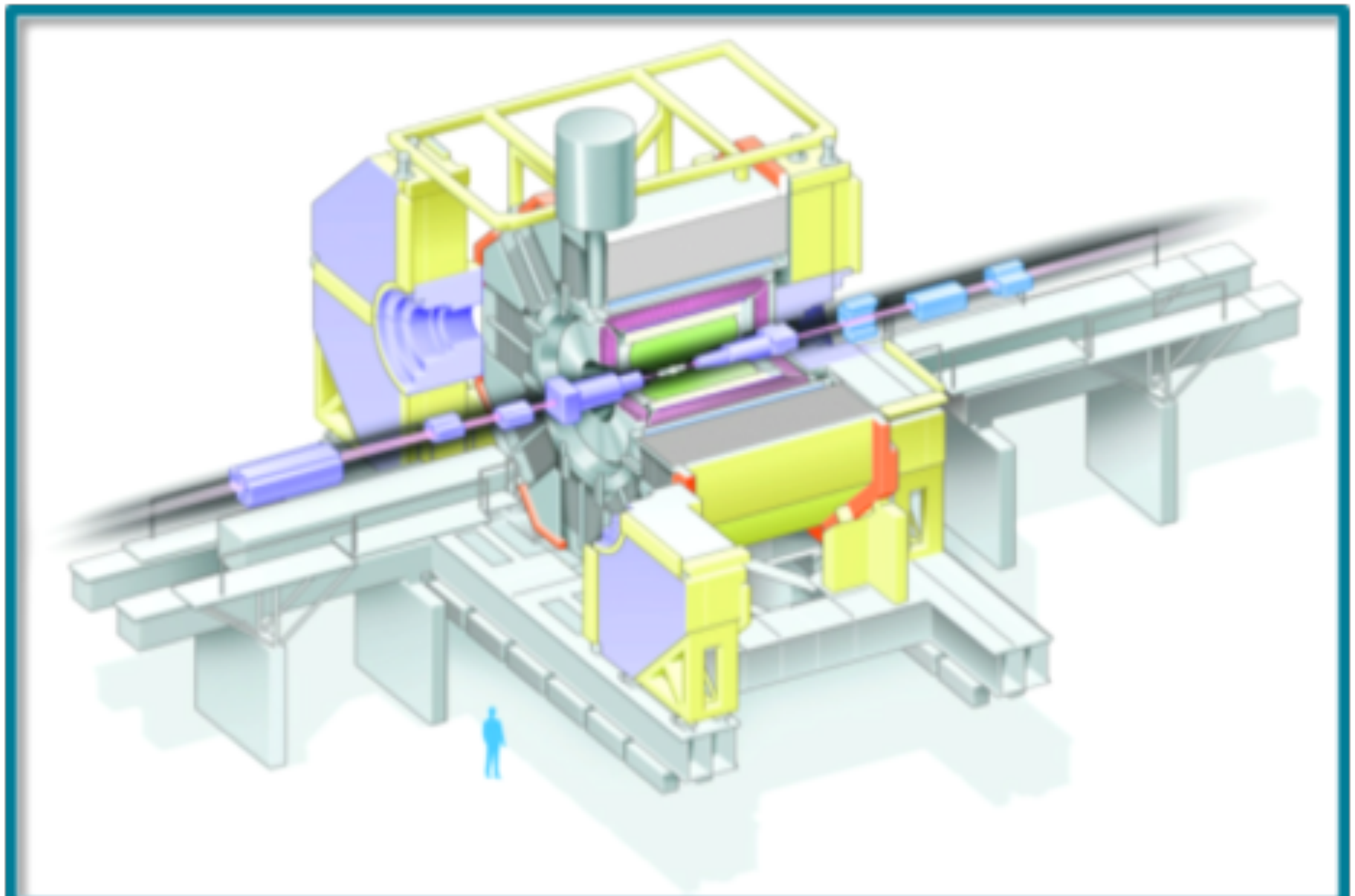
Search for $B^0 \rightarrow \ell^+\ell^-$ at Belle



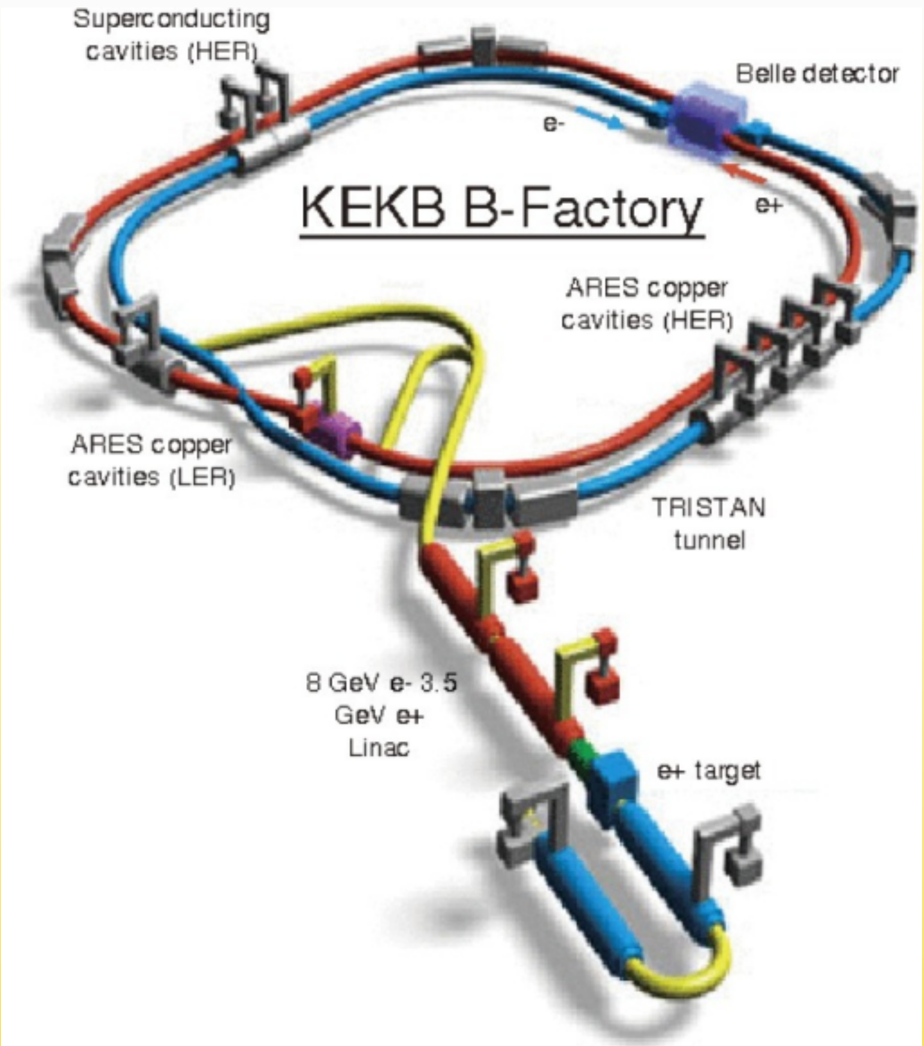
Kimberly Williams
Virginia Tech

DPF, August 4, 2015

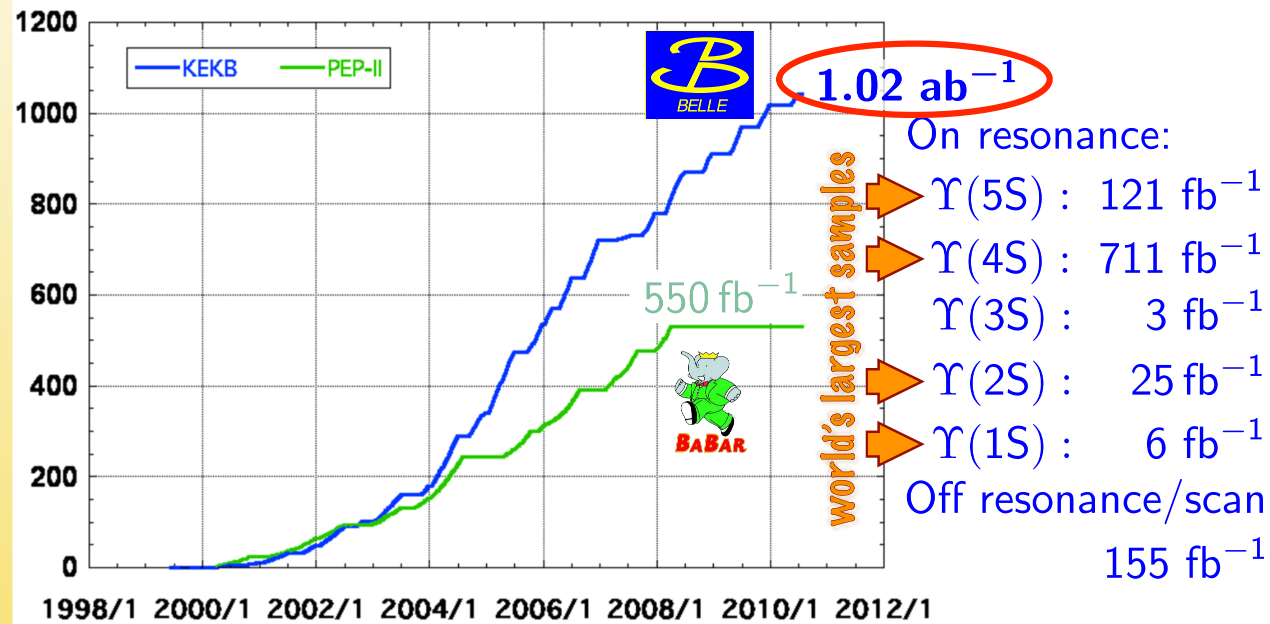
Content

- Belle experiment
- Data skimming
- Cut optimization
- Sensitivity study
- Linearity study
- Summary and Plan

The Belle Collaboration has accumulated 772 million events at the $\Upsilon(4S)$ resonance.



Data-taking ended in 2010 and was reprocessed with better tracking in 2011. Analysis of these data is on-going.



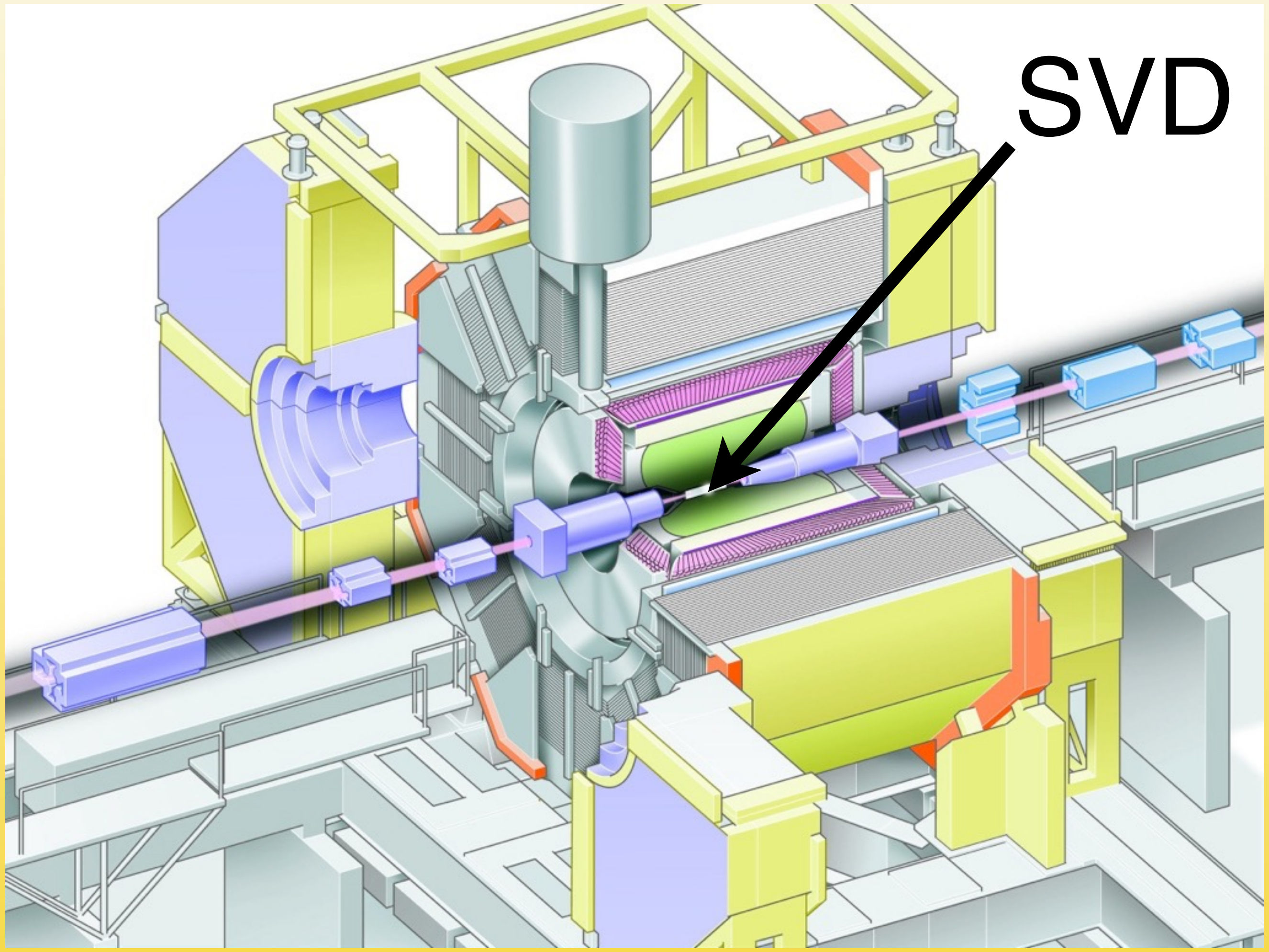
KEKB instantaneous luminosity: $\mathcal{L} = 2.1 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

$\sqrt{s}$ = 10.58GeV → e+e- → $\Upsilon(4S)$ → $B\bar{B}$

Peak luminosity = 2.1×10^{34} cm^{-2}s^{-1}

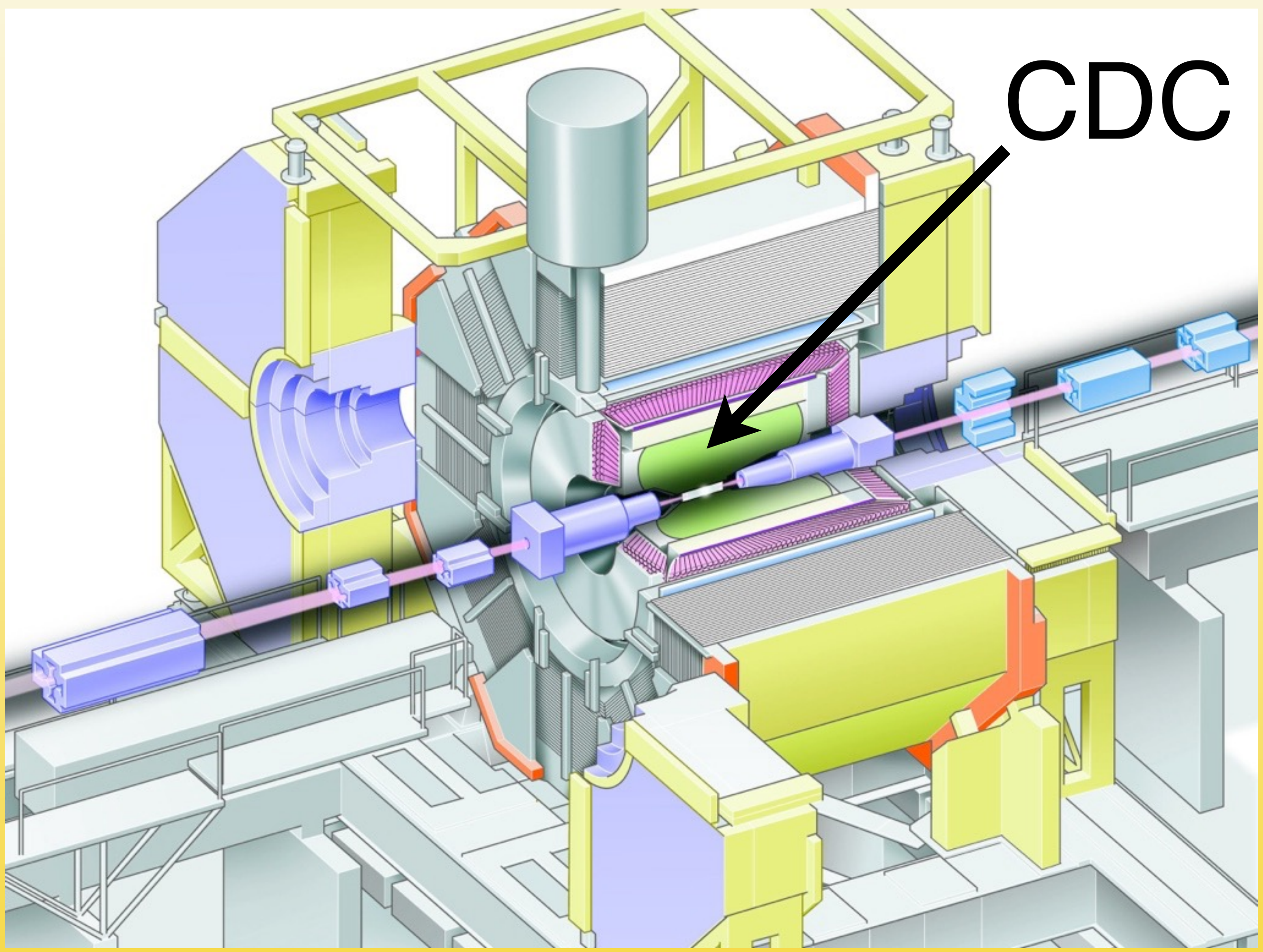
Integrated luminosity ~=1000 fb^{-1}

SVD measures $B\bar{B}$ vertices.



The Silicon Vertex Detector provides vertex reconstruction resolution of better than 100 μm.

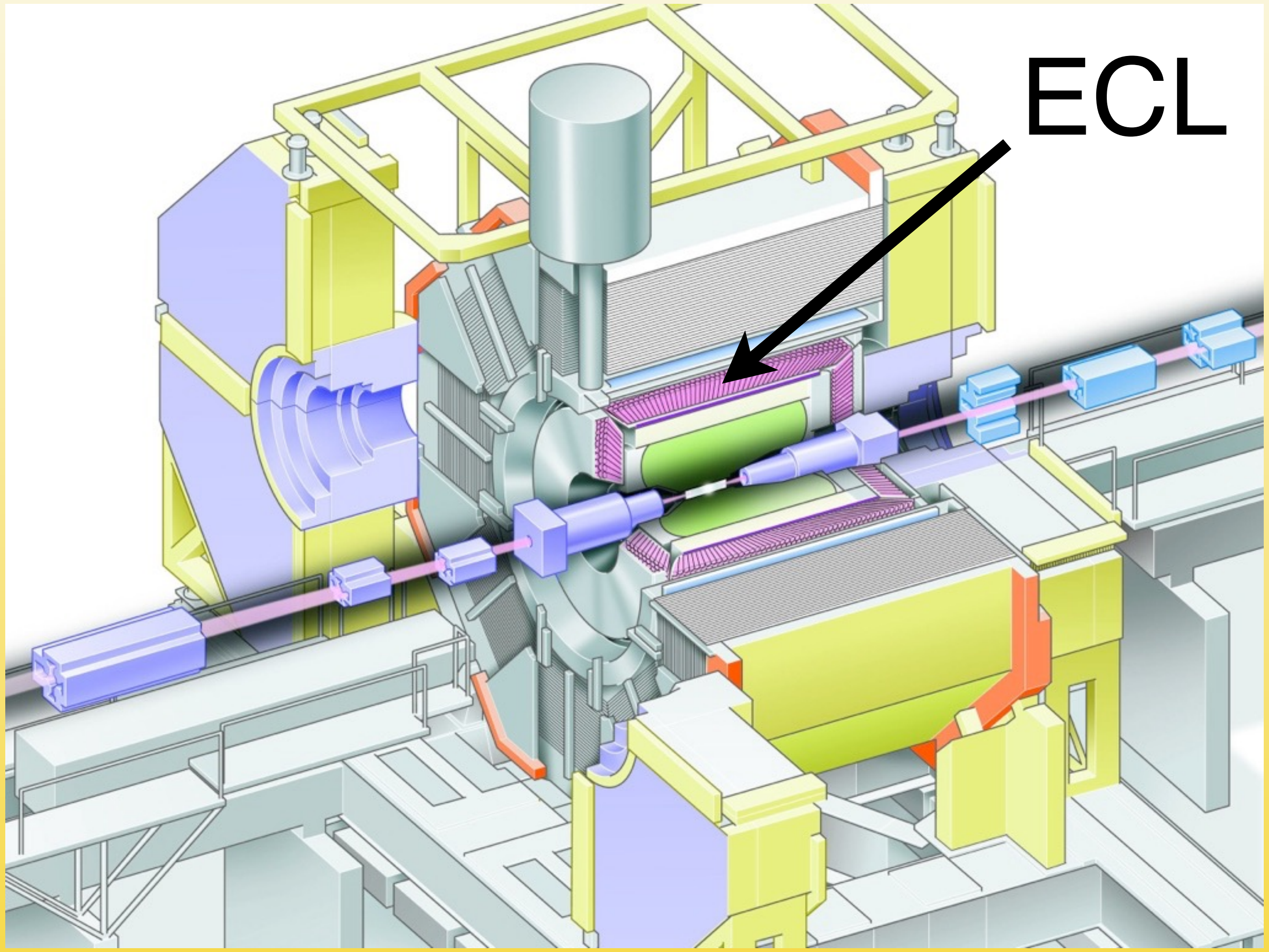
CDC provides tracking data.



The Central Drift Chamber provides:

- 3D trajectories and momentum vectors
- Measurement of charged particle energy loss in the chamber gas (dE/dx) for particle identification

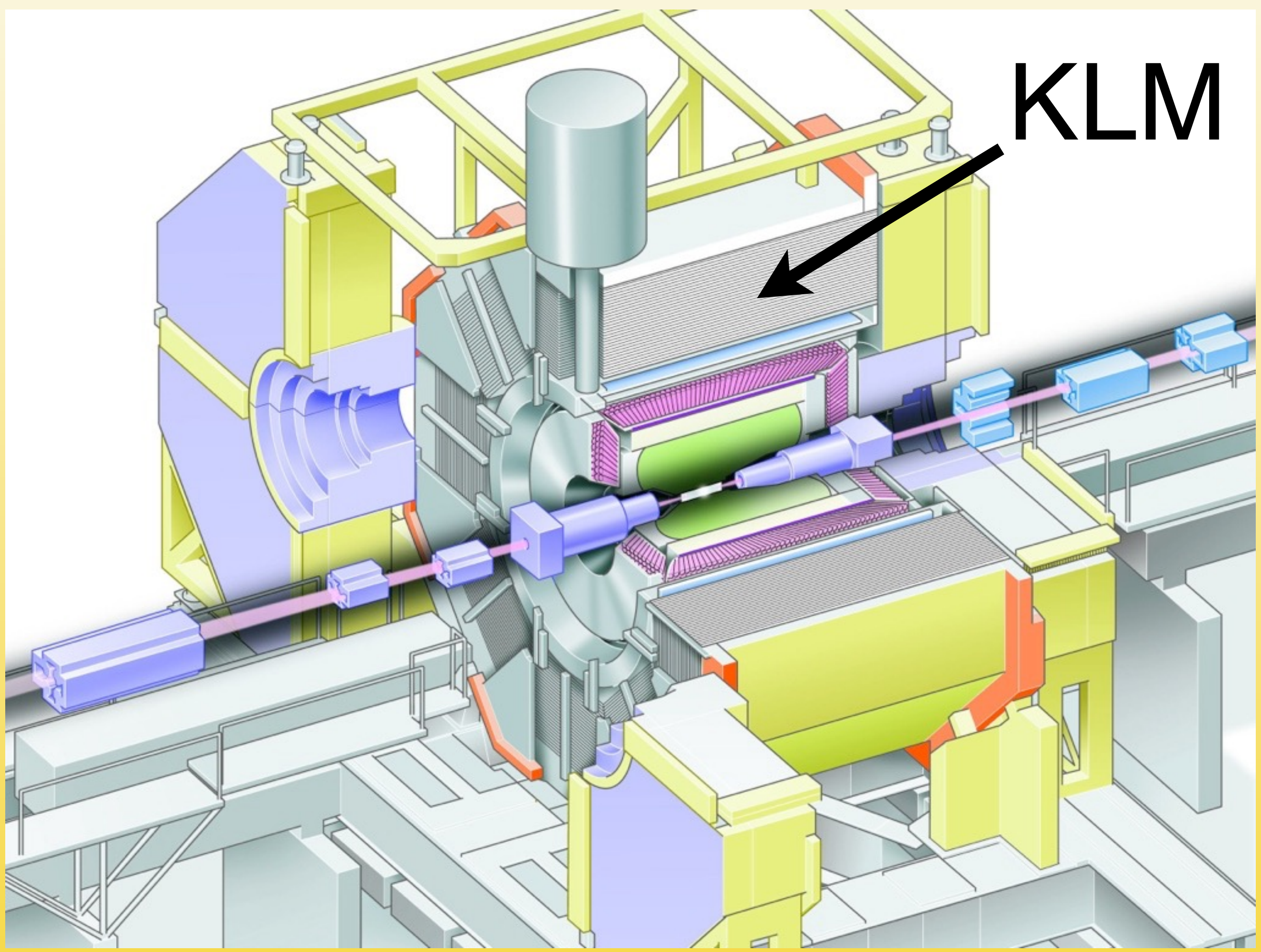
ECL identifies electrons.



The electromagnetic calorimeter is the main sub-detector for electron identification.

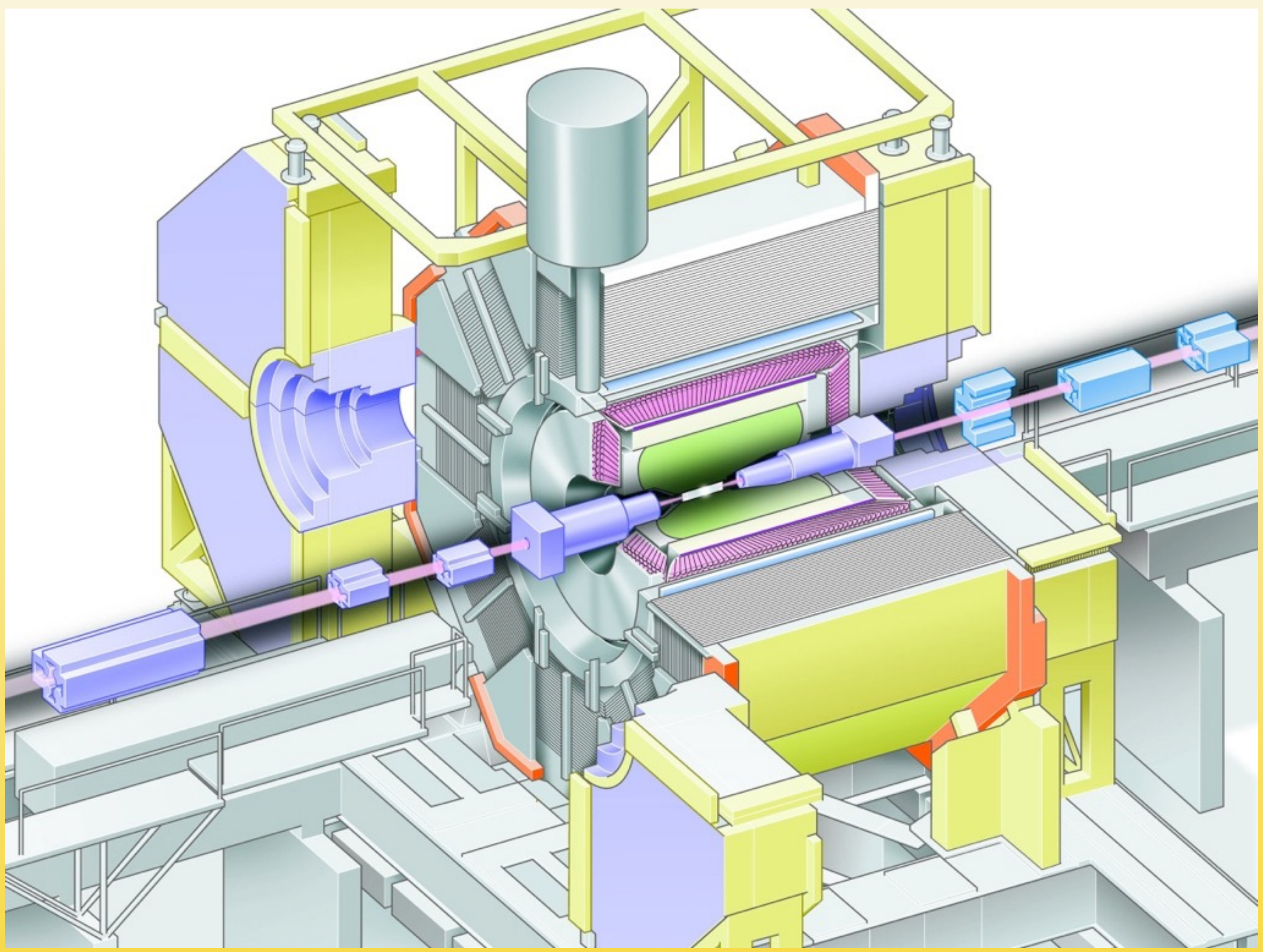
The ECL also detects photons.

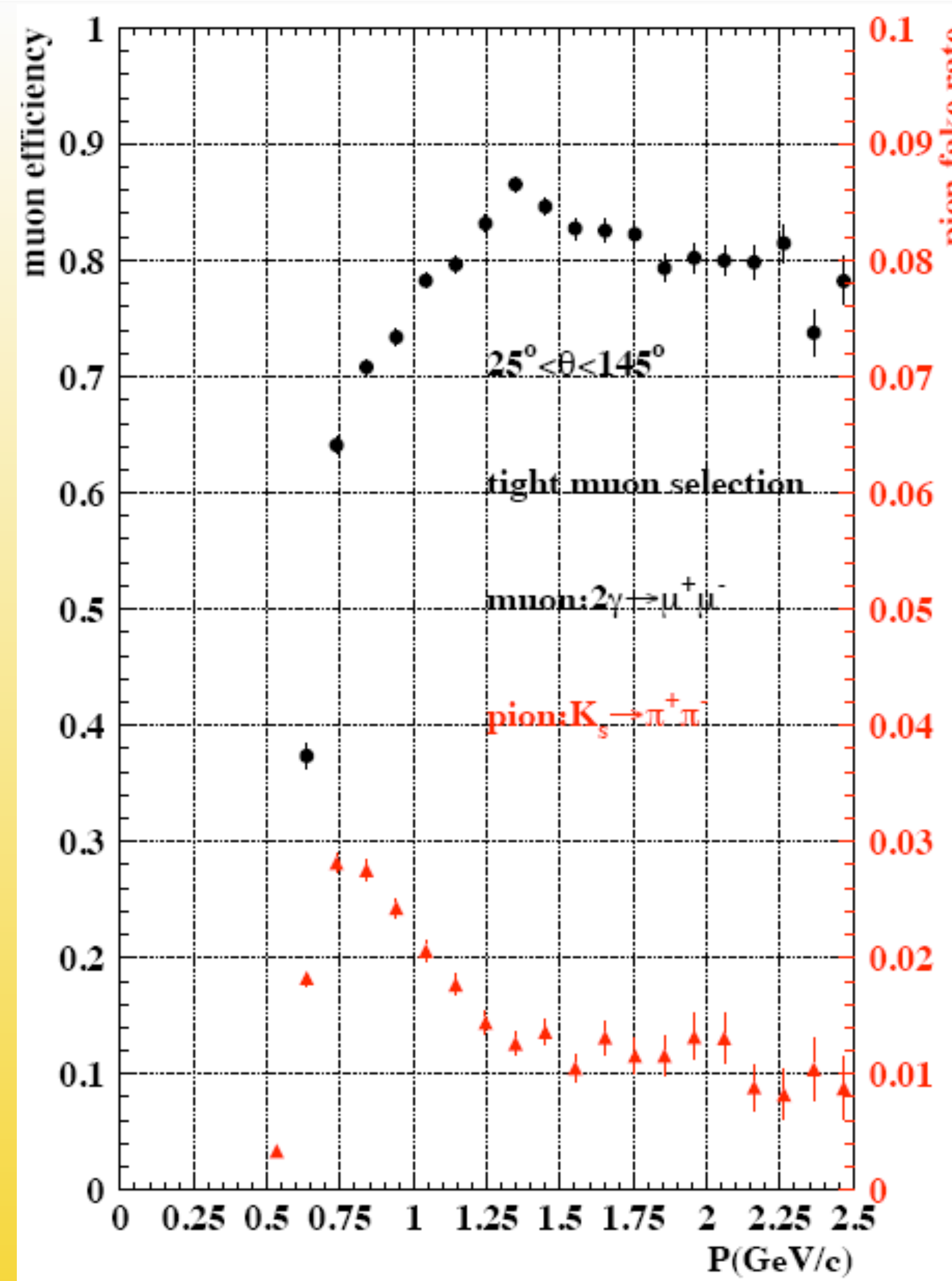
KLM identifies muons.



The K_{Long}-μ detector identifies muons and K_L particles over a large momentum range.

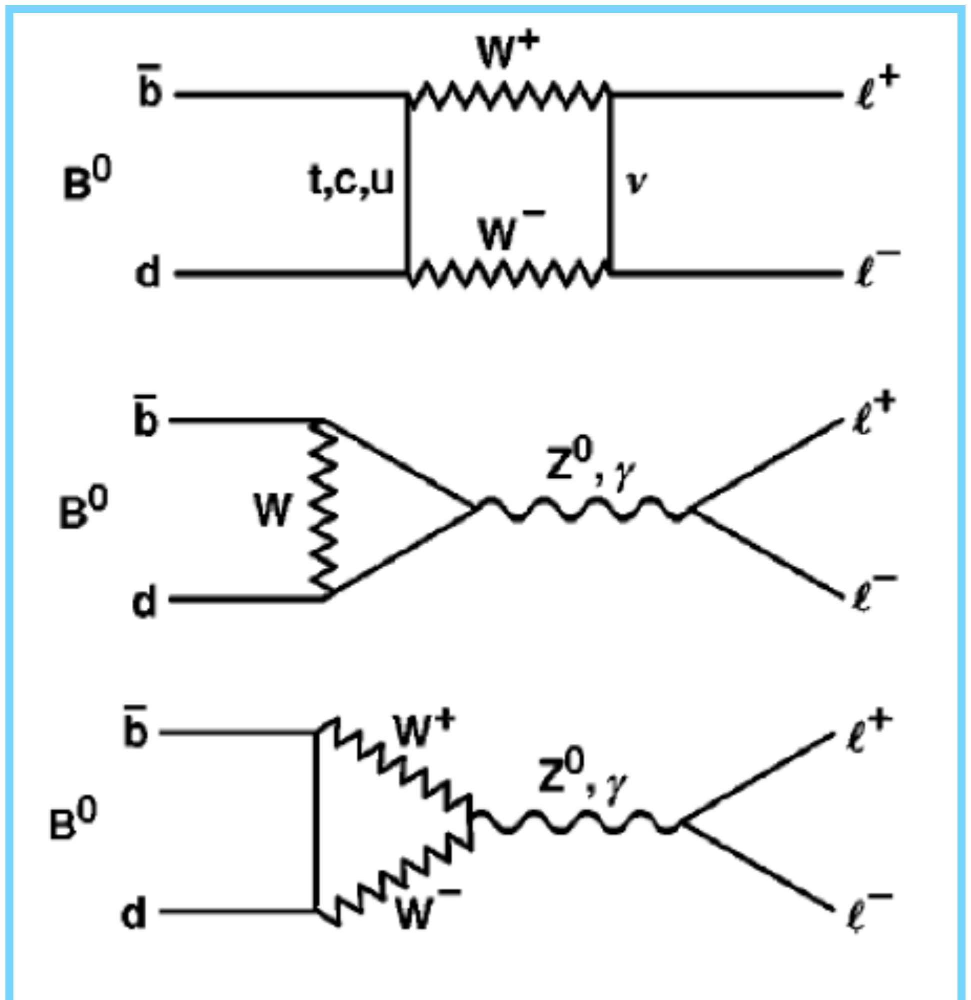
The sub-detectors combine for efficient particle identification.

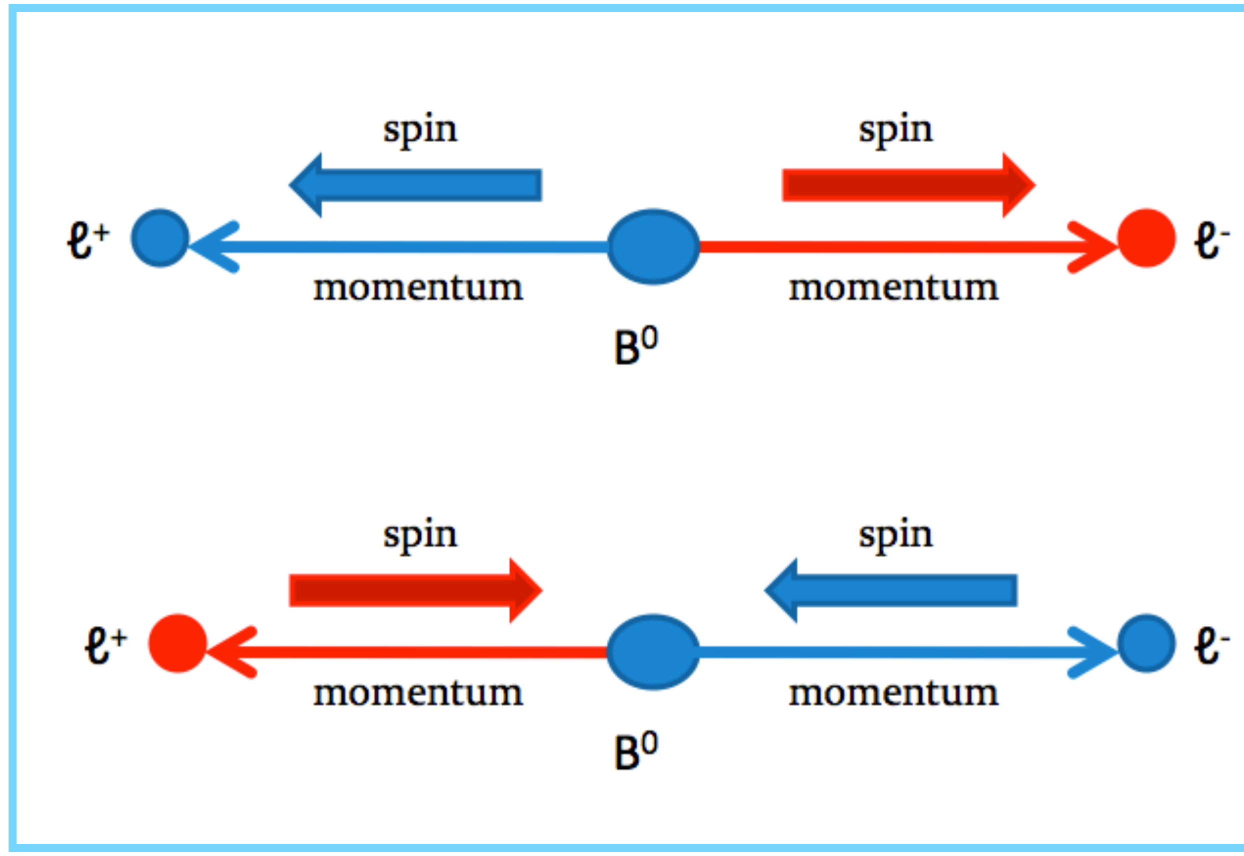




The standard model allows for $B^0 \to e^+e^-$ and $B^0 \to \mu^+\mu^-$ but not $B^0 \to e^\pm\mu^\mp$.

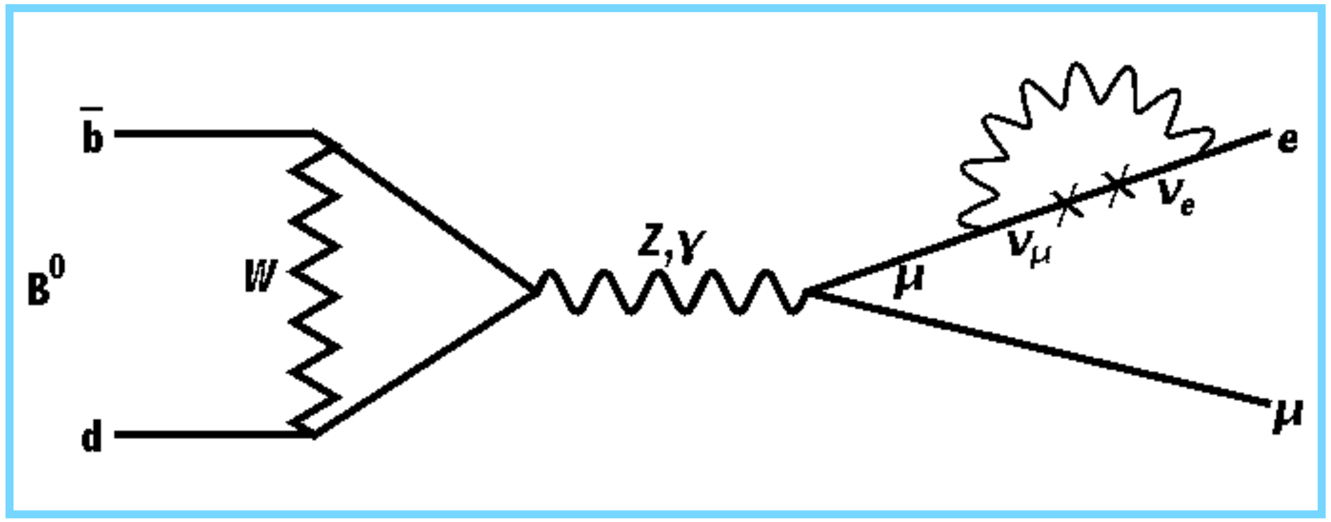
$B^0 \to e^+e^-$ and $B^0 \to \mu^+\mu^-$ proceed through flavor changing weak current.



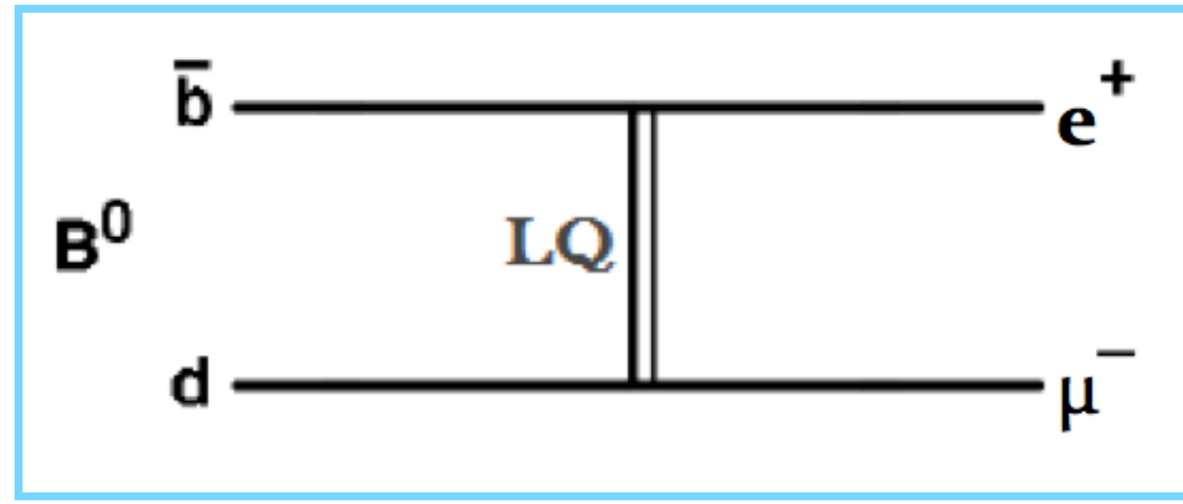


$B^0 \to \ell^+\ell^-$ is a helicity suppressed decay. Either the lepton or anti-lepton must be in a suppressed state.

Extensions of the standard model could allow $B^0 \to e^\pm \mu^\mp$ to occur.



Neutrino Oscillation ($\approx 10^{-60}$)



Hypothetical particles like leptoquarks

Any observation of $B^0 \to e^\pm \mu^\mp$ would indicate new physics.

Previous studies have set upper limits on branching fractions.

Mode	Standard Model Prediction	Measured Branching fraction	Experiment
$B \to e^+e^-$	2.3×10^{-15}	$<8.3\times10^{-8}$	CDF
$B \to \mu^+\mu^-$	1.0×10^{-10}	$<6.3\times10^{-10}$	LHCb
$B \to e^\pm\mu^\mp$	0	$<2.8\times10^{-9}$	LHCb

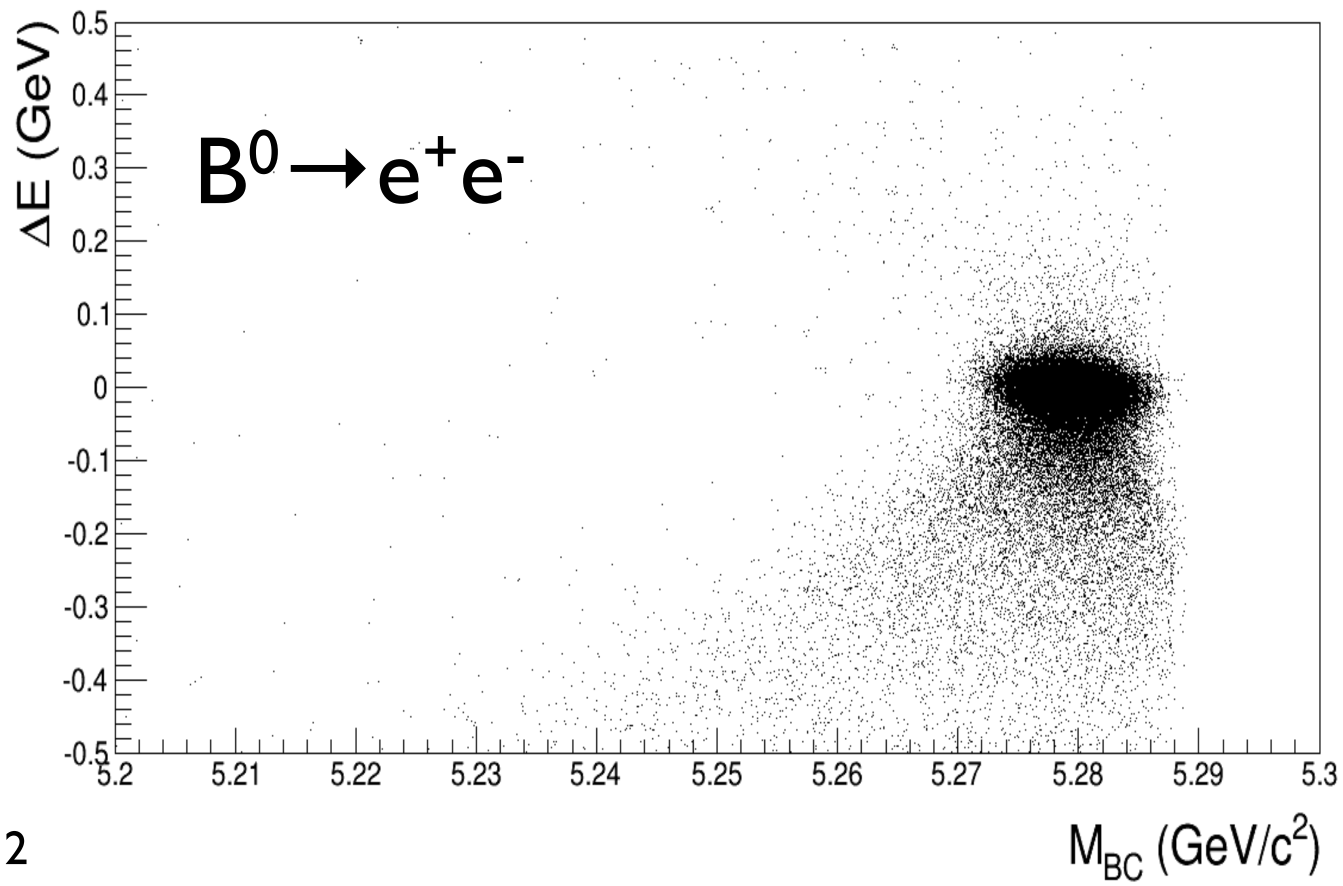
LHCb measured
$\mathcal{B}(B_s \to \mu^+\mu^-) = [3.1 \pm 0.7]\times10^{-9}$

K.A. Olive *et al.* (Particle Data Group), Chin. Phys. C, **38**, 090001 (2014)

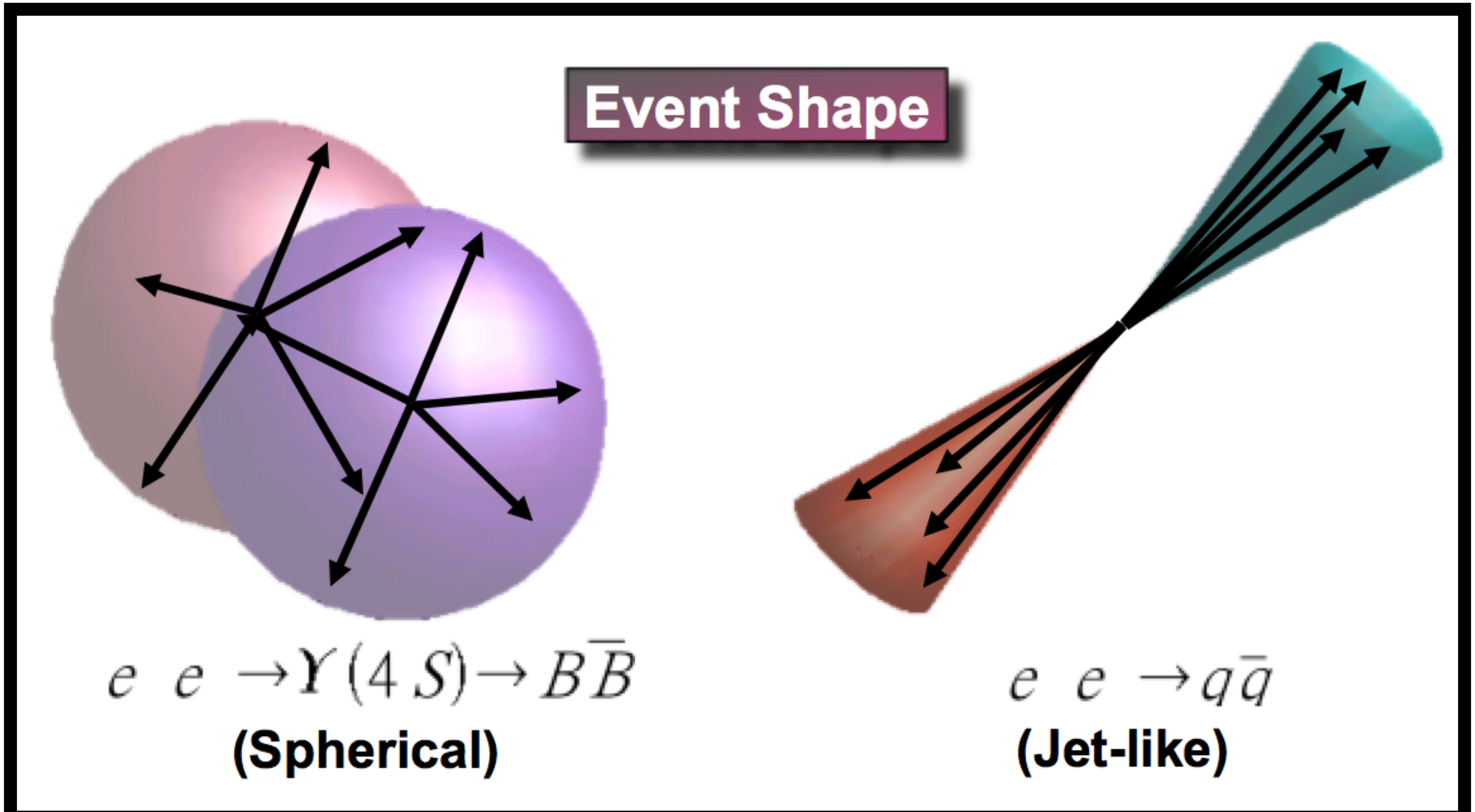
Skimming requirements

- Uses one positive and one negative track to form a B candidate.
- Skim pass range
  - $-1.0\ \text{GeV} \leq \Delta E \leq 0.5\ \text{GeV}$
  - $5.20\ \text{GeV}/c^2 \leq M_{BC} \leq 5.30\ \text{GeV}/c^2$
- Skimmed data are written to ROOT files for analysis.

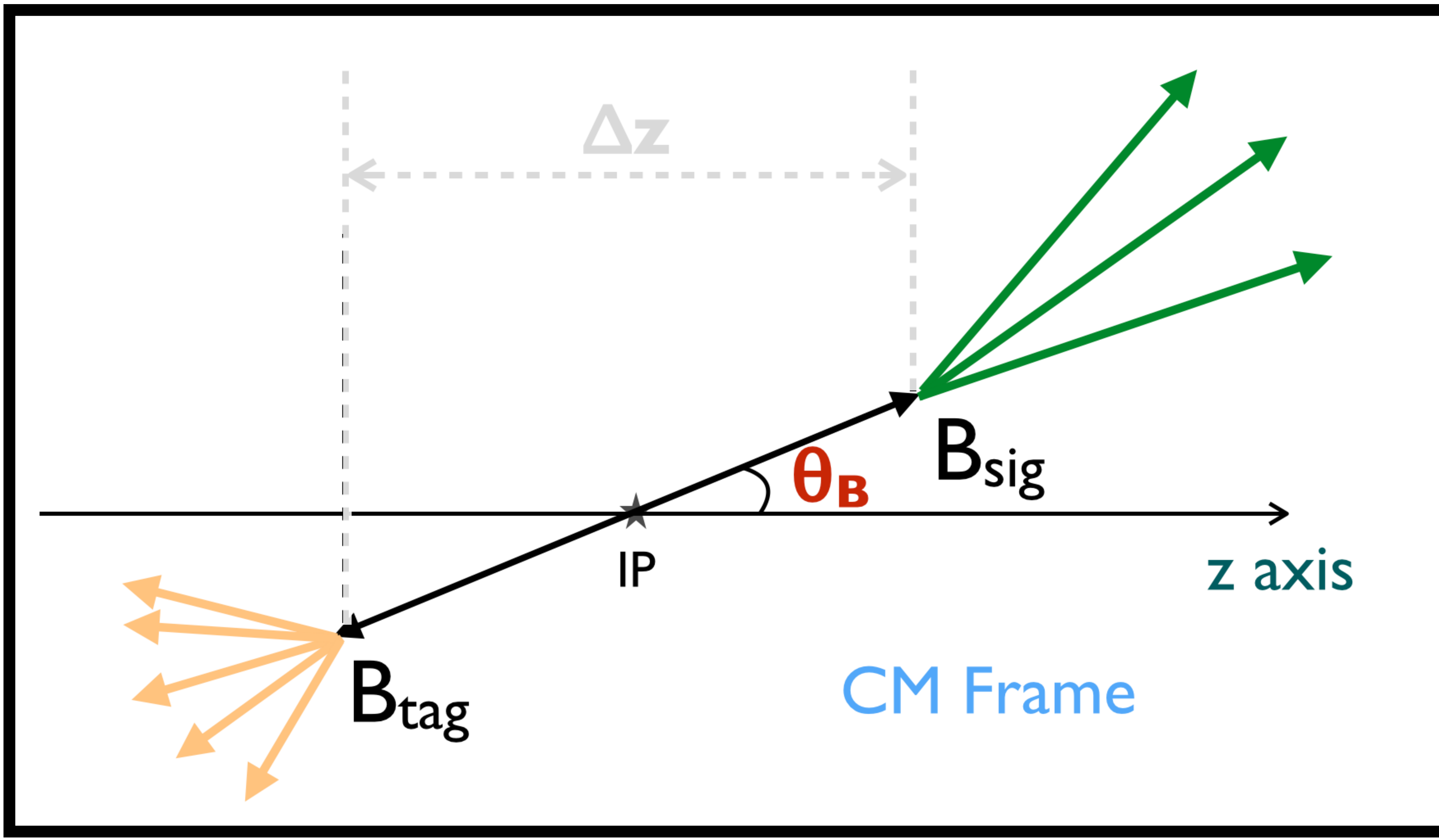
ΔE has an asymmetric range to allow for electron bremsstrahlung.



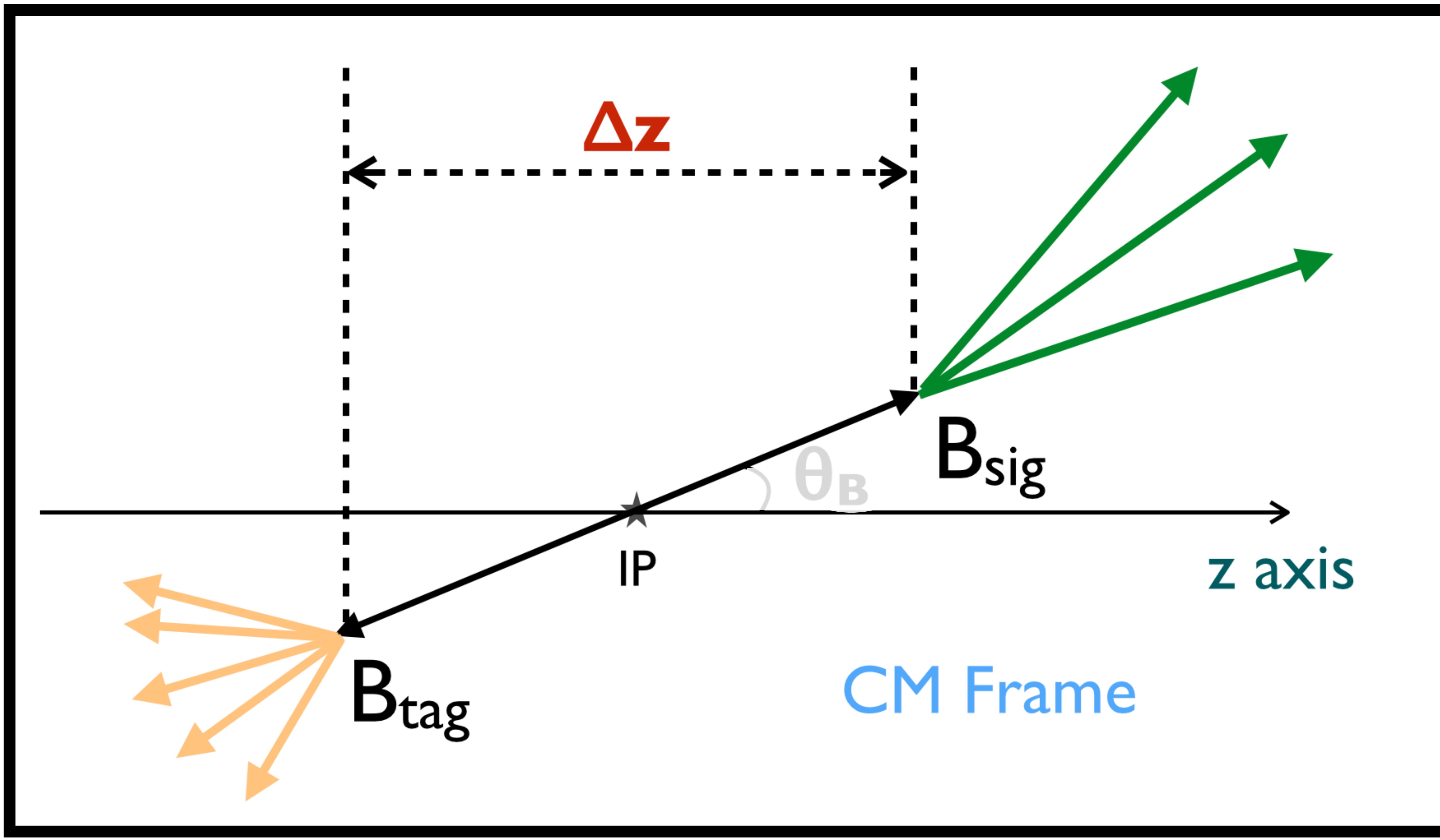
Continuum suppression variables: Event shape



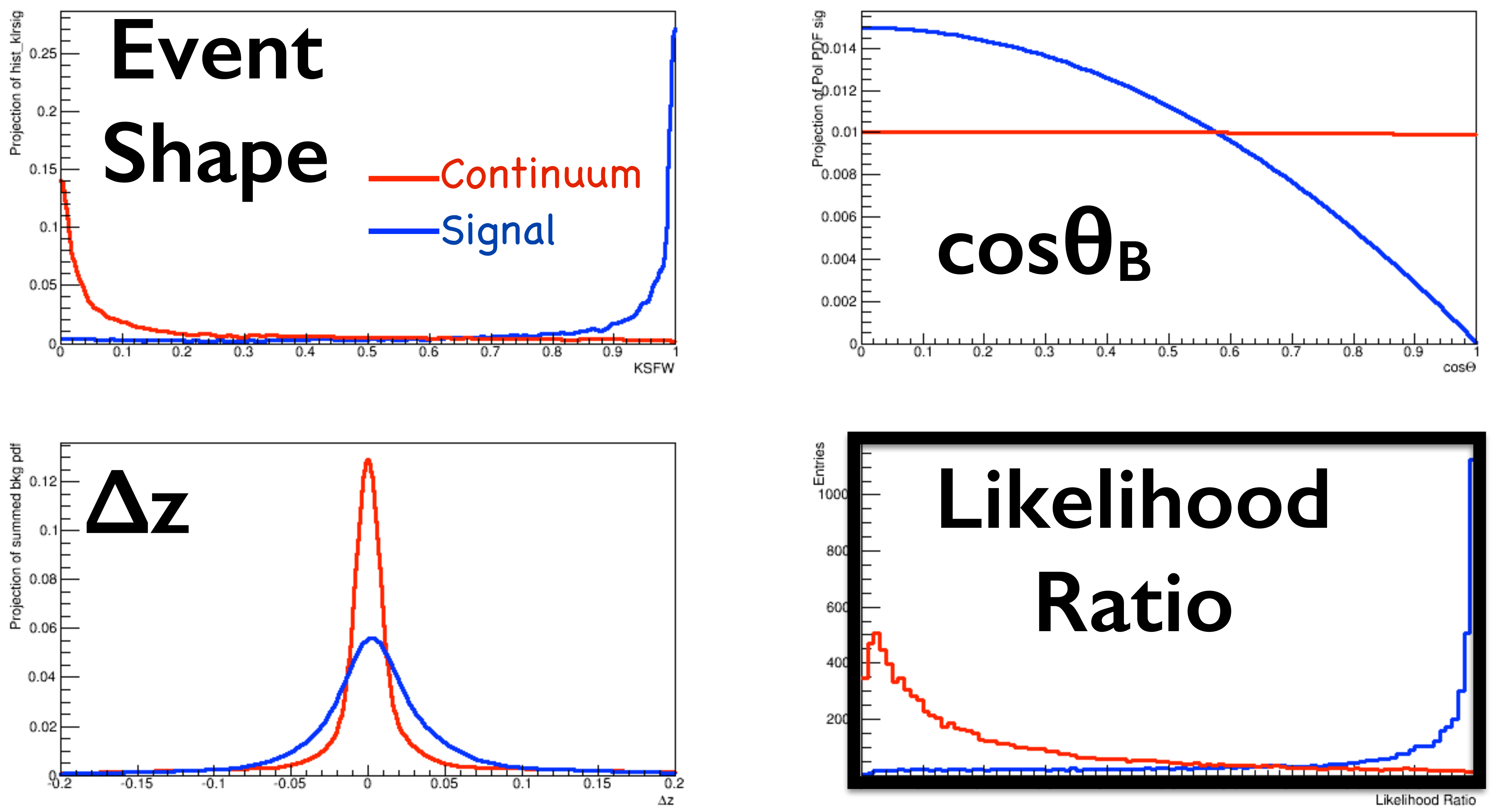
Continuum suppression variables: $\cos\theta_B$



Continuum suppression variables: Δz

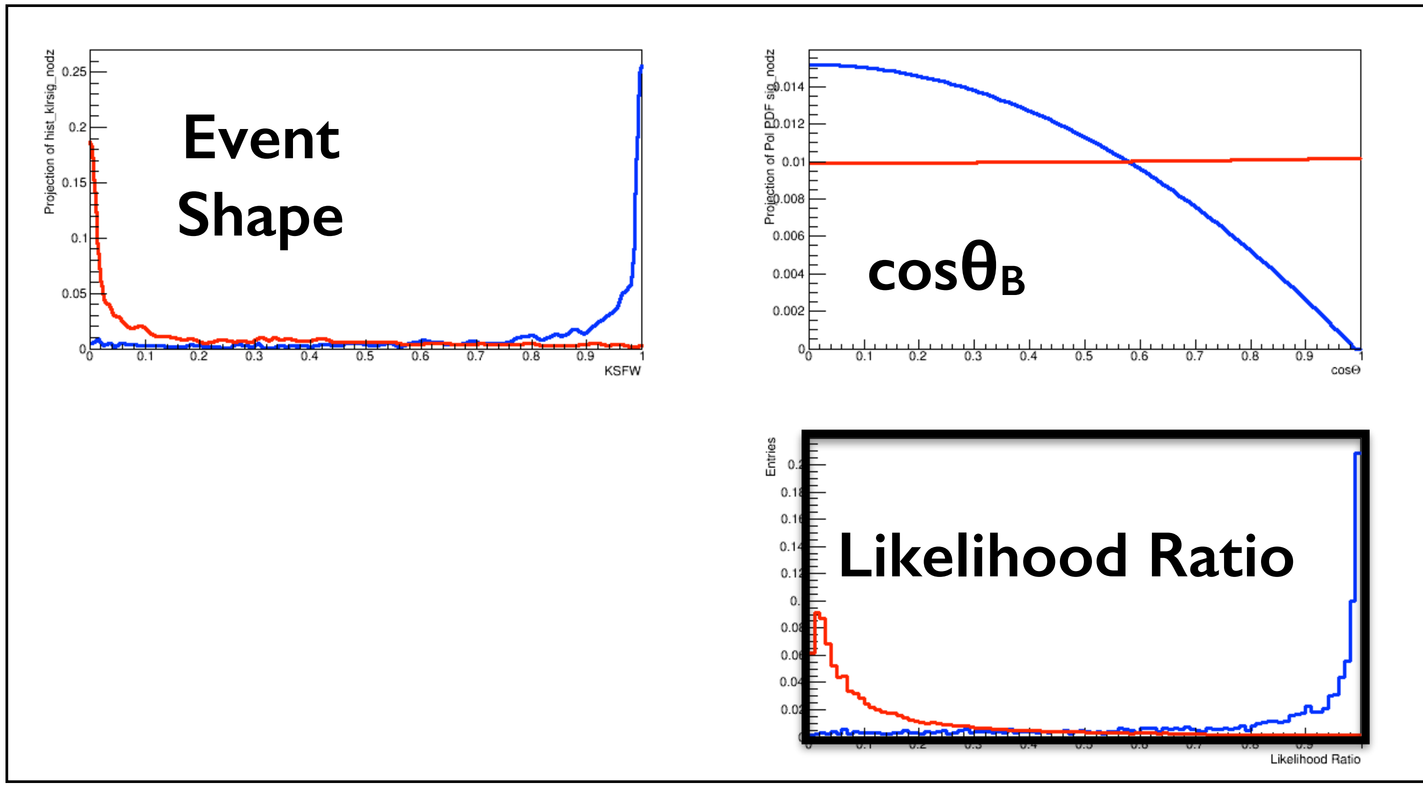


Continuum suppression variables are combined into a single likelihood ratio.

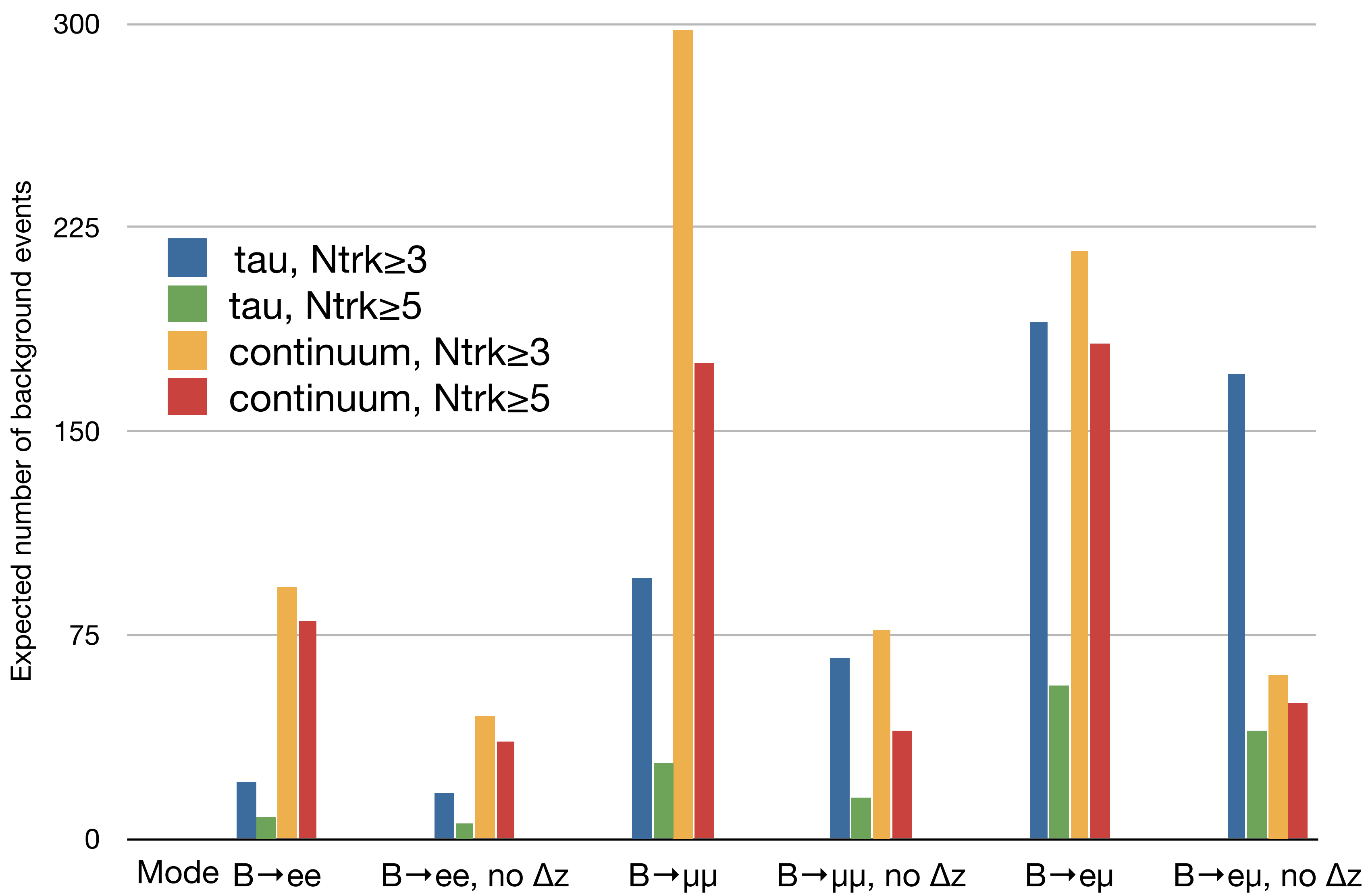


Around 10% of events have no Δz.

- These are otherwise good events but with a failed vertex reconstruction.
- These events are treated separately.
- All events are recombined into one data set at the end of analysis.



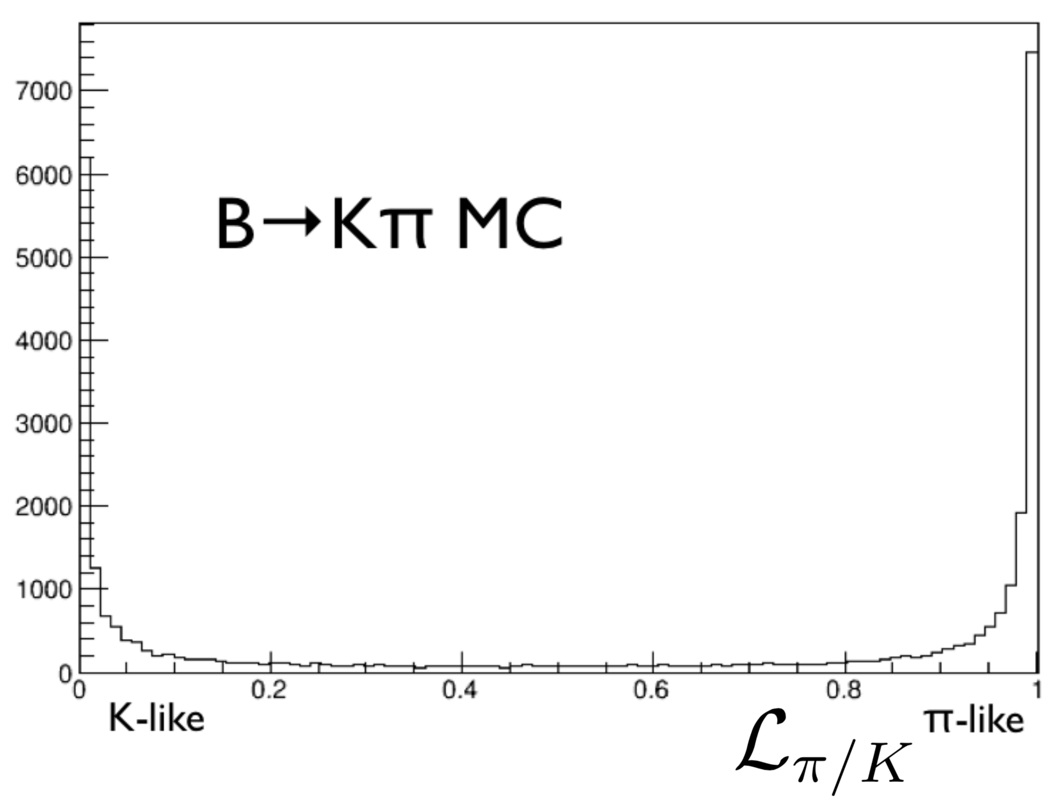
A cut on $N_{track} \geq 5$ helped reduce continuum and tau-pair bkgs.



Number of events expected for one stream of data across full fit region ($5.2 \leq M_{BC} \leq 5.3$ GeV/c^2 and $|\Delta E| \leq 0.5$ GeV)

A cut on the pion ID reduces B→Kπ background.

$$\mathcal{L}_{\pi/K} = \frac{\mathcal{L}_\pi}{\mathcal{L}_\pi + \mathcal{L}_K}$$



- Cut is placed at $\mathcal{L}_{\pi/K} \geq 0.5$.
- Reduces B → Kπ by a factor of 10 and B → KK by a factor of 100.
- Signal modes reduced by 0% - 3%.

A sensitivity study found the best expected upper limit.

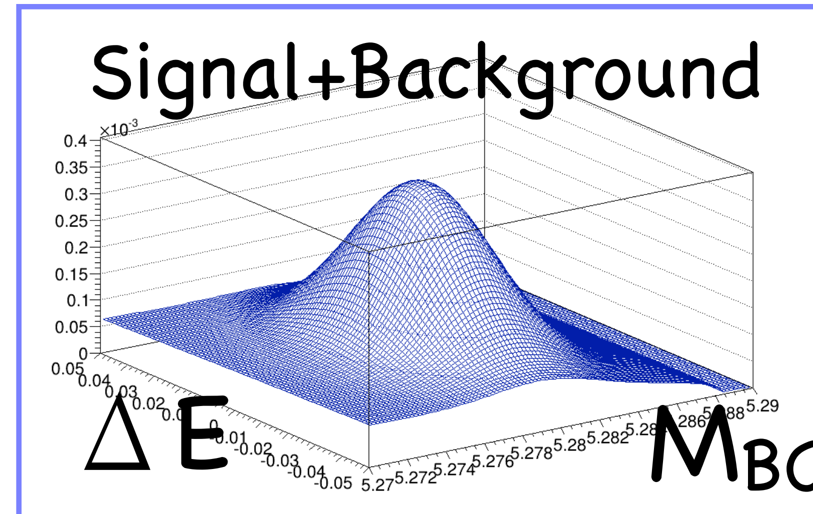
Use null signal and the expected number of background events.

Generate 10,000 toy MC sets.

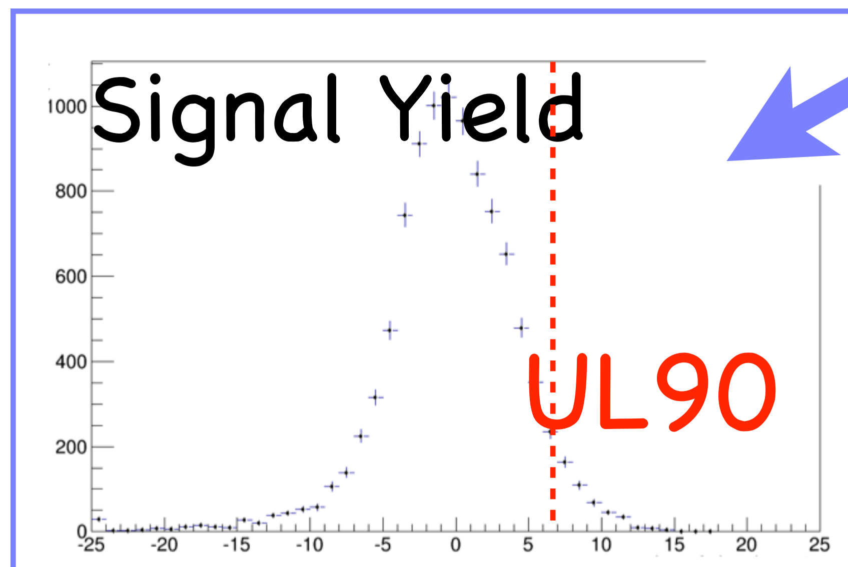
Fit toy MC to PDFs of signal and background.

Extract signal yield.

Optimize cuts on continuum suppression to get best sensitivity on branching fraction.



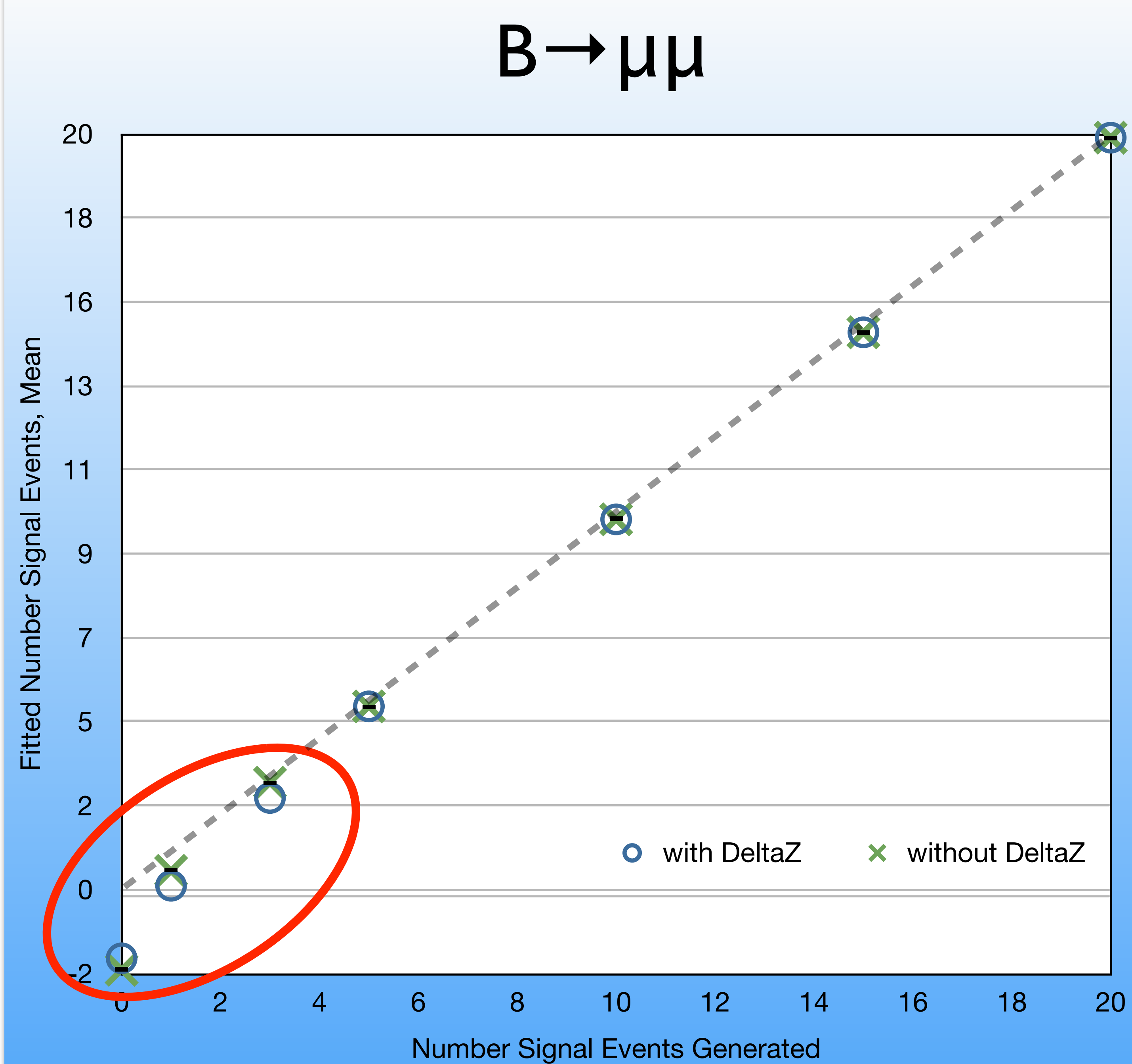
Fit 10000x



Calculate

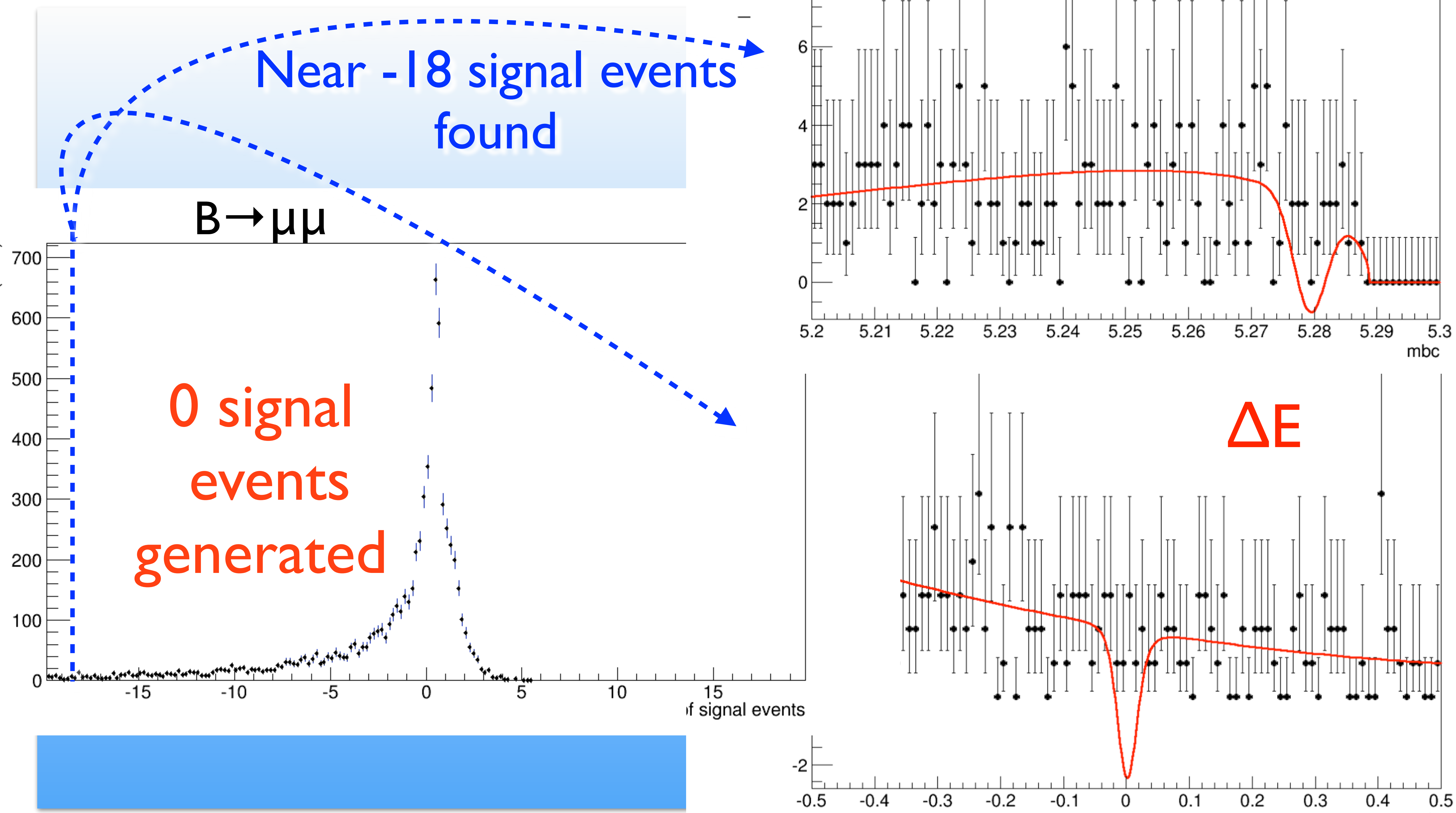
$$BF_{UL} = \frac{UL90}{\varepsilon_{sig} N_{events}}$$

Linearity study: Previous method used standard ROOT fits.

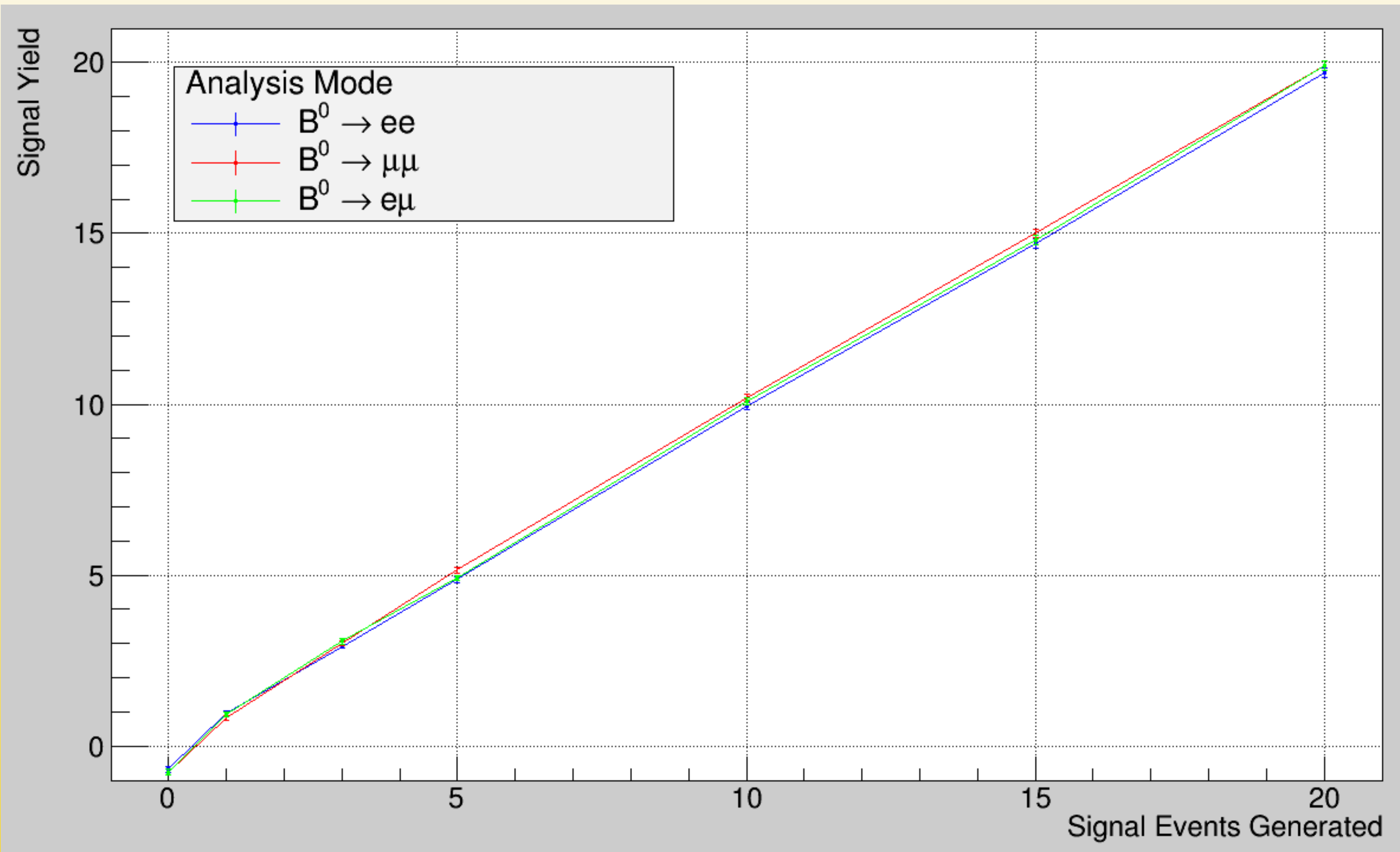


- Gives negative bias for $\#signal_{gen} < 5$
- Negative bias is caused by a low tail in number of fitted signal yield distribution

Linearity study: Previous method used



Linearity Study: New method uses multiple initial guesses.



- Good for $\#signal_{gen} > 0$.
- $\#signal_{gen} = 0$ values show improvement but still low ($-0.7 \to -0.8$).

Summary and Plan

SUMMARY

- Skimmed data
- Optimized cuts
- Completed sensitivity and linearity studies

PLAN

- Unblind the study
- Calculate systematic errors
- Publish results