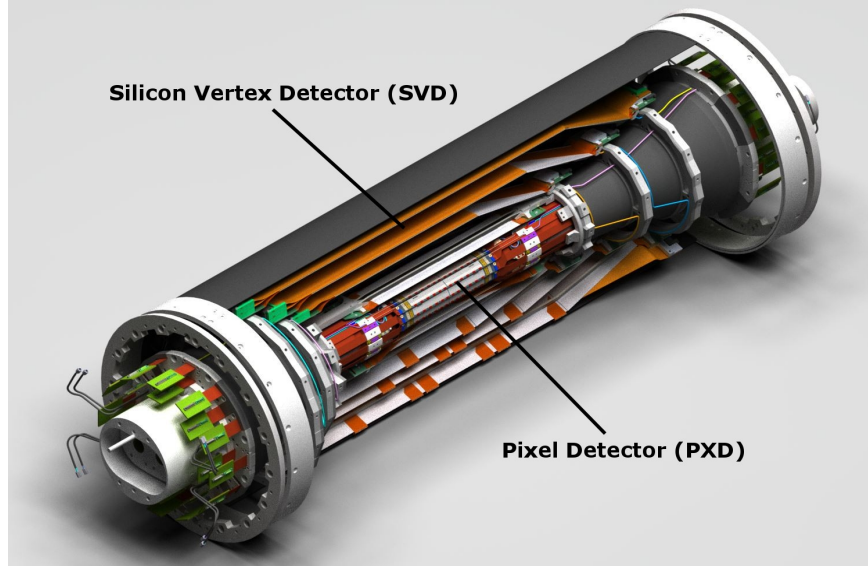# PXD performance: preparation for the Belle II physics analysis

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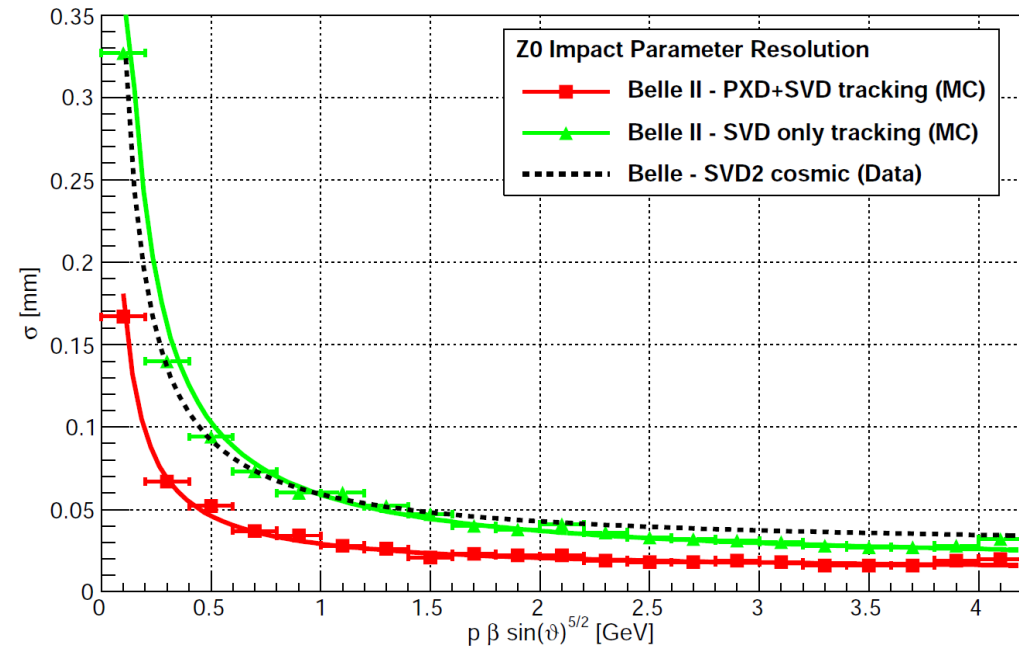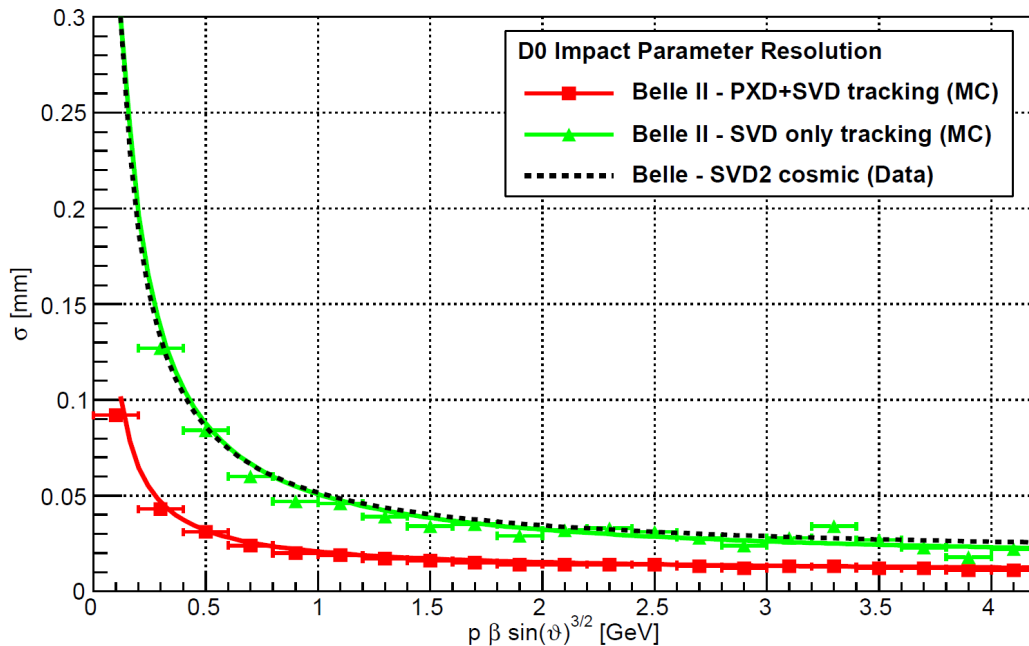
16th International Workshop on DEPFET Detectors and Applications

May 26th 2014

Belle II Pixel Vertex Detector
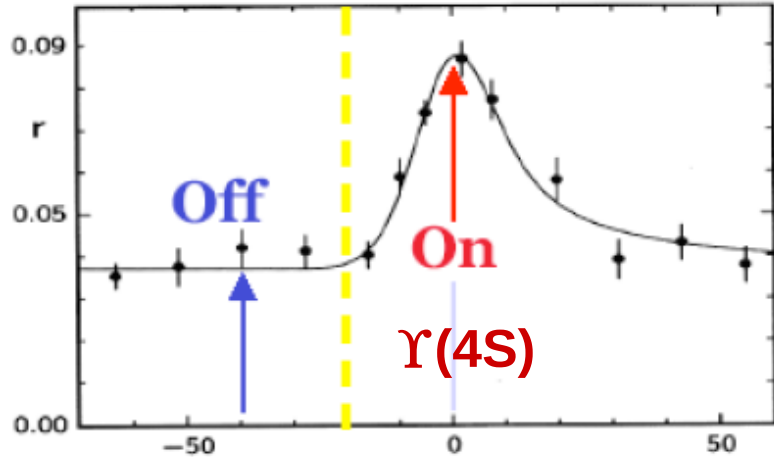

Silicon Vertex Detector (SVD)

Pixel Detector (PXD)

- Innermost detector system as close as possible to IP
- highly granular pixel sensors provide most accurate 2D position information

- reconstruction of primary and secondary vertices of short-lived particles
- decay of particles is typical in the order of 100μm from the IP

Significant improvement in impact parameter resolution

D0 Impact Parameter Resolution
- Belle II - PXD+SVD tracking (MC)
- Belle II - SVD only tracking (MC)
- Belle - SVD2 cosmic (Data)

σ [mm] vs $p\,\beta\,\sin(\vartheta)^{3/2}$ [GeV]

Z0 Impact Parameter Resolution
- Belle II - PXD+SVD tracking (MC)
- Belle II - SVD only tracking (MC)
- Belle - SVD2 cosmic (Data)

σ [mm] vs $p\,\beta\,\sin(\vartheta)^{5/2}$ [GeV]

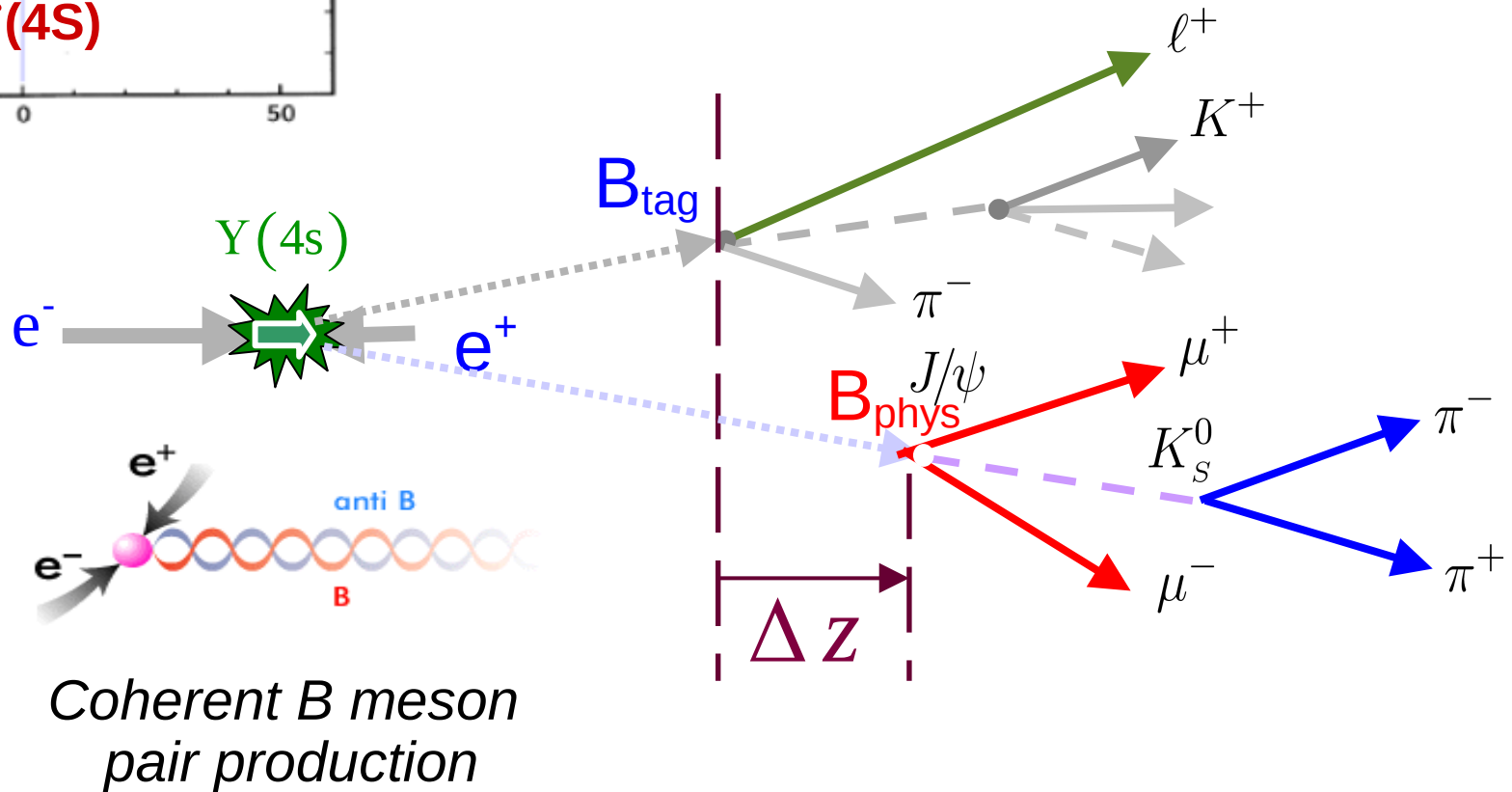# Time dependent measurements

- Y(4S) is the first resonance just above the $B\bar{B}$ production threshold
- Only $B\bar{B}$ pairs are produced, and are at rest in the Y(4S) frame

$$\Delta t = \frac{\Delta z}{\beta \gamma c}$$

Resolution on Δt will be dominated by the resolution of the tagging side vertex
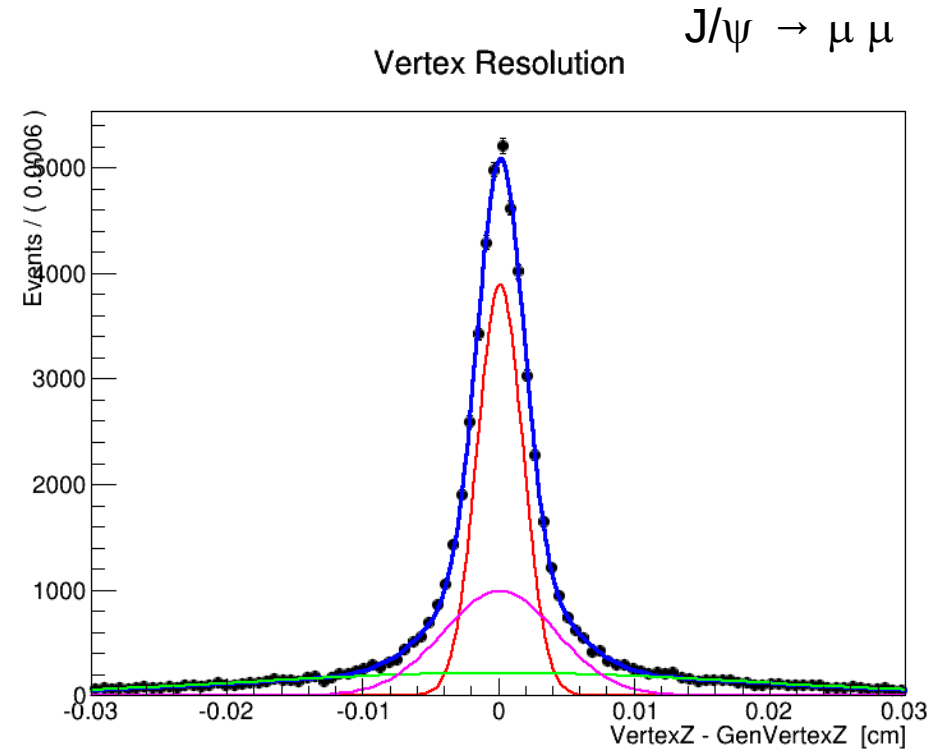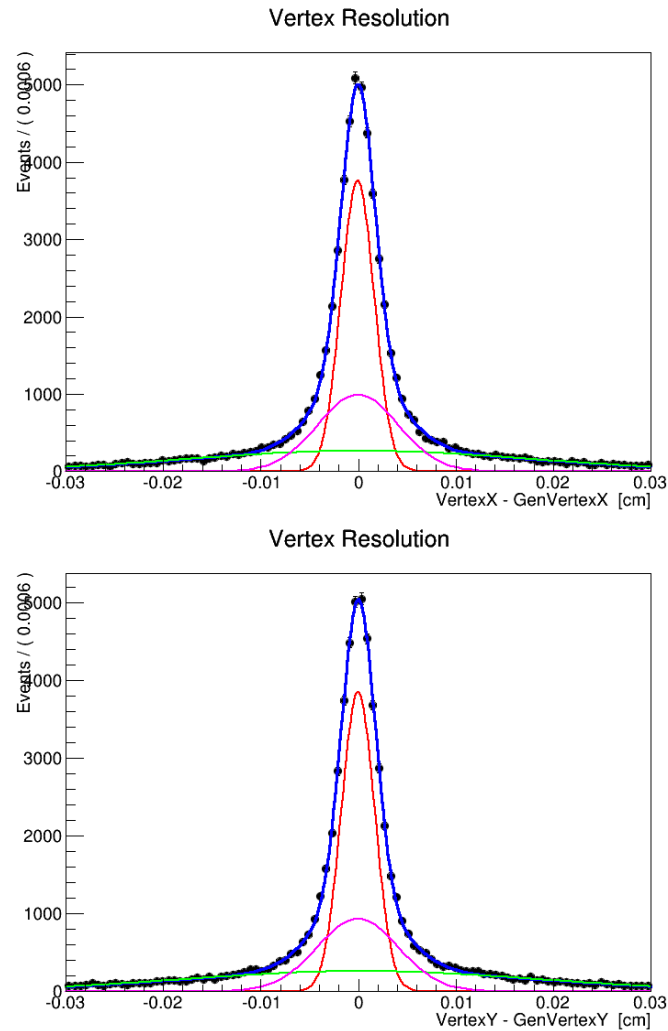
Coherent B meson pair production

Δt probability parametrization $\quad \mathcal{P}(\Delta t, q) = \frac{e^{-|\Delta t|/\tau_{B^0}}}{4\tau_{B^0}}\left[1 + q\left(\mathcal{A}_{CP}\cos \Delta m_d \Delta t + \mathcal{S}_{CP}\sin \Delta m_d \Delta t\right)\right]$

Vertexing: Breco side

Two vertex fitters used for kinematic vertex fit
- Kfit : used in Belle
- RAVE: a CMS tool, see https://rave.hepforge.org/)

Quasi identical results

$J/\psi \rightarrow \mu\mu$

Floating Parameter	FinalValue +/-	Error
Mu1	1.6707e-04 +/-	1.61e-05
Mu2	6.9441e-05 +/-	2.01e-04
Mu3	1.3686e-04 +/-	5.31e-05
Sigma1	1.6787e-03 +/-	2.76e-05
Sigma2	1.8251e-02 +/-	4.15e-04
Sigma3	4.1844e-03 +/-	1.30e-04
frac1	4.6151e-01 +/-	1.34e-02
frac2	2.4712e-01 +/-	4.97e-03

Shift (micron) = 1.34141
Resolution (micron) = 65.0417

Rave: Adaptive Vertex Fitter

Down-weights outliers dynamically, instead of using hard cutoffs (important for 3+ track vertices).

Minimization of the weighted least sum of squares

square of the standardized residual

$$w_i\left(\chi_i^2\right) = \frac{\exp(-\chi_i^2/2T)}{\exp(-\chi_i^2/2T) + \exp(-\sigma_{cut}^2/2T)}$$

Weight

cutoff parameter

"temperature" parameter
"softness" of the weight function

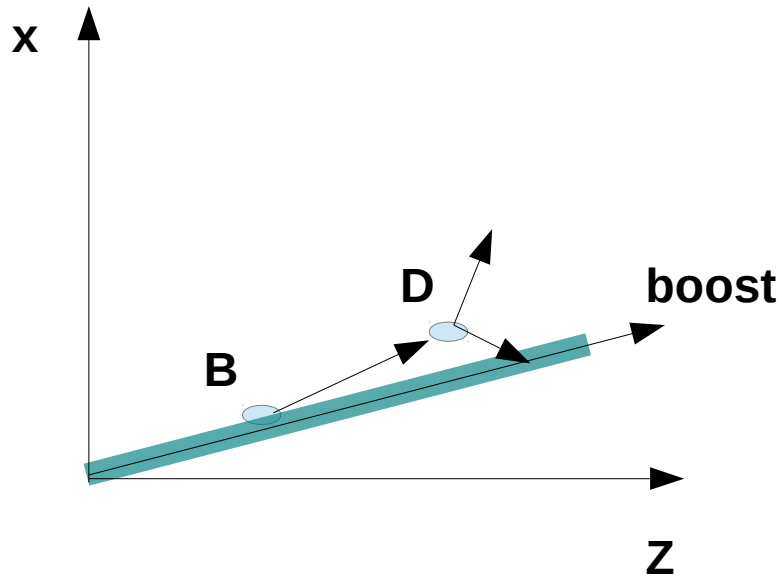in each iteration step
the temperature parameter is lowered
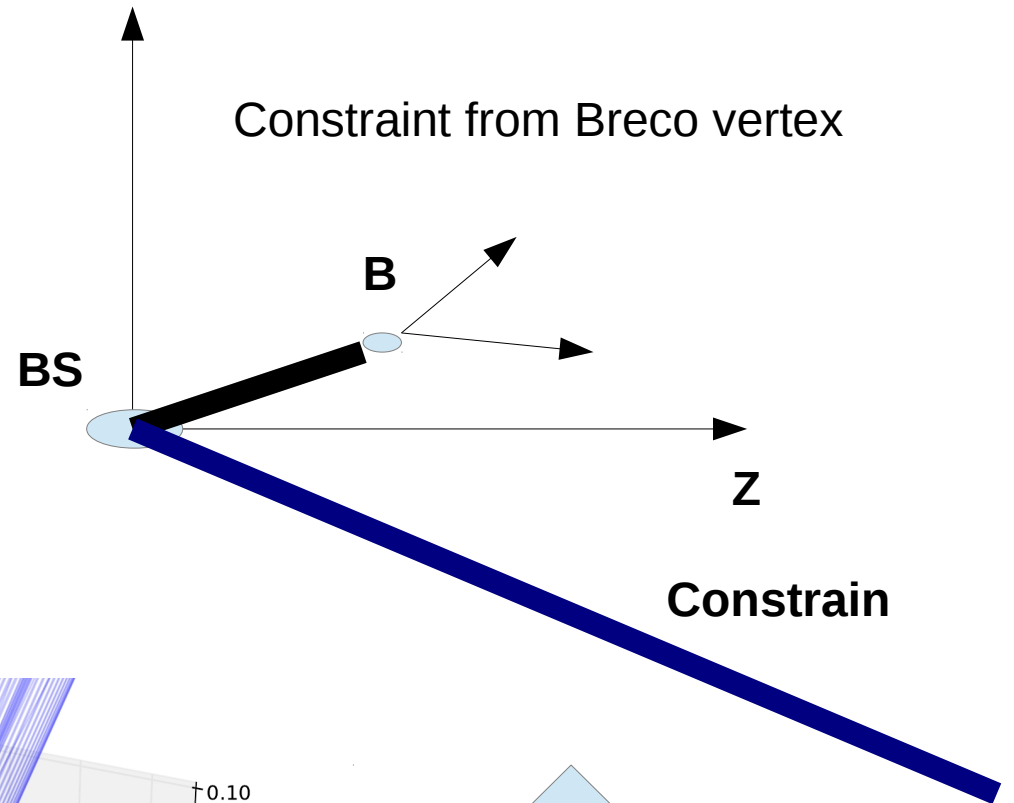
$$T_i = 1 + r \cdot (T_{i-1} - 1)$$

0<r<1

Rave: Adaptive Vertex Fitter

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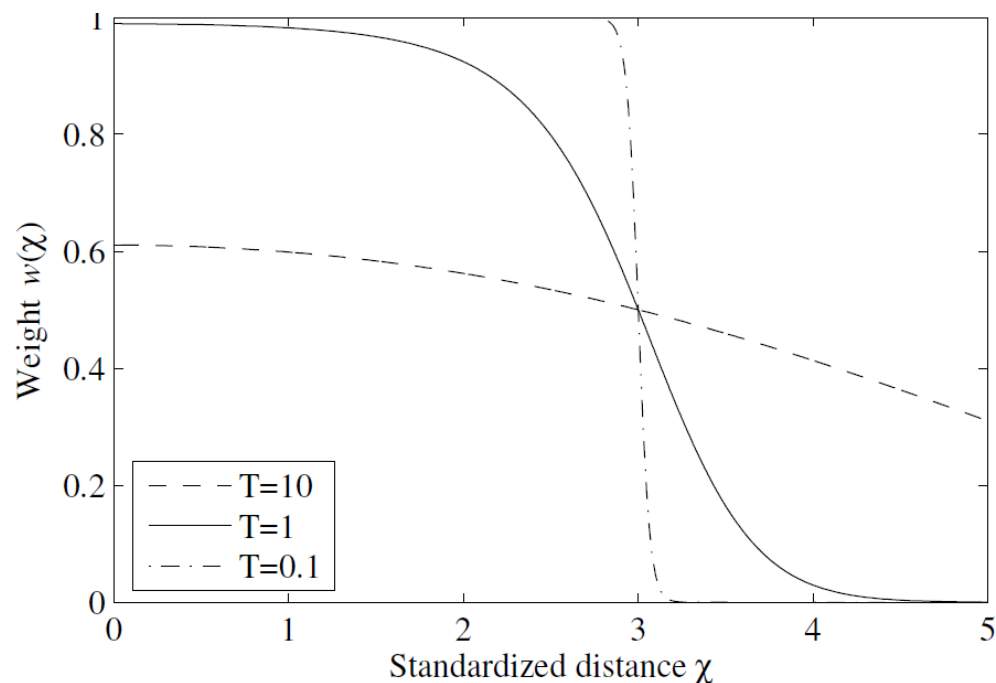
Tag side fit constraints

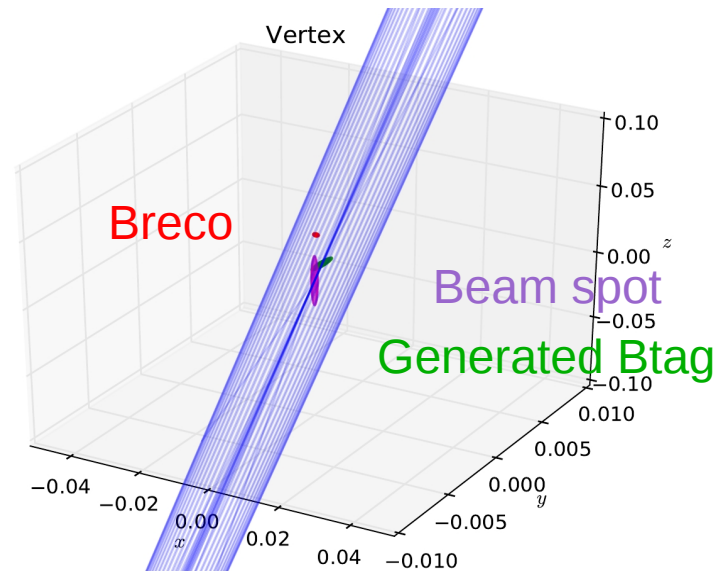Tube constraint around boost direction

x

D

B

boost

Z

Y(4S) generated
in (0,0,0)

Constraint from Breco vertex

B

BS

Z

Constrain

Vertex

Breco

Beam spot

Generated Btag

0.10
0.05
0.00
−0.05
−0.10

0.010
0.005
0.000
−0.005
−0.010

−0.04
−0.02
0.00
0.02
0.04

No Constraint
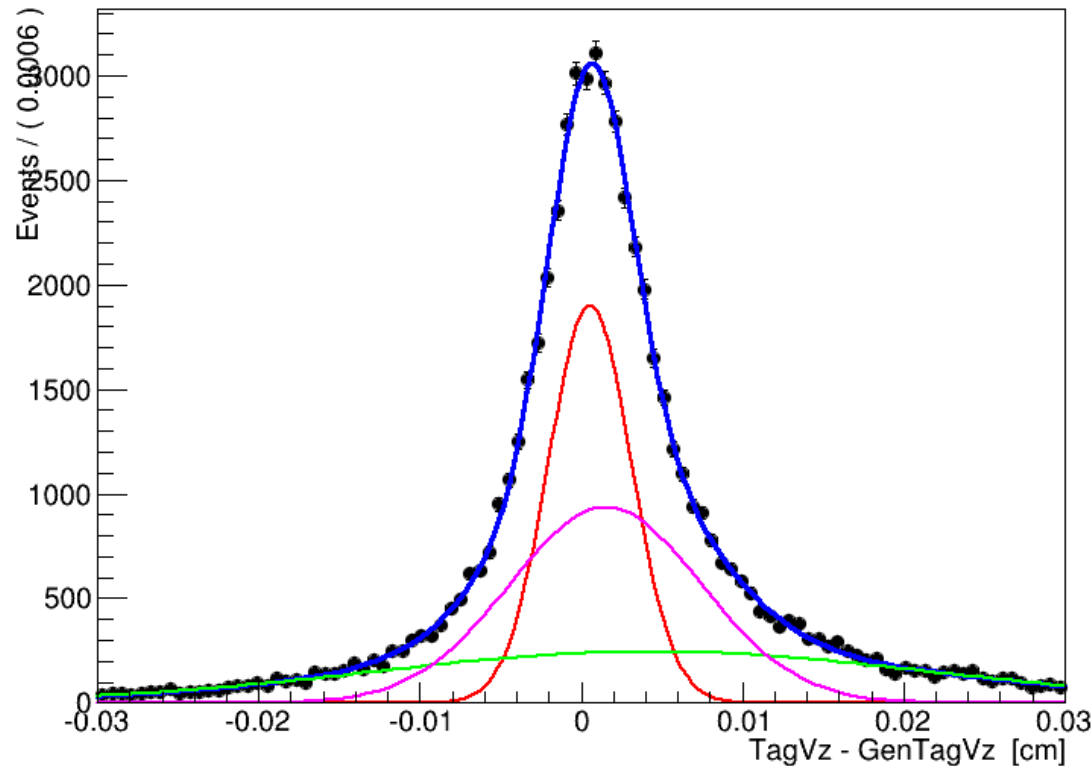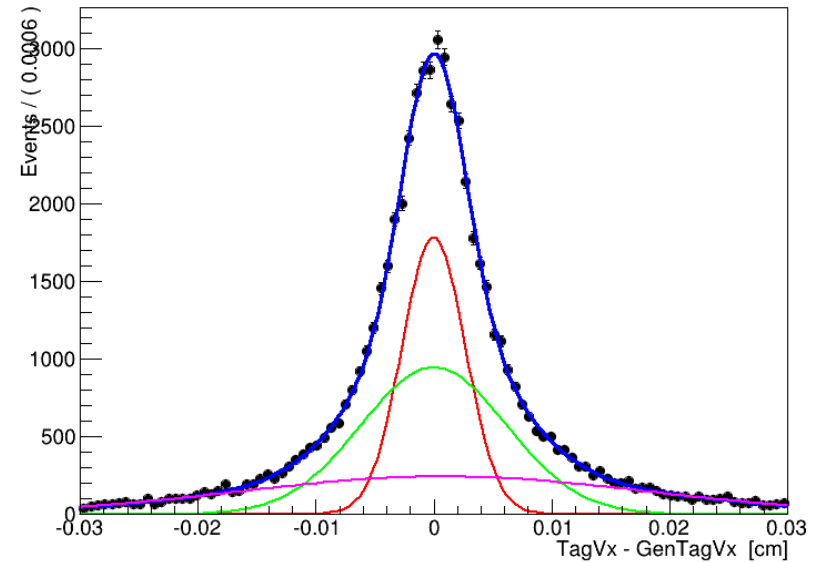
Tag Vertex Resolution

Floating Parameter	FinalValue +/-	Error
Mu1	5.7377e-04 +/-	3.74e-05
Mu2	4.4432e-03 +/-	3.07e-04
Mu3	1.5472e-03 +/-	9.84e-05
Sigma1	2.5718e-03 +/-	7.17e-05
Sigma2	1.7190e-02 +/-	6.24e-04
Sigma3	5.9441e-03 +/-	2.31e-04
frac1	3.4259e-01 +/-	2.01e-02
frac2	2.6827e-01 +/-	1.33e-02

Shift (micron) = 19.906
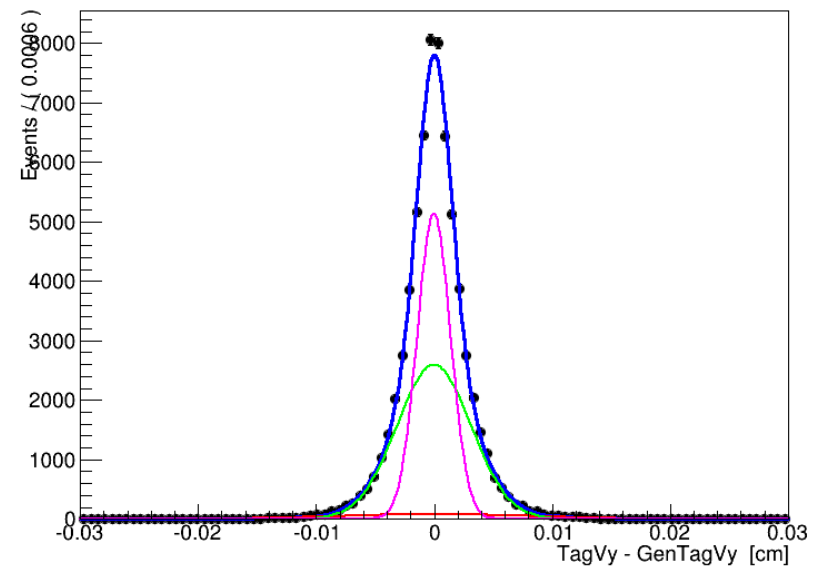Resolution (micron) = 78.0581

Breco Constraint

Tag Vertex Resolution
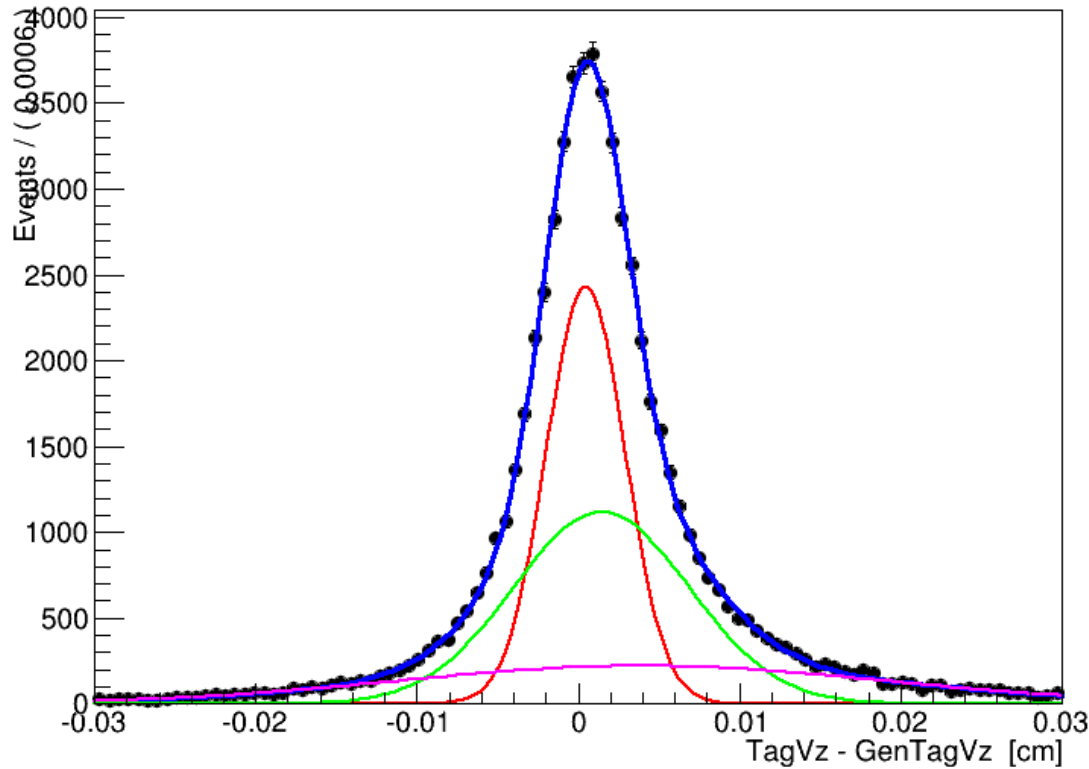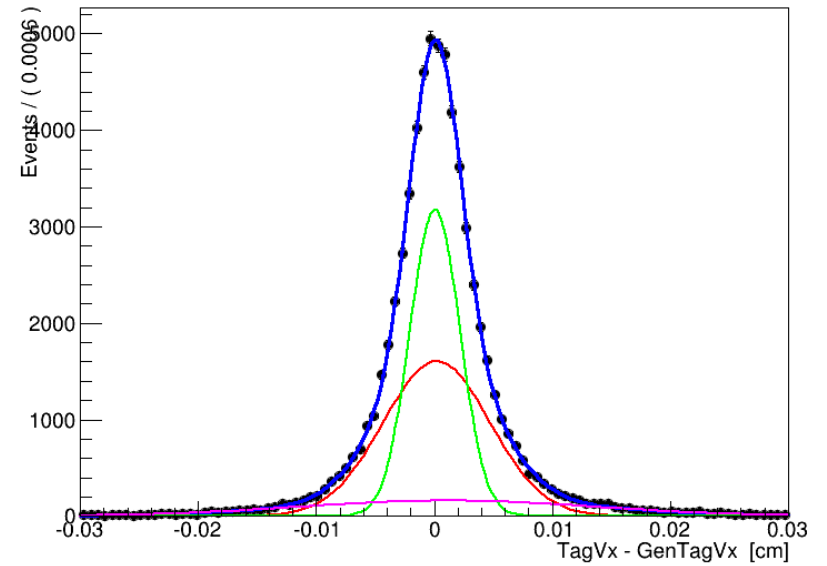
Floating Parameter	FinalValue +/-	Error
Mu1	4.9525e-04 +/-	3.22e-05
Mu2	1.4717e-03 +/-	8.76e-05
Mu3	4.0272e-03 +/-	2.37e-04
Sigma1	2.4471e-03 +/-	6.18e-05
Sigma2	5.4347e-03 +/-	1.87e-04
Sigma3	1.4937e-02 +/-	4.43e-04
frac1	3.9248e-01 +/-	2.14e-02
frac2	4.0085e-01 +/-	1.62e-02

Shift (micron) = 16.166
Resolution (micron) = 62.2582

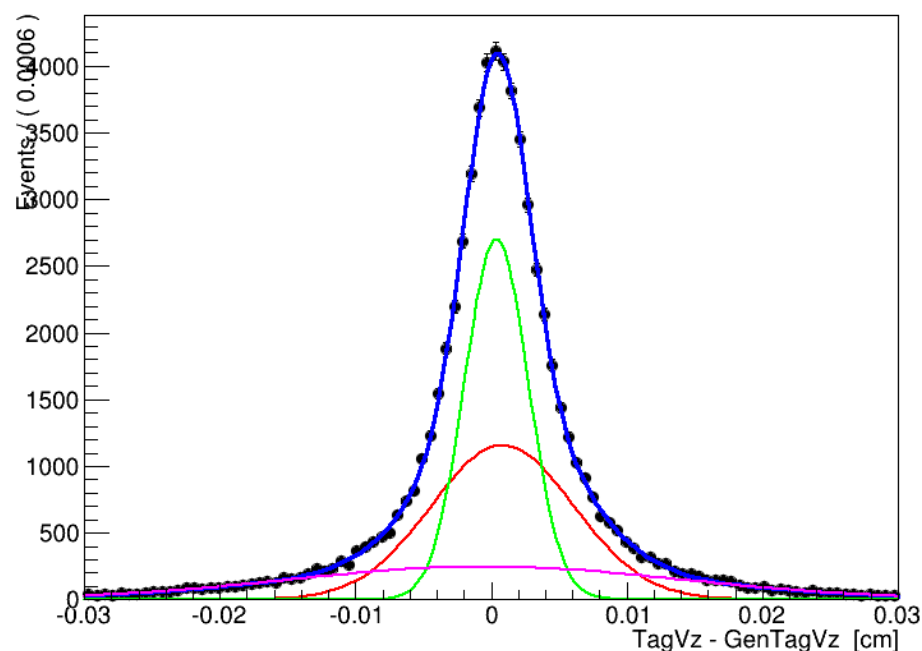# Boost tube Constraint

Constraint on maximum in boost direction

Tag Vertex Resolution
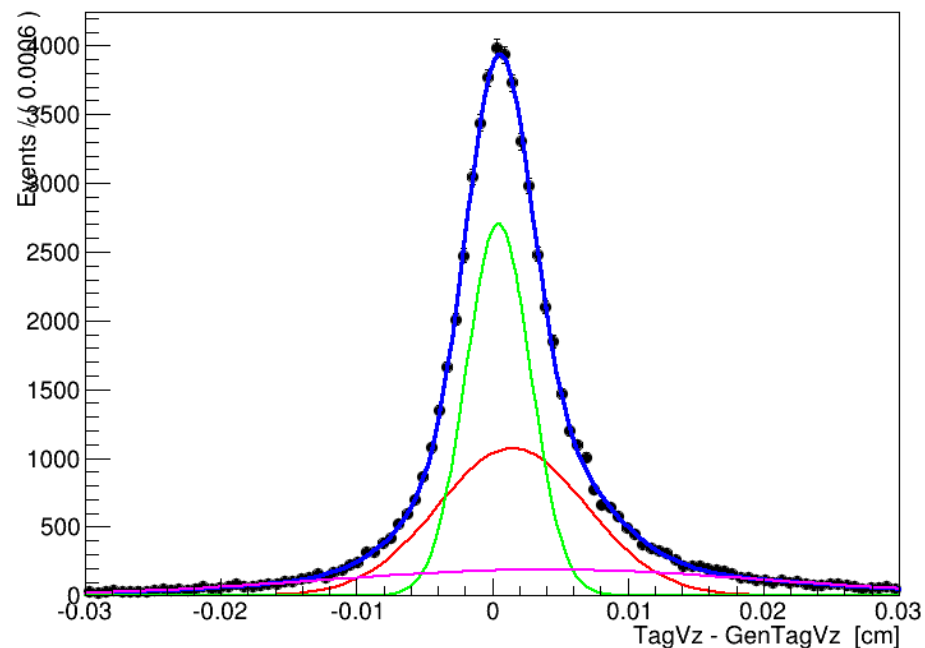
Floating Parameter	FinalValue +/-	Error
Mu1	1.5046e-03 +/-	8.79e-05
Mu2	4.8266e-04 +/-	2.88e-05
Mu3	4.0103e-03 +/-	2.77e-04
Sigma1	5.4976e-03 +/-	1.91e-04
Sigma2	2.3784e-03 +/-	5.82e-05
Sigma3	1.6140e-02 +/-	5.48e-04
frac1	3.8888e-01 +/-	1.67e-02
frac2	4.2485e-01 +/-	2.14e-02

Shift (micron) = 15.3717
Resolution (micron) = 61.5481

Tag Vertex Resolution

Floating Parameter	FinalValue +/-	Error
Mu1	8.6626e-04 +/-	6.50e-05
Mu2	4.1614e-04 +/-	2.83e-05
Mu3	-3.8806e-04 +/-	1.70e-04
Sigma1	5.2511e-03 +/-	2.10e-04
Sigma2	2.3454e-03 +/-	6.82e-05
Sigma3	1.4316e-02 +/-	3.44e-04
frac1	3.8385e-01 +/-	2.03e-02
frac2	4.0071e-01 +/-	2.57e-02

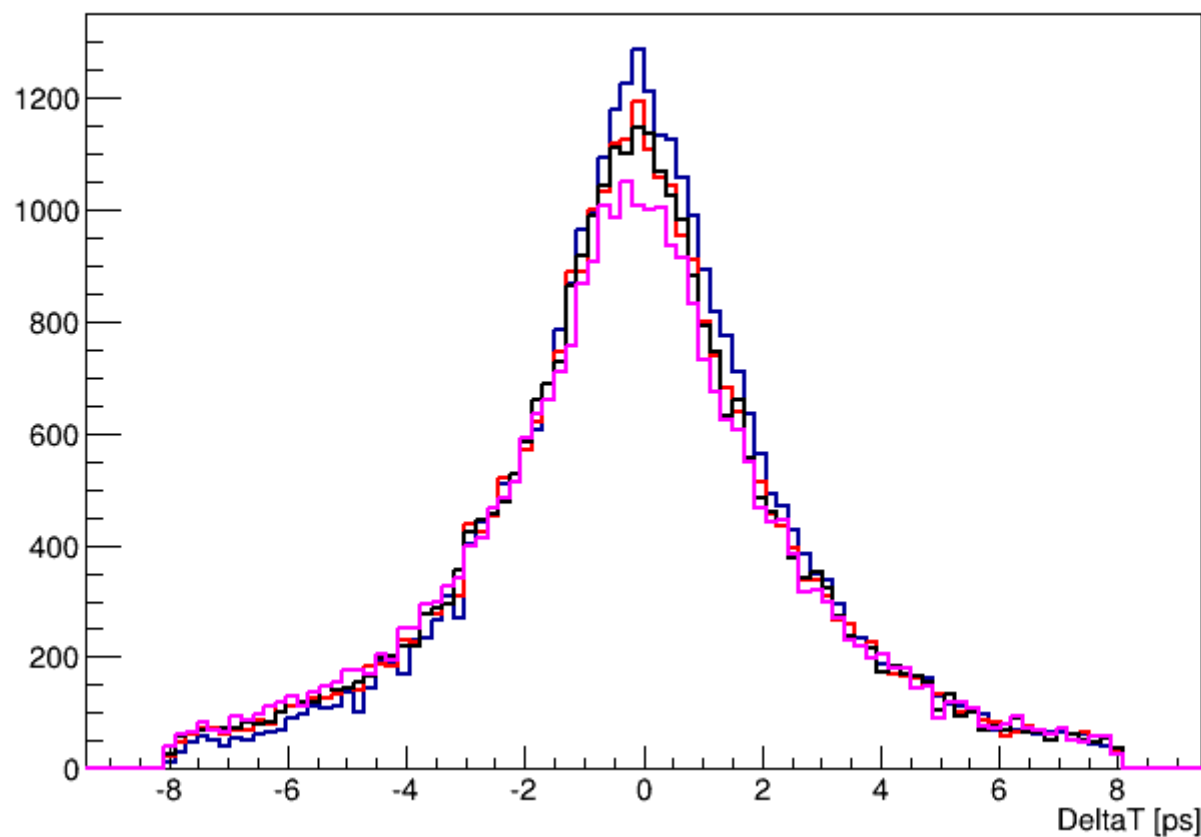Shift (micron) = 4.1566
Resolution (micron) = 60.3979

Generated Delta T

A RooPlot of "DT"
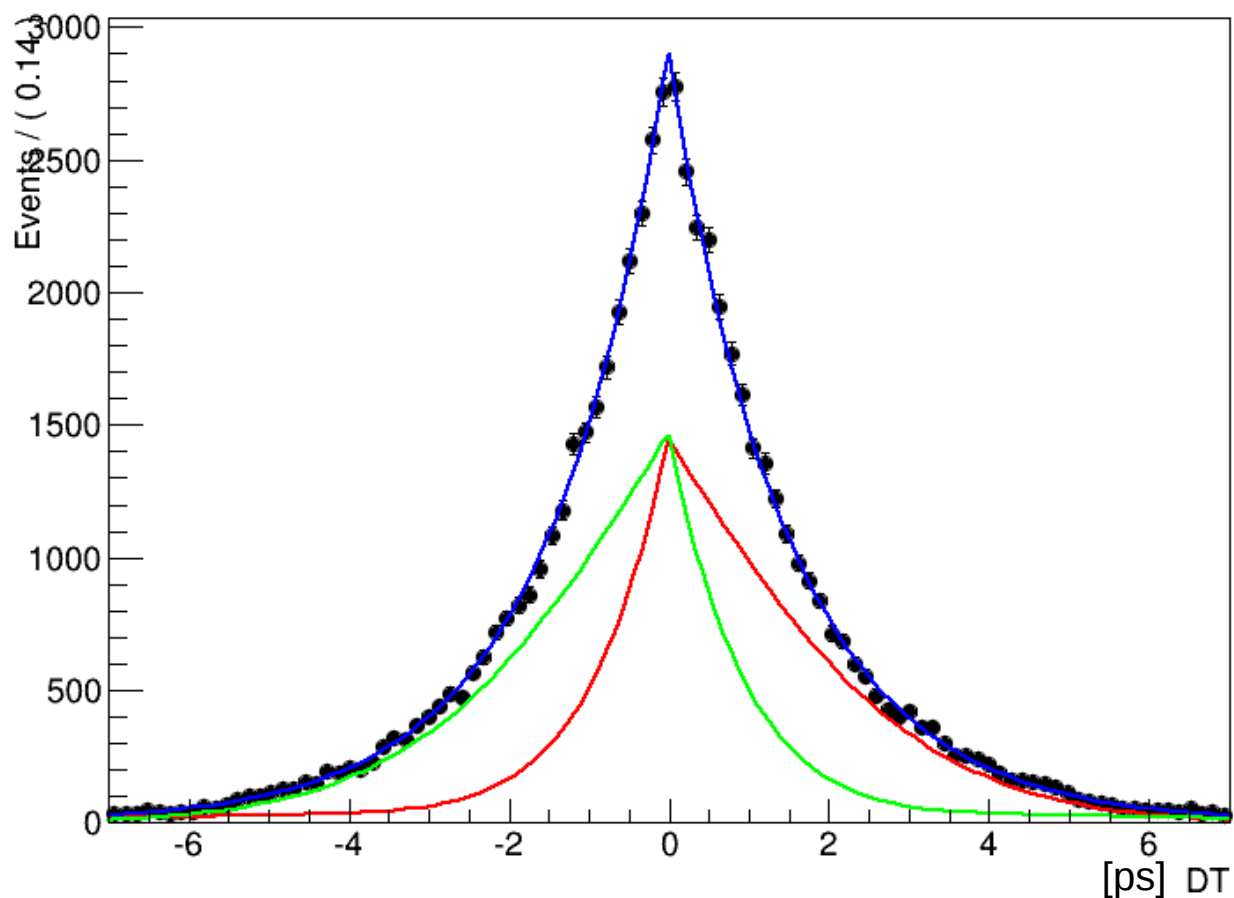
Floating Parameter	InitialValue	FinalValue +/-	Error	GblCorr.
A	0.0000e+00	-6.8791e-03 +/-	8.17e-03	\<none\>
DM	5.0700e-01	4.8861e-01 +/-	4.33e-03	\<none\>
DT0	0.0000e+00	-6.7928e-03 +/-	7.03e-03	\<none\>
S	7.0300e-01	6.9584e-01 +/-	5.77e-03	\<none\>
Tau	1.5250e+00	1.5064e+00 +/-	6.82e-03	\<none\>

Delta T: all constraints

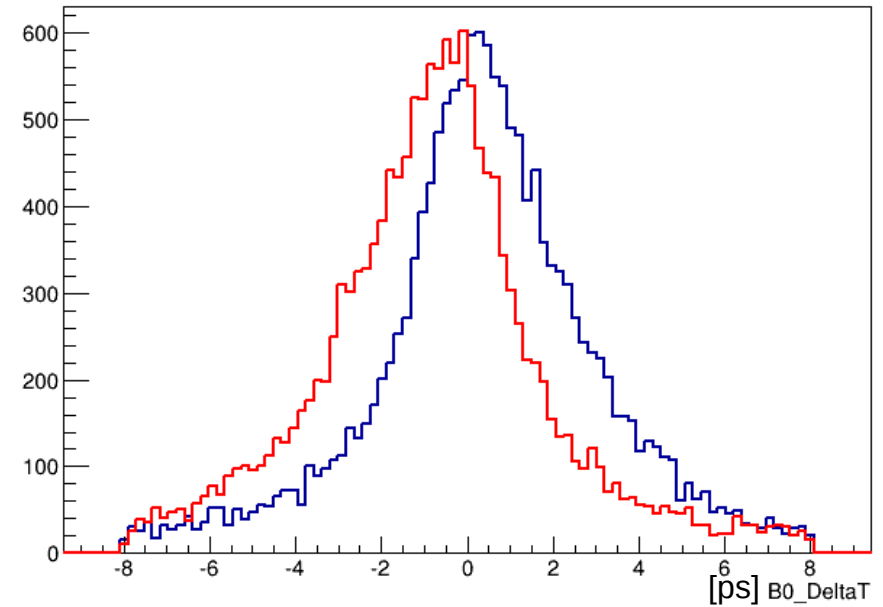$$\Delta t = \frac{\Delta b}{\beta \gamma c}$$

No constraint
Constraint from Breco
Boost tube constraint
Boost cut tube constraint
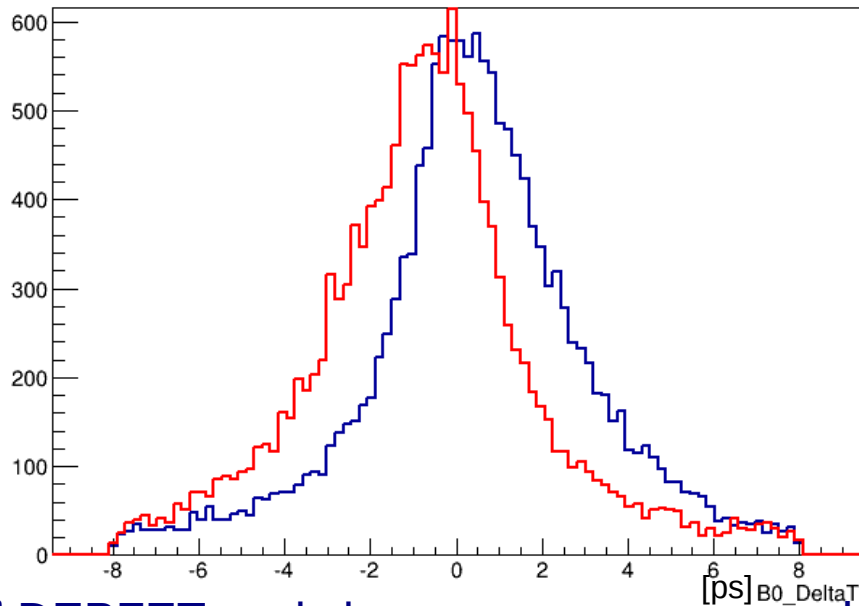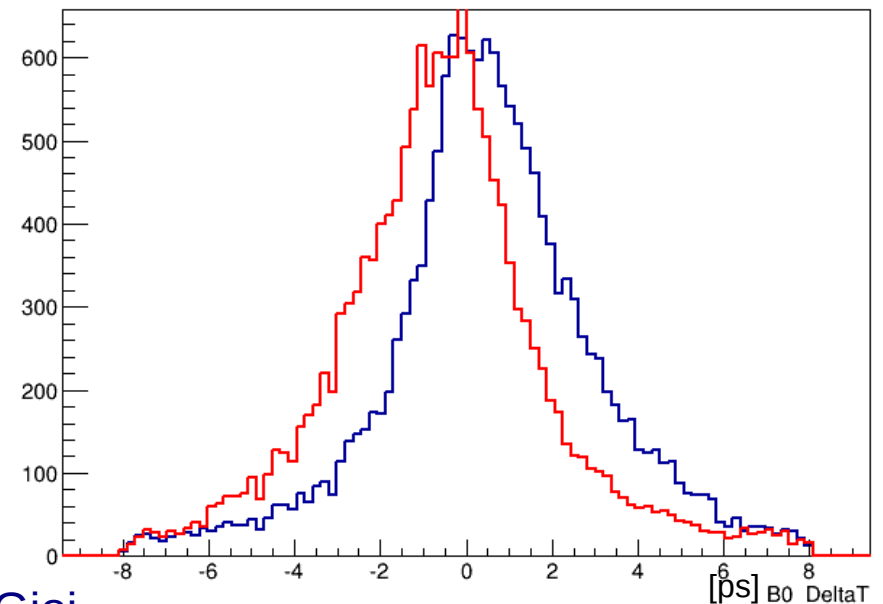
Delta T: assuming 100% tagging

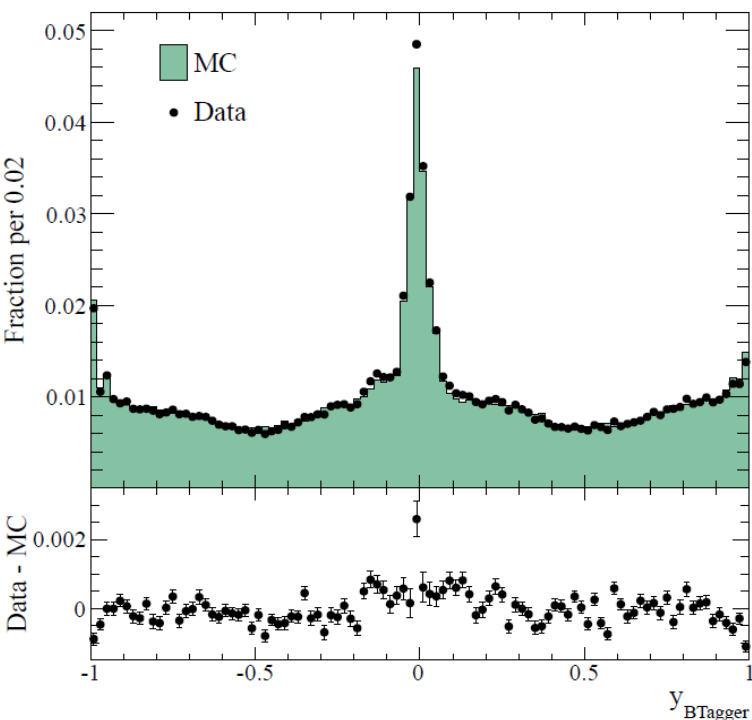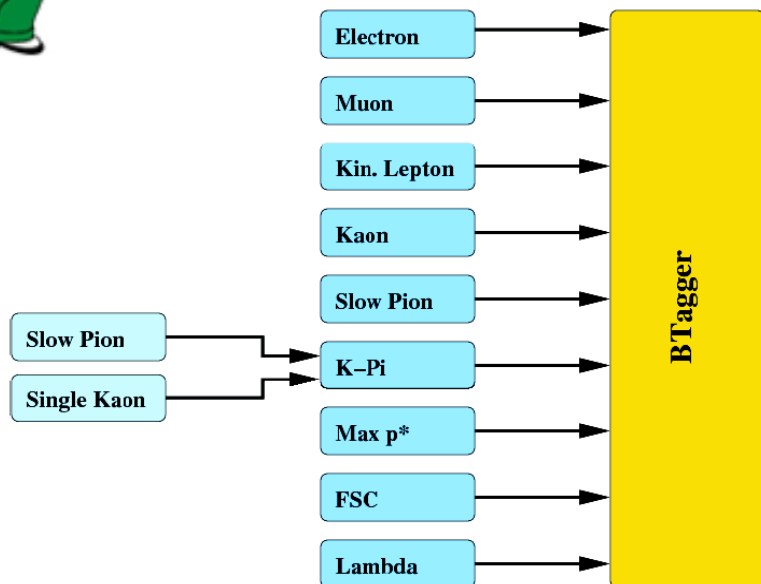No constraint
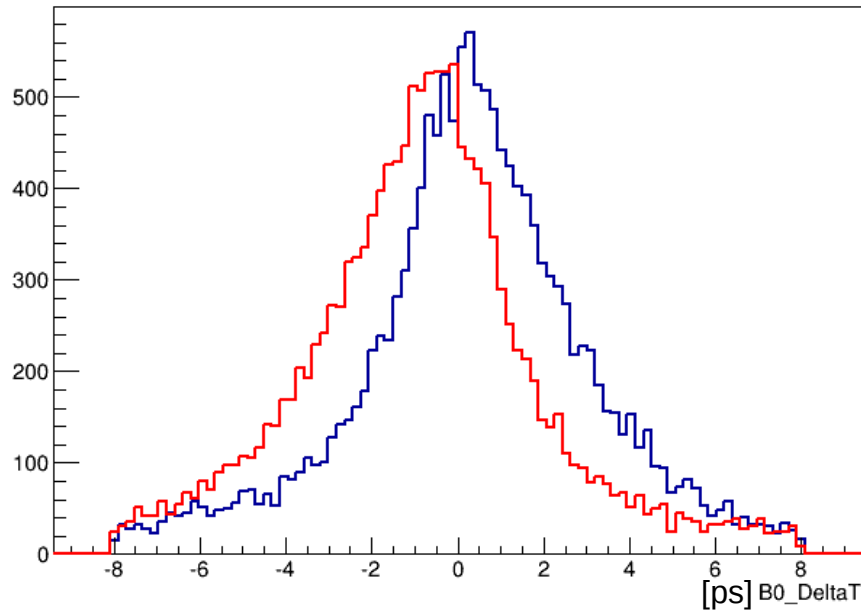
Breco constraint

Boost constraint

Boostcut constraint

Luigi Li Gioi

Flavor tagging

Optimize the tagging vertex fit algorithm according to the flavor tagging category

(1) high-momentum leptons from $B^0 \to X\ell^+\nu$ decays,
(2) kaons, since the majority of them originate from $B^0 \to K^+X$ decays through the cascade transition $\bar{b} \to \bar{c} \to \bar{s}$,
(3) intermediate momentum leptons from $\bar{b} \to \bar{c} \to \bar{s}\ell^-\bar{\nu}$ decays,
(4) high momentum pions coming from $B^0 \to D^{(*)}\pi^+X$ decays,
(5) slow pions from $B^0 \to D^{*-}X, D^{*-} \to \overline{D}^0\pi^-$ decays, and
(6) $\overline{\Lambda}$ baryons from the cascade decay $\bar{b} \to \bar{c} \to \bar{s}$.
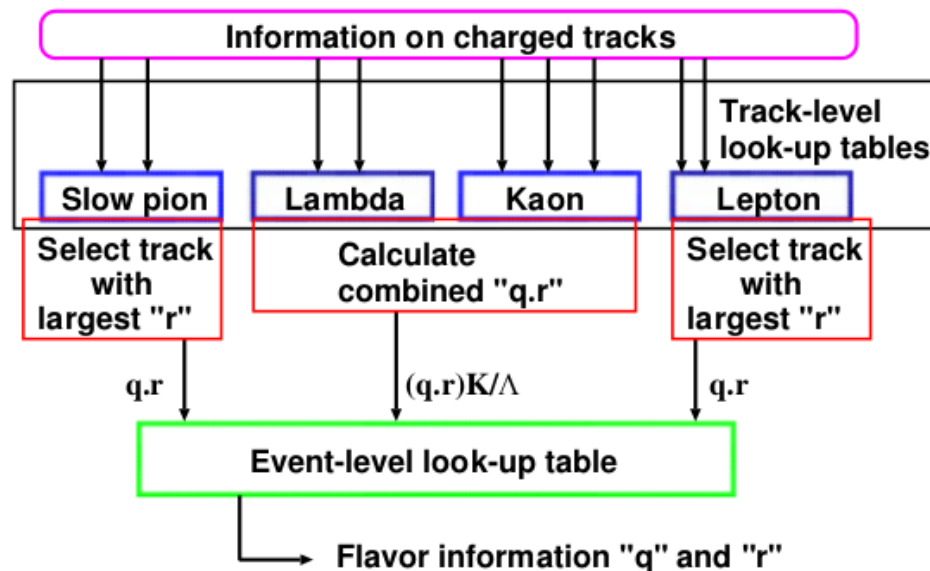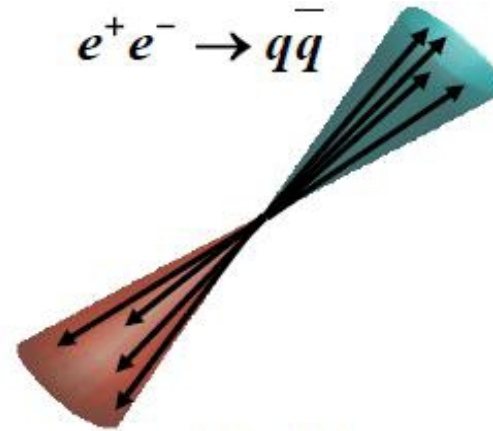
Continuum suppression

$$e^+e^- \rightarrow Y(4S) \rightarrow B\bar{B}$$
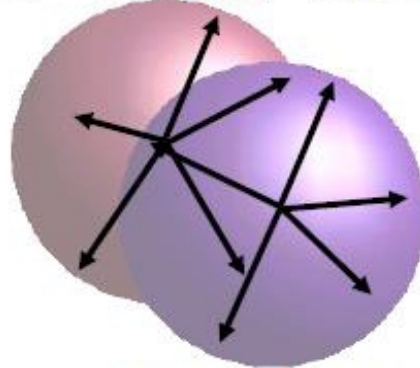
$$e^+e^- \rightarrow q\bar{q}$$

Spherical

Jet-like

- Continuum events are the primary source of background (larger cross section)
- $e^+e^- \rightarrow q\bar{q}$ (q = u, d, s and c) $\rightarrow$ fragmentation $\rightarrow$ hadrons as two back-to-back jets
- The B mesons decays without any preferred direction

- Shape variables are used to discriminate between B and continuum events
- Dz: the vertex separation along the z axis between the B candidate and the remaining tracks

Summary

- The Belle II Pixel Vertex Detector (PXD) is crucial for the Belle II physics program

- PXD performances are being studied in Monte Carlo simulation
  - Belle II physics software in under strong development
  - New results soon