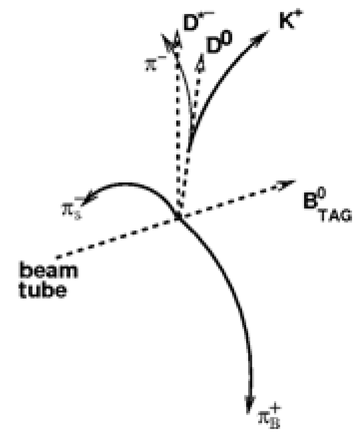


Tag side (+c.c.):

$\bar{B}^0 \to D^{*-}\pi^+$

$\to \bar{D}^0\pi^-$

$\to K^+\pi^-$



- Match generator level to reconstructed candidates by hit fraction requirement on all daughter tracks
- Three consistent analysis:

  Belle-I (BASF & LCIO) and Belle-II (LCIO)

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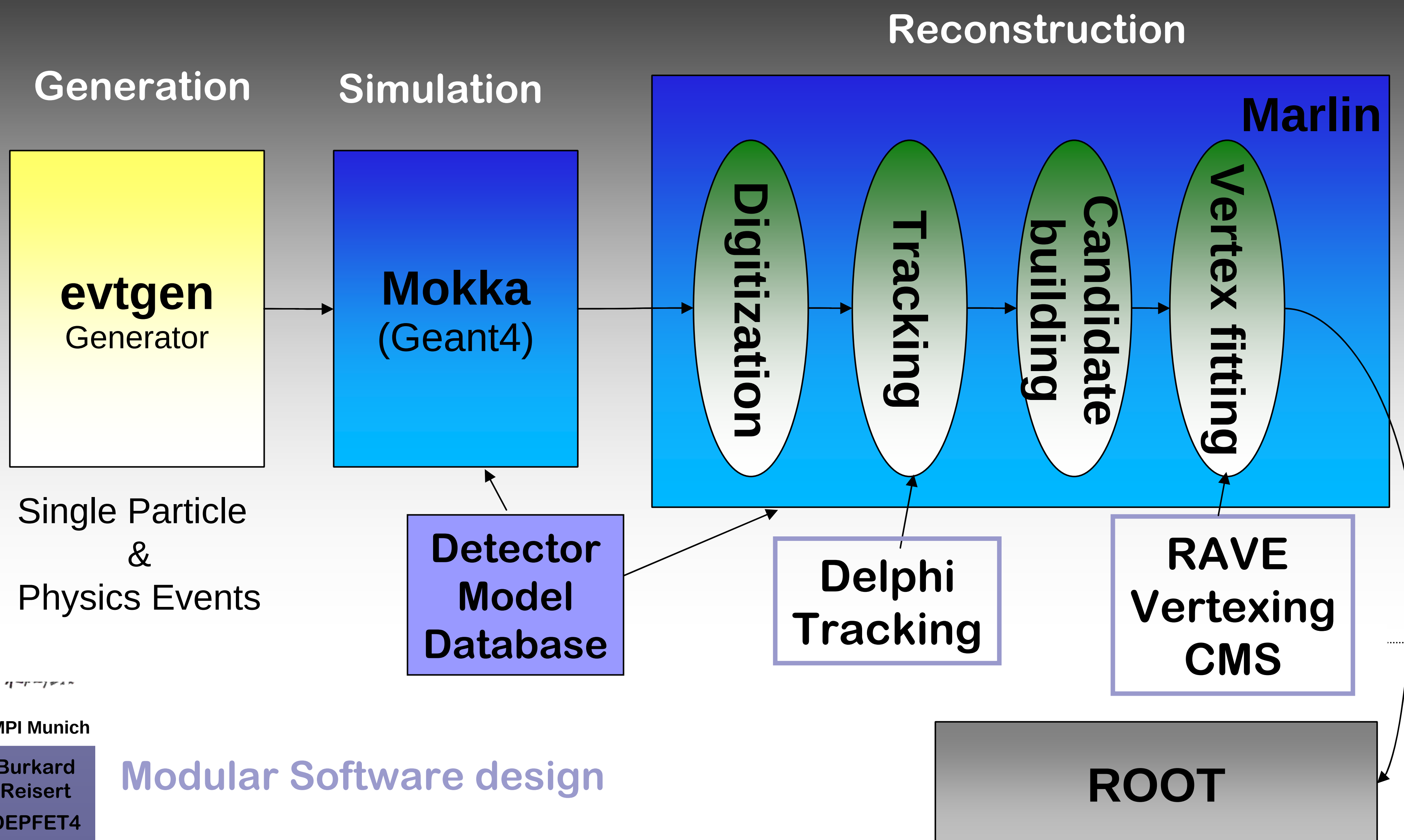
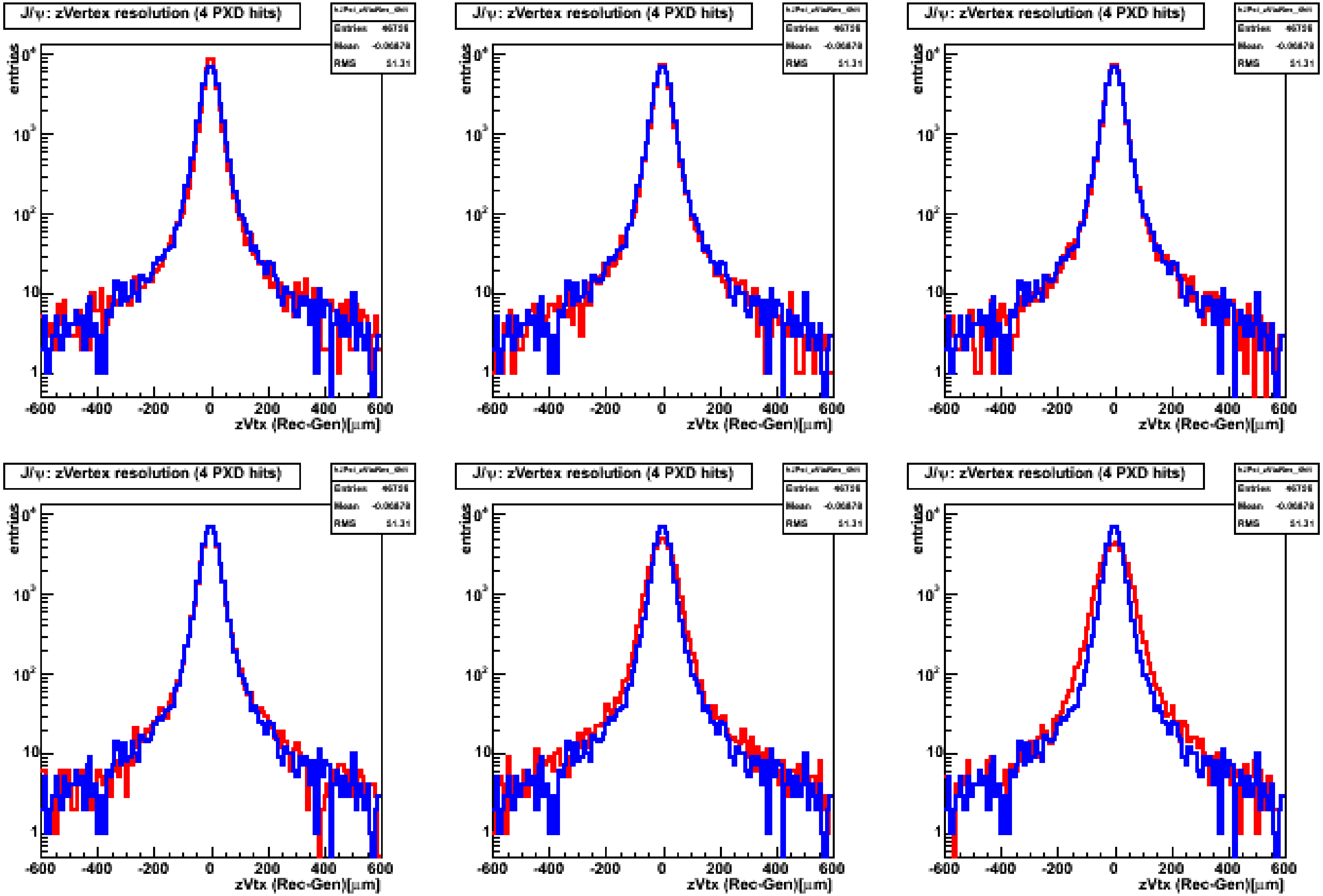
Simulation ILC-Framework



Modular Software design

More details see Kolja Prothmann

J/Psi z-Vertex resolution



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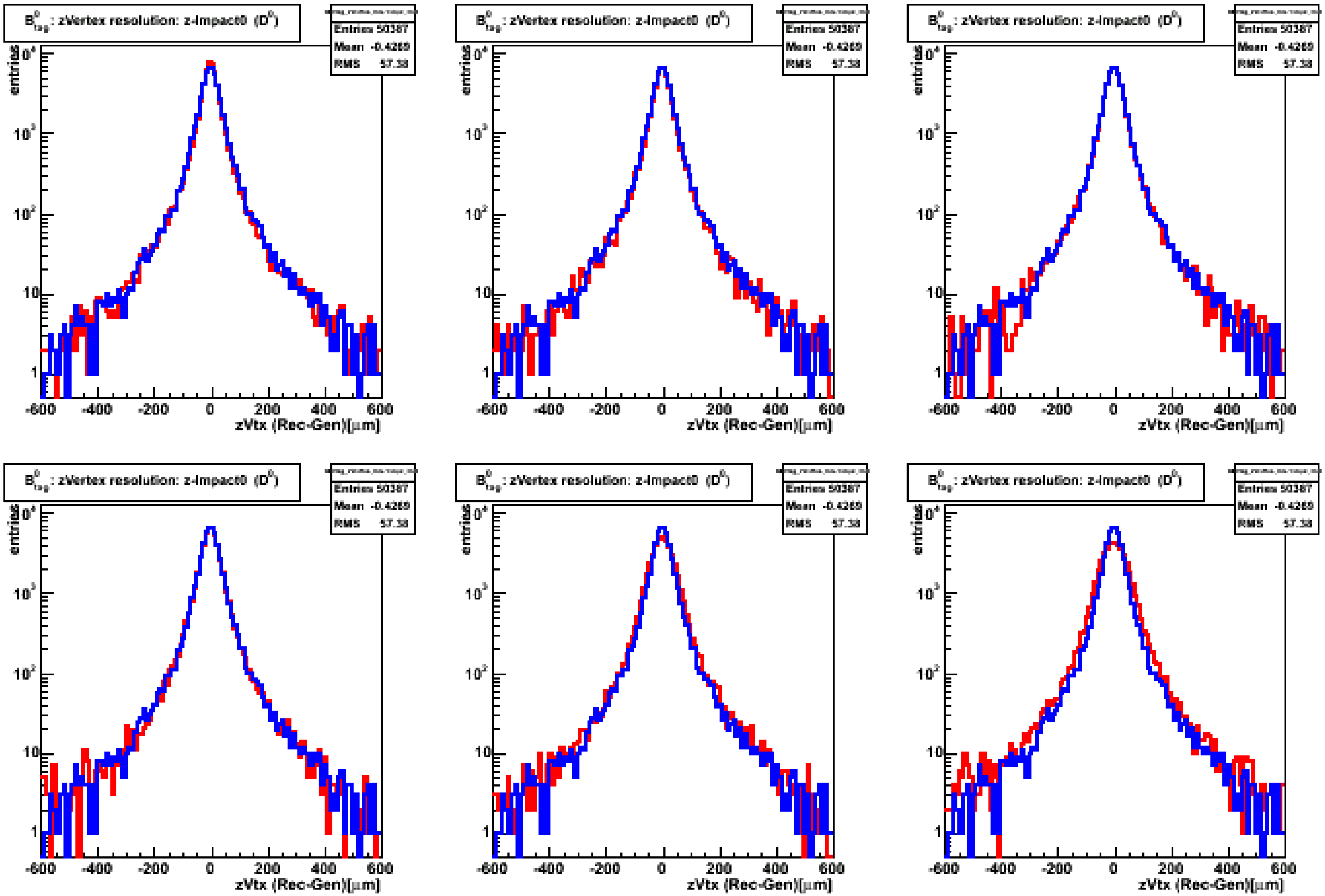
B^0_{tag} z-Vertex: resolution extrapolate D^0 back to beam line



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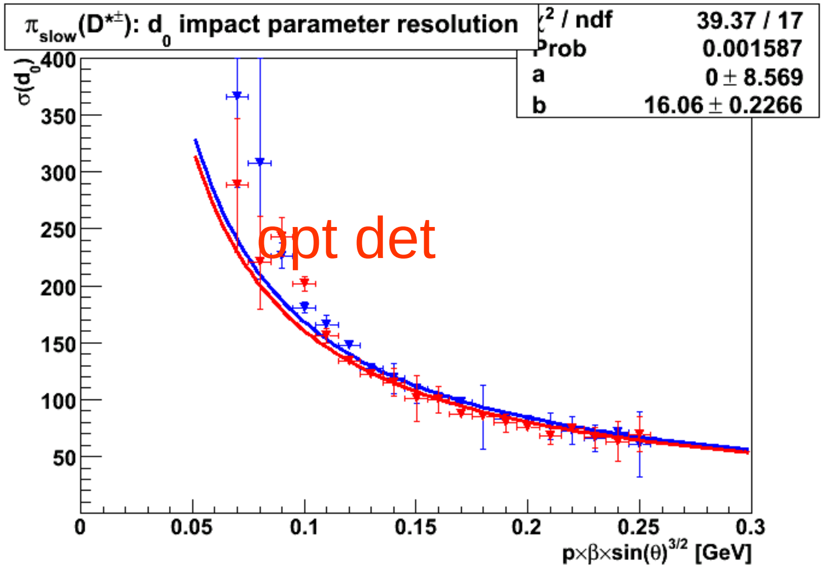
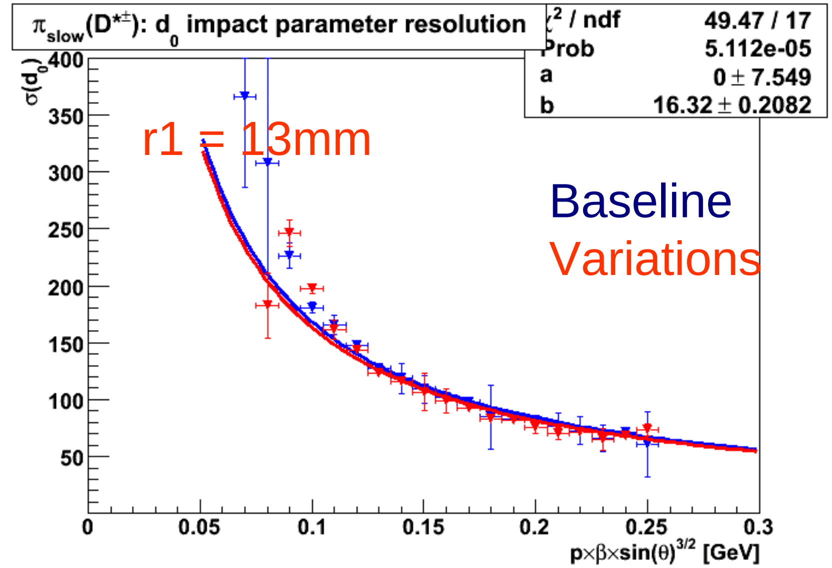
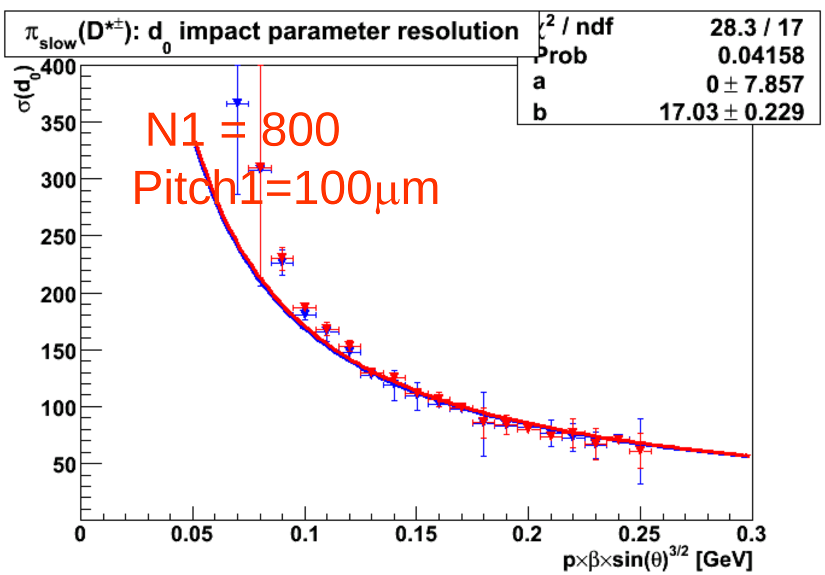
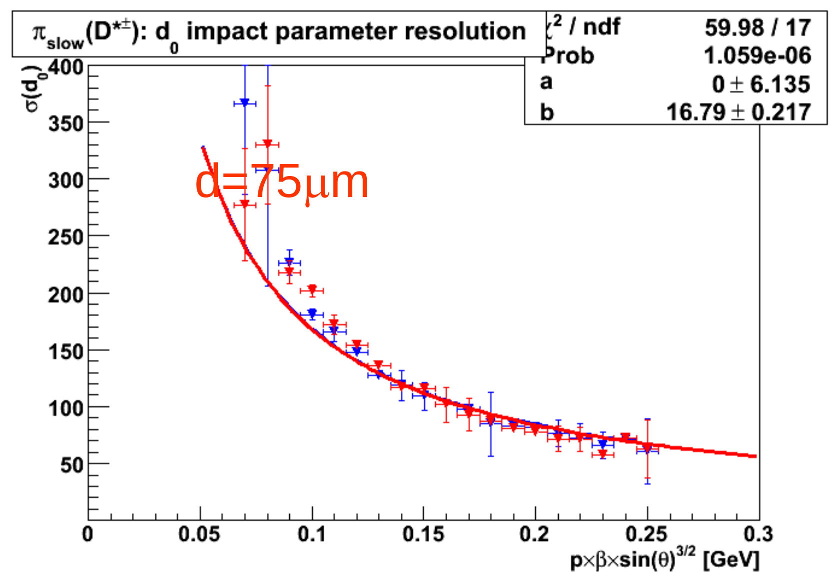
Track Impact Parameter of π_{slow} (D^{*+})









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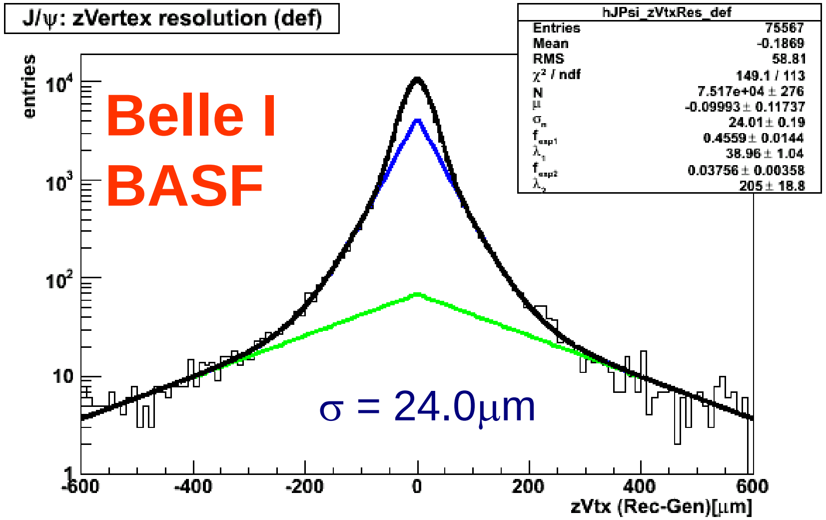
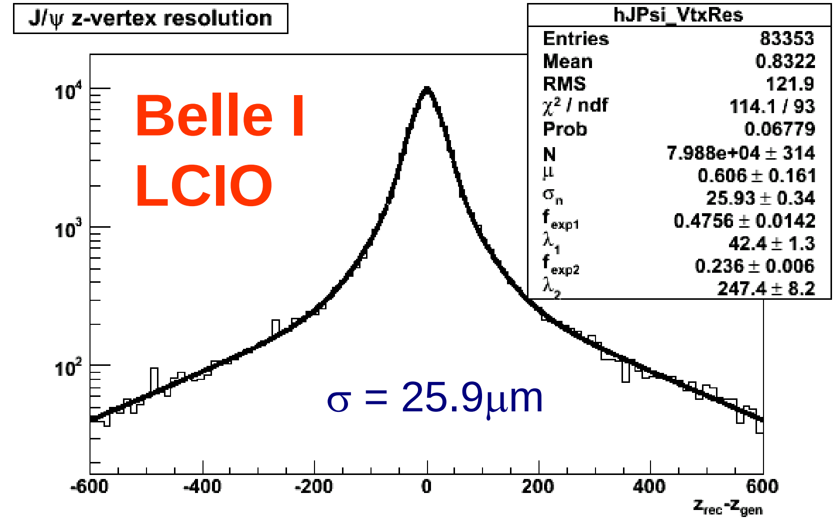
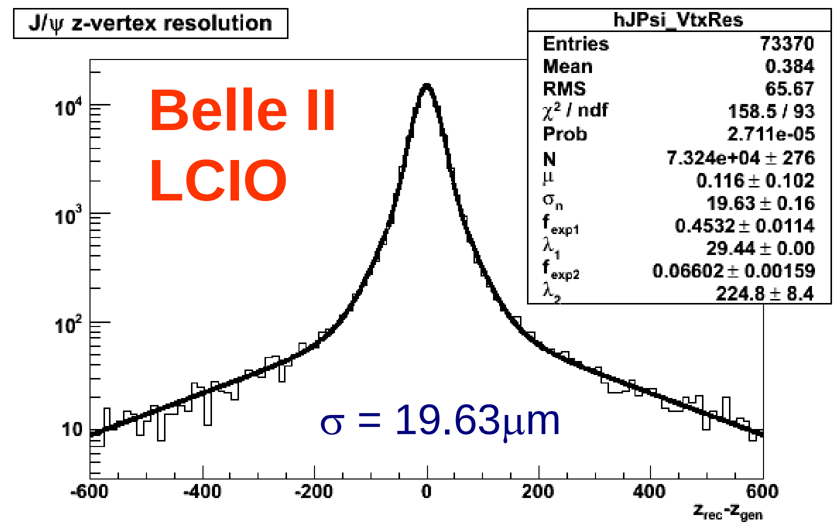
J/ψ Vertex Resolution





Golden Mode: $(J/\Psi K_s)_{cp}$ $(D^*\pi)_{tag}$
Detailed comparison of Belle-I (BASF), Belle-I(ILC) and Belle-II (ILC)



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