Acceptance Issues in a *Super* B Detector

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- Guiding Principles
- Acceptance and efficiency
- Acceptance and background rejection
  - Recoil analysis
  - τ physics

Extremely Naive Scaling Laws

- For most analyses, efficiency scales ~ (acceptance)$^{\text{some power}}$
  - "some power" typically number of decay products in final state
  - Background rates scale at the same rate
  - Increasing acceptance behaves like increasing luminosity

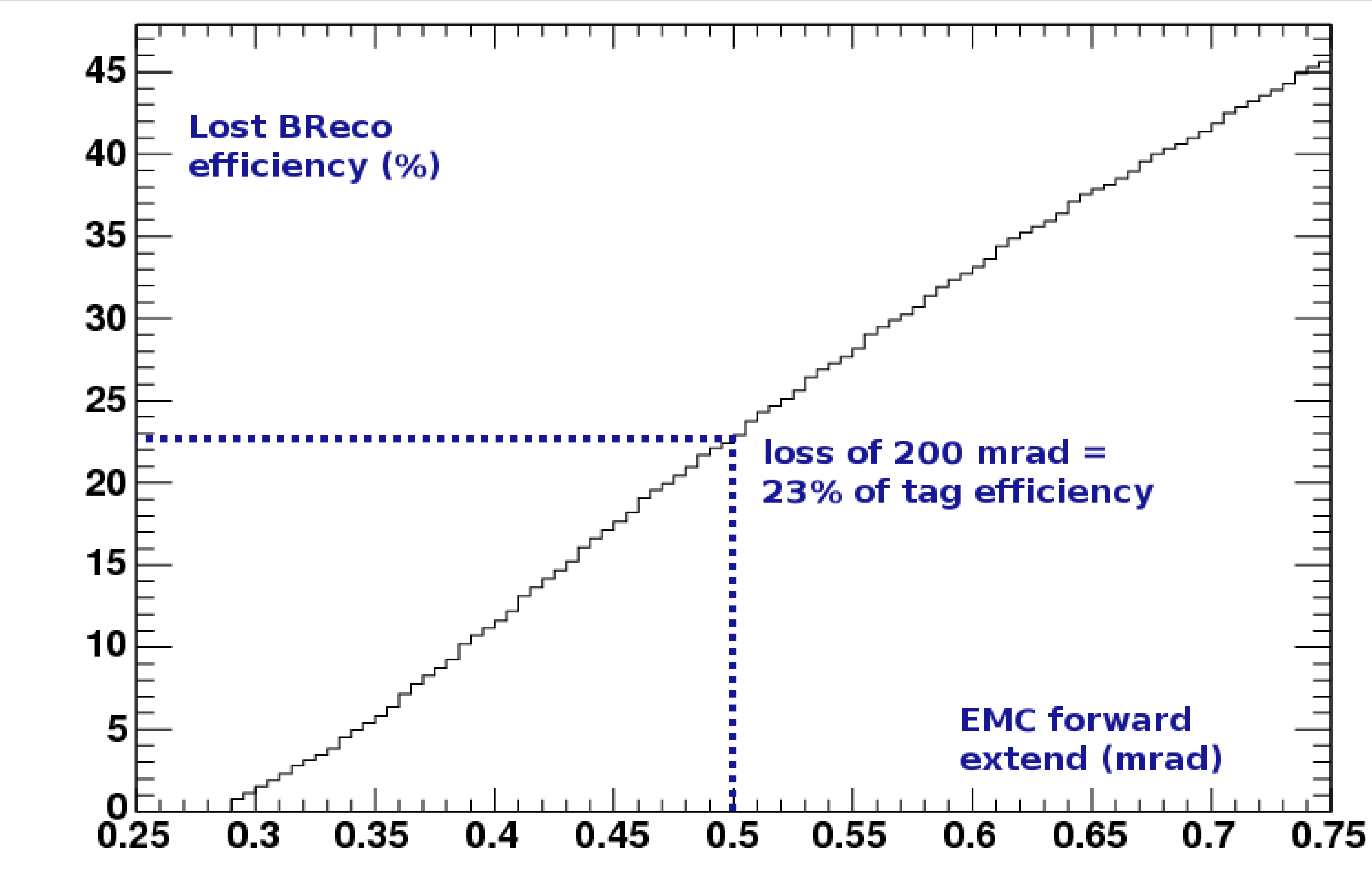
- Recoil analyses are a whole new ballgame
  - Analyses dominated by backgrounds, typically lost particles
  - Background rates scale ~ (1 – acceptance)$^{\text{some other power}}$
  - Efficiency still scales ~ (acceptance)$^{\text{some power}}$
  - Increasing acceptance improves the measurement *faster* than the equivalent increase in luminosity

- Recoil analyses ($B\to\tau\nu$, $B\to K/\pi\nu\nu$, $B\to D\tau\nu$, $B\to\nu\nu(\gamma)$, $B\to\tau\tau$, $B\to l\nu(\gamma)$,...) are a major part of a *Super* physics program

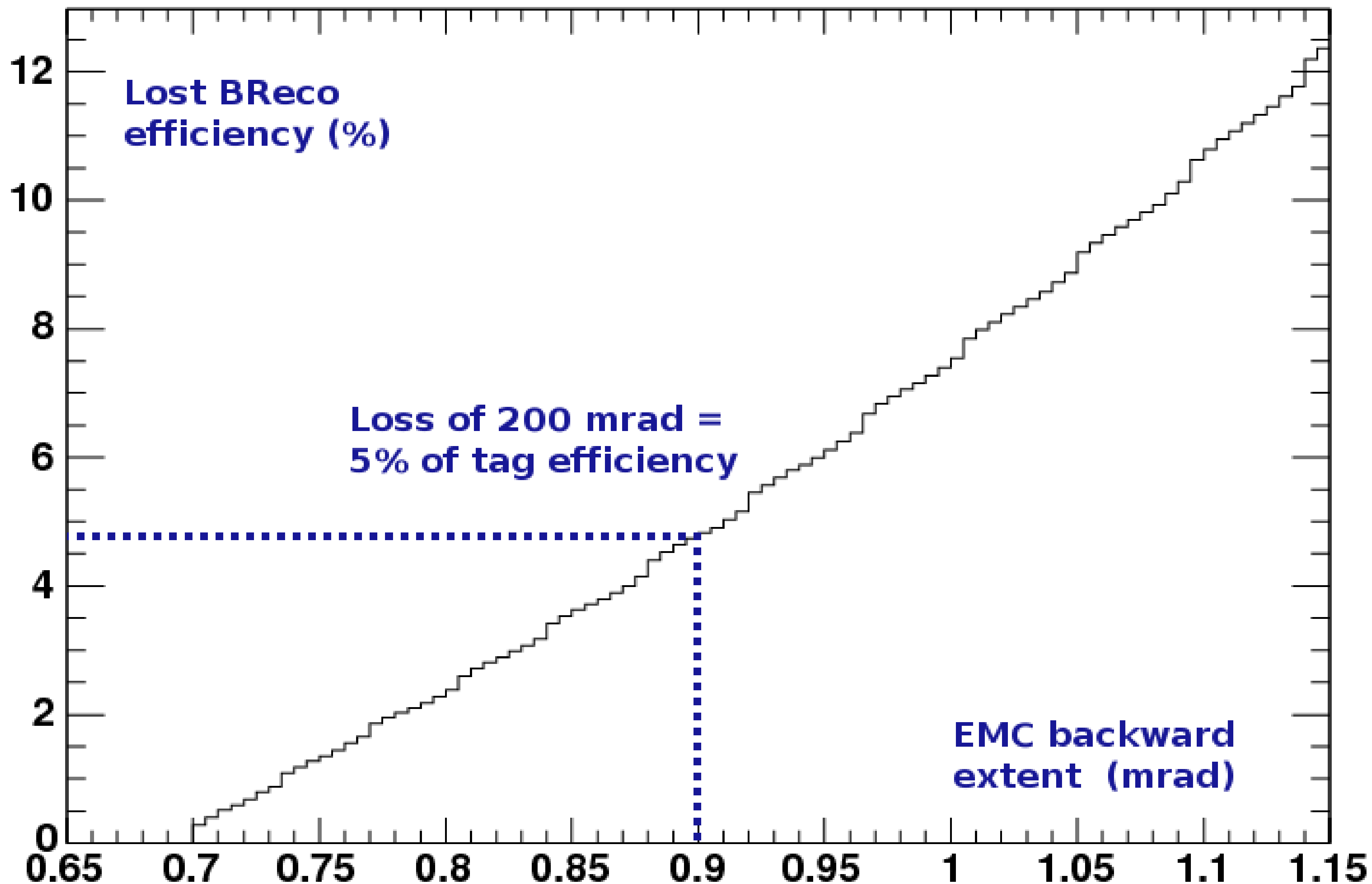
Acceptance and Efficiency What can be gained?

- If efficiency ~ $(\text{acceptance})^{\text{some power}}$, the gain is clearly largest in high multiplicity modes
- The semiexclusive BReco modes are a good candidate:
  - <N charged tracks> = 4.4 (5.2) for $B^{+(0)}$ reco, maximum 9 (8) tracks
  - <N neutral clusters> = 2.6 (1.8), maximum 8 (6) clusters
- Would like to study BReco efficiency as a function of acceptance in an arbitrary manner, but this is impossible – need full MC, algorithm tuning, infinite patience
- Instead, we will work backwards – imagine that BaBar is smaller than it actually is and see how much we lose
  - Uses full BaBar MC, including boost of 9+3 and semiexcl algorithm optimized for the current machine
  - Gives a rough estimate of how much we might gain

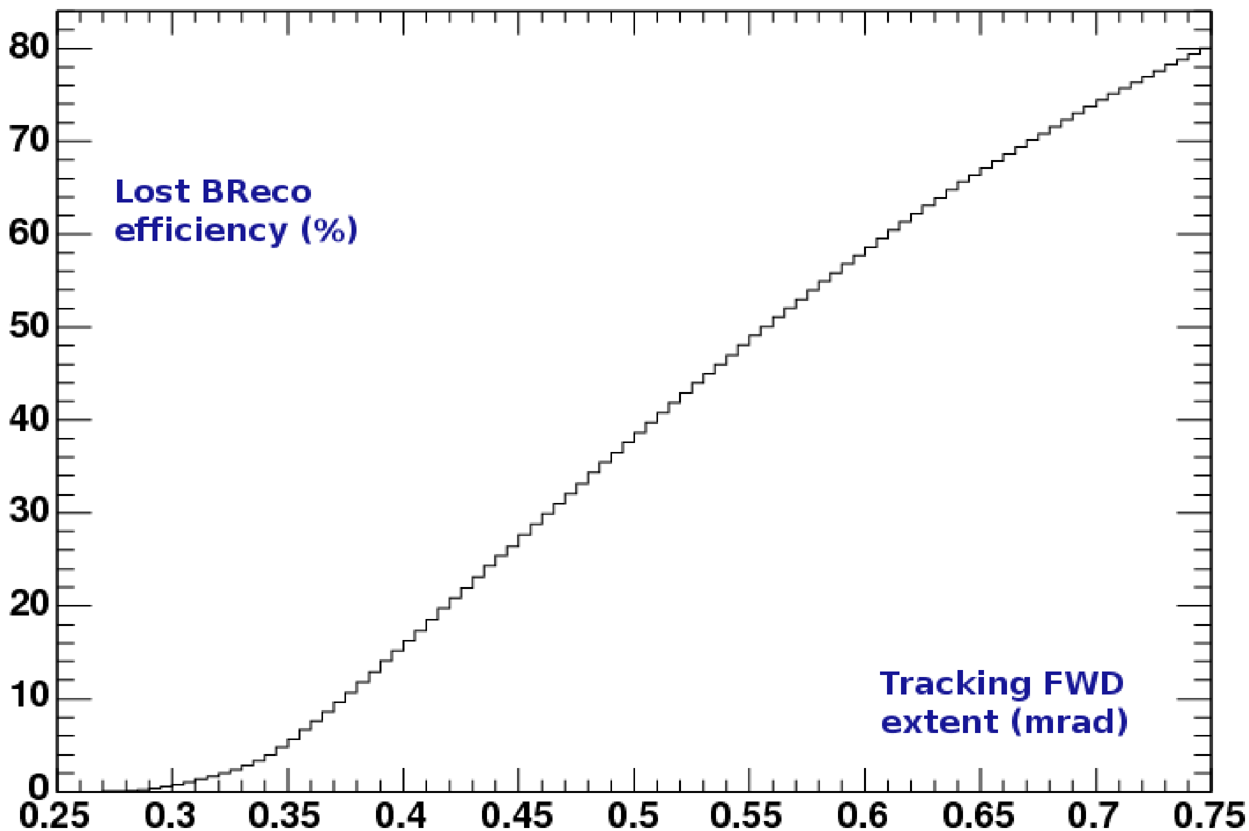
BSemiExcl Efficiency vs EMC Forward Acceptance



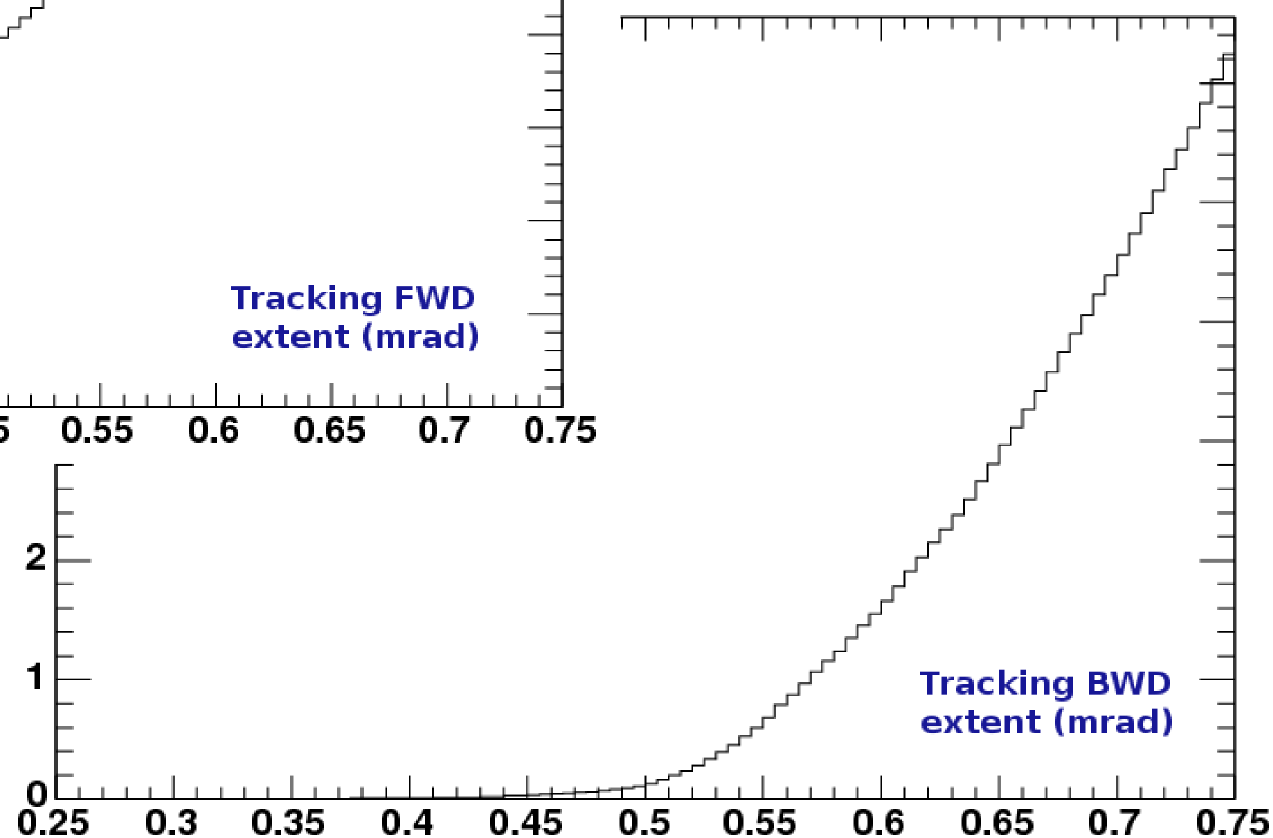
BSemiExcl Efficiency vs EMC Backward Acceptance



BSemiExcl Efficiency vs Tracking Acceptance



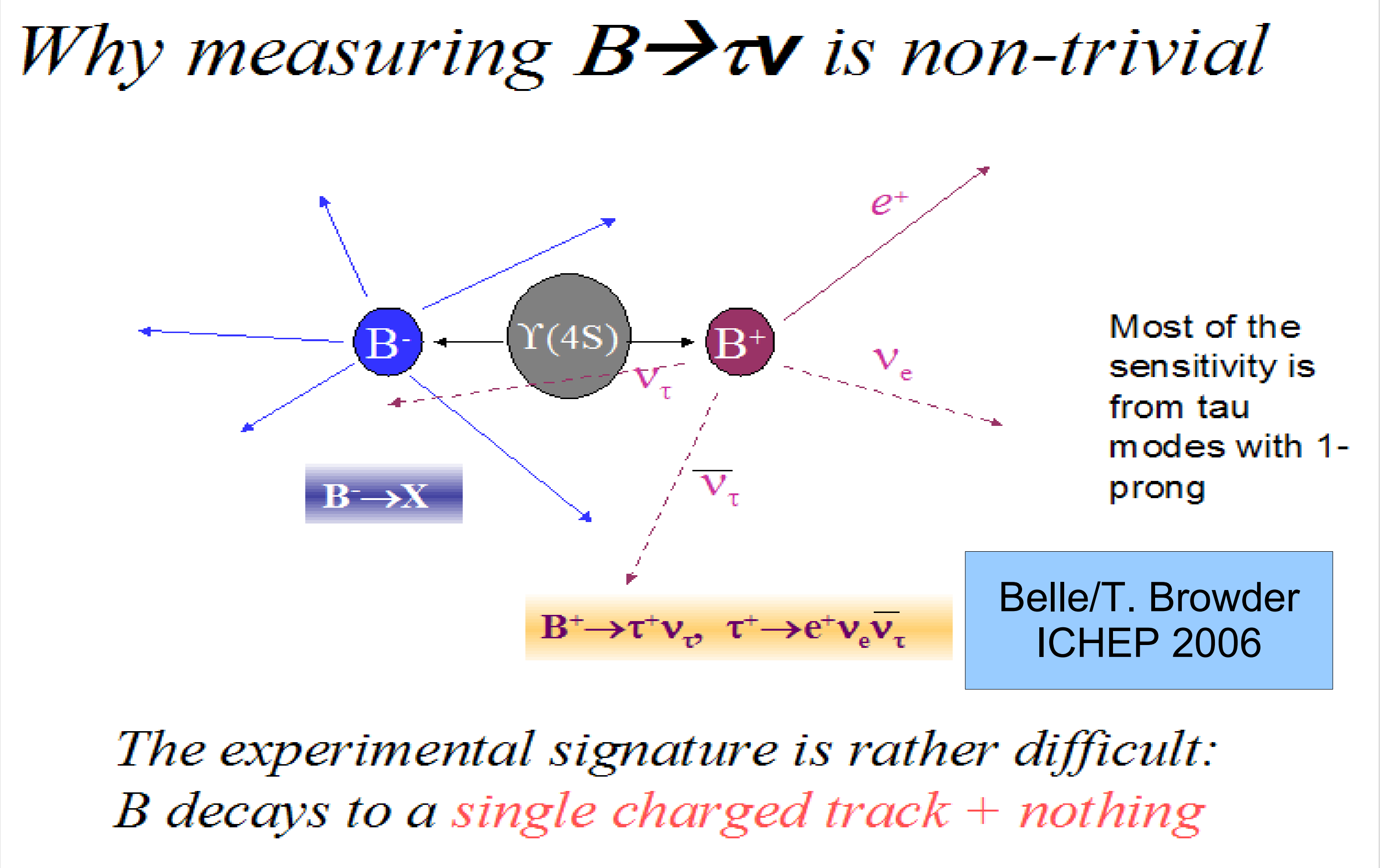
Shapes driven by BReco and tracking cuts... selection on fiducial volume and number of DCH hits



A Benchmark Recoil Analysis: $B \to \tau\nu$

- We are at the frontier of $B\to\tau\nu$ measurement today
  - Belle: BF = 1.8×10^{-4} BaBar: $< 0.9\times10^{-4}$ Avg: 1.4×10^{-4}
  - The B factories will establish the existence of this channel
  - Detailed study of $B\to\tau\nu$ requires a superB factory

BF($\tau\to l\nu\nu$) = 18%
Product BF = 2.5×10^{-5}



Background Processes to $B \to \tau\nu$

- Irreducible background processes have a B_{tag} candidate, a lepton, and missing momentum
- A partial list of processes that contribute...

Process	BF	Relative to signal	
$B^+ \to \pi^0 l\nu$	7.4×10^{-5}	3x	Lose one or both photons
$B^+ \to \rho^0 l\nu$	1.2×10^{-4}	5x	Lose two charged pions
$B^0 \to \pi^+ l\nu$	1.4×10^{-4}	5x	Lose pion, misreconstruct tag charge
$B^0 \to \rho^+ l\nu$	2.3×10^{-4}	10x	Lose pion, one or two photons, misreco tag
$B^+ \to D^0 l\nu$	2.2×10^{-2}	900 x (!!!)	Lose all decay products of the D
... $D^0 \to K\pi$	3.8%	33x	Lose K,π
... $D^0 \to K_L \pi^0$	1.1%	10x	Lose K_L, one or both photons
... $D^0 \to K_S \pi^0$	1.1%	10x	Lose K_S, one or both photons
... $D^0 \to 0$ Prong	19.0%	150x	Lose some or all neutrals

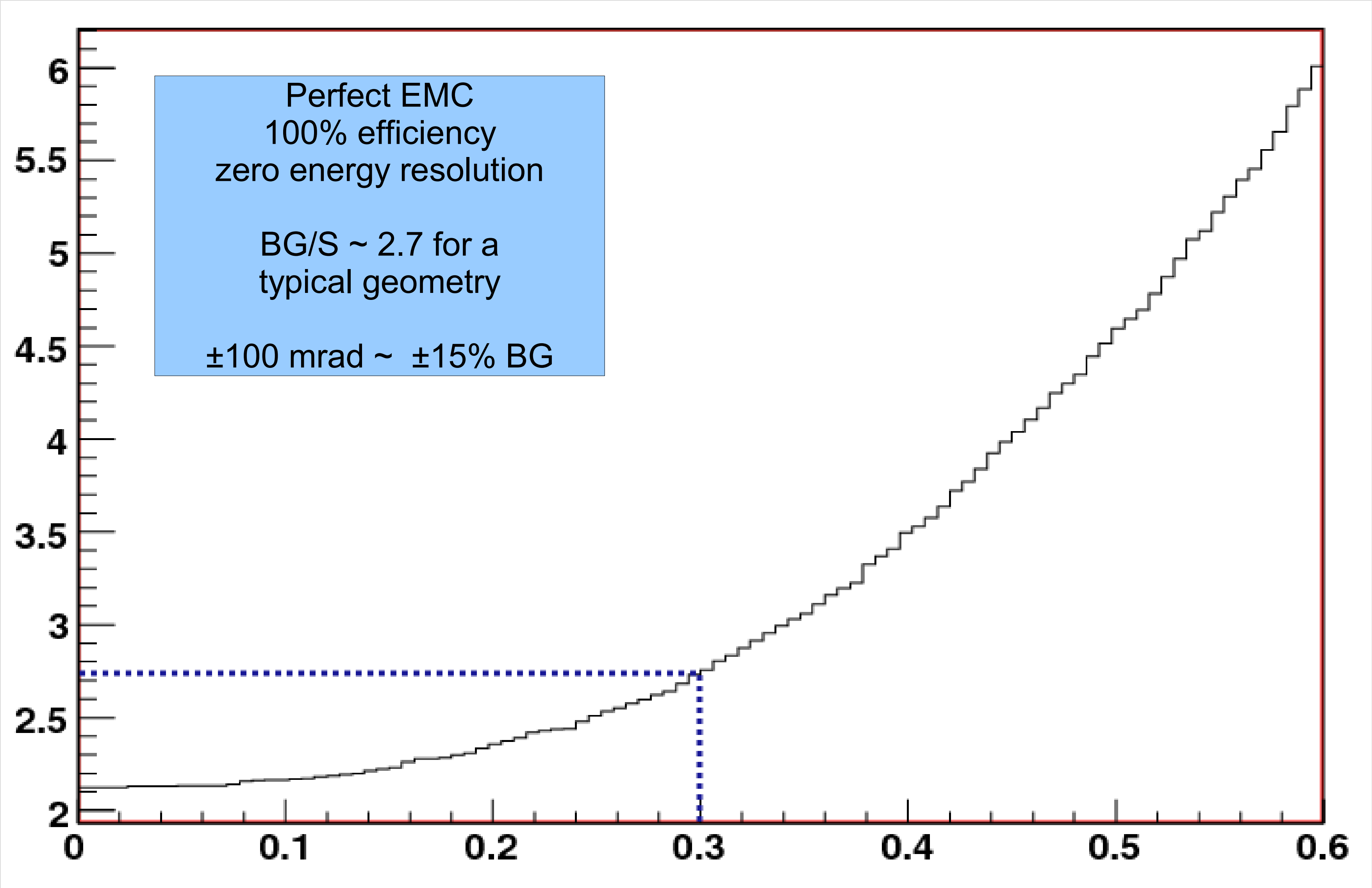
Methodology

- Use EvtGen to simulate 5M generic B^+B^- decays
  - Veto events with $B\to\tau\nu$ signal decay
  - Ignore all decay products of one B meson
    - Equivalent to perfect tagging with 100% efficiency
  - Equivalent to ~2 ab^{-1}
  - Select events with a true lepton (e/μ) with the correct charge
  - Veto events with any other charged track inside the acceptance
    - 300 mrad fwd, 400 mrad bwd
  - Store all neutrals (γ/K_L) in an ntuple for offline analysis
    - Allows fast re-analysis with arbitrary smearing
    - Will show two scenarios: one "perfect" and one with the backward endcap region heavily degraded

- Starting point: B/S ratio 160:1 with no cut on E_{extra}

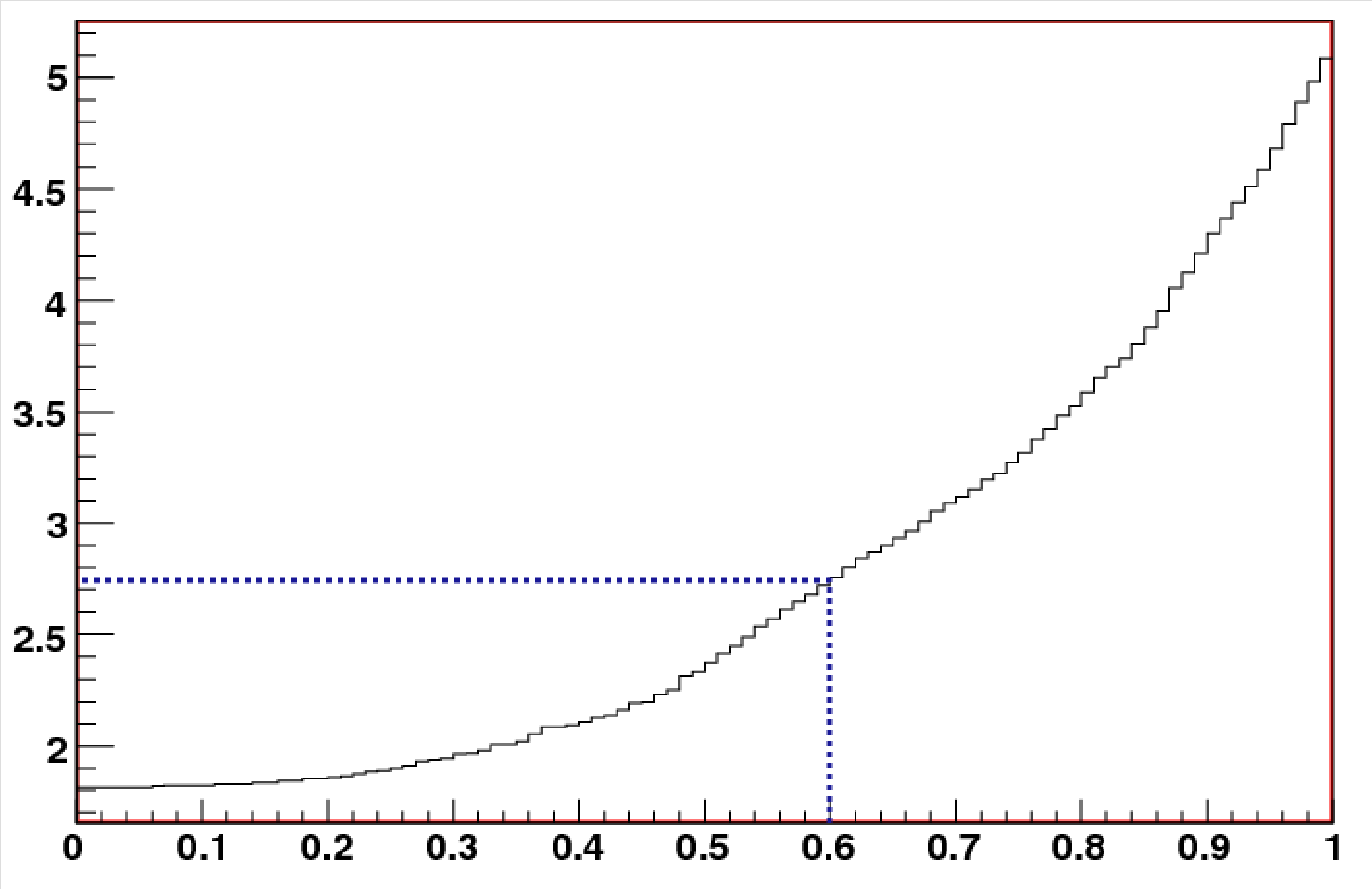
BG/S Ratio vs EMC Fwd Acceptance

- Backward acceptance cut fixed at 600 mrad



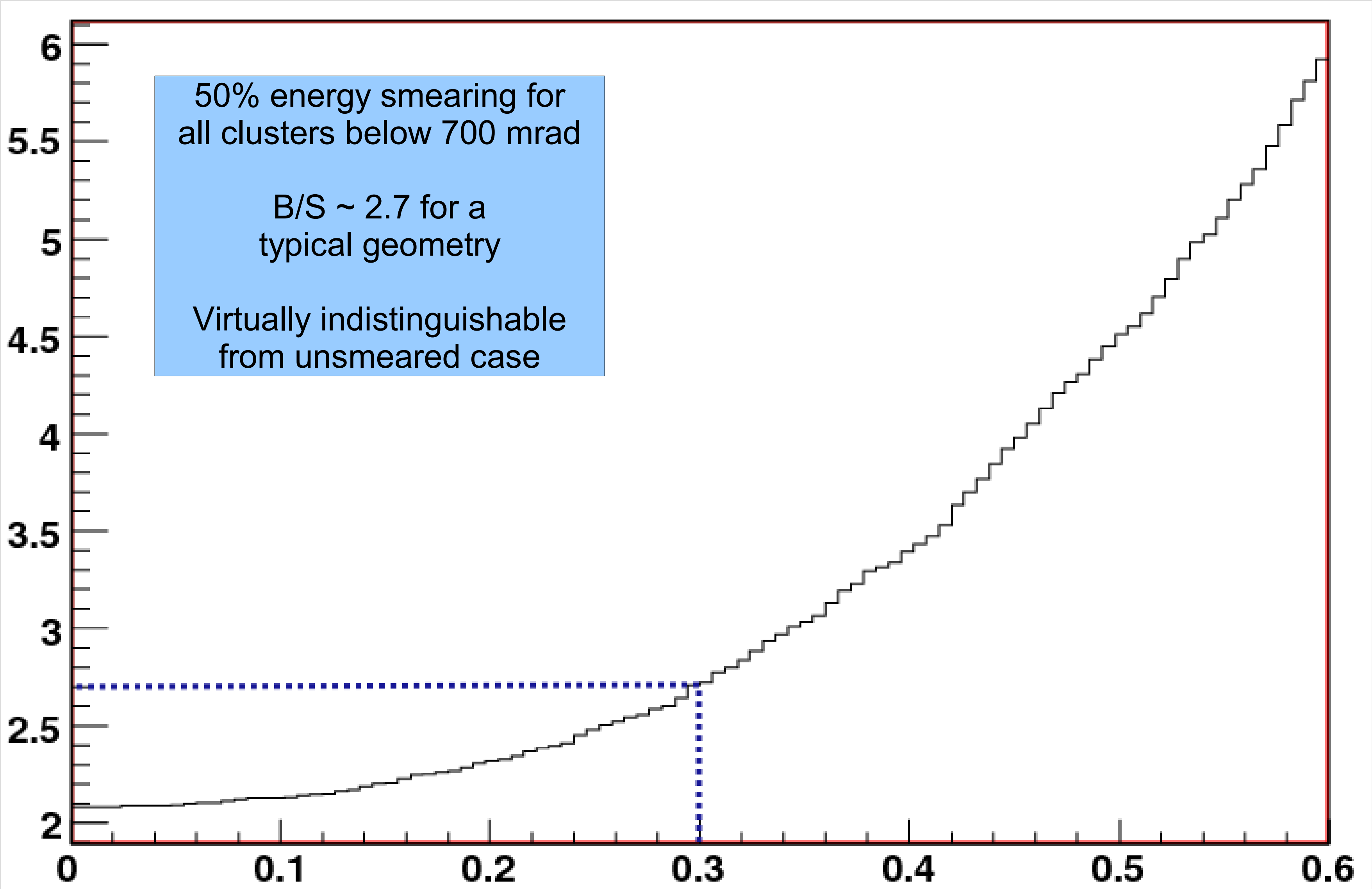
BG/S Ratio vs EMC Bwd Acceptance

- Forward acceptance cut fixed at 300 mrad



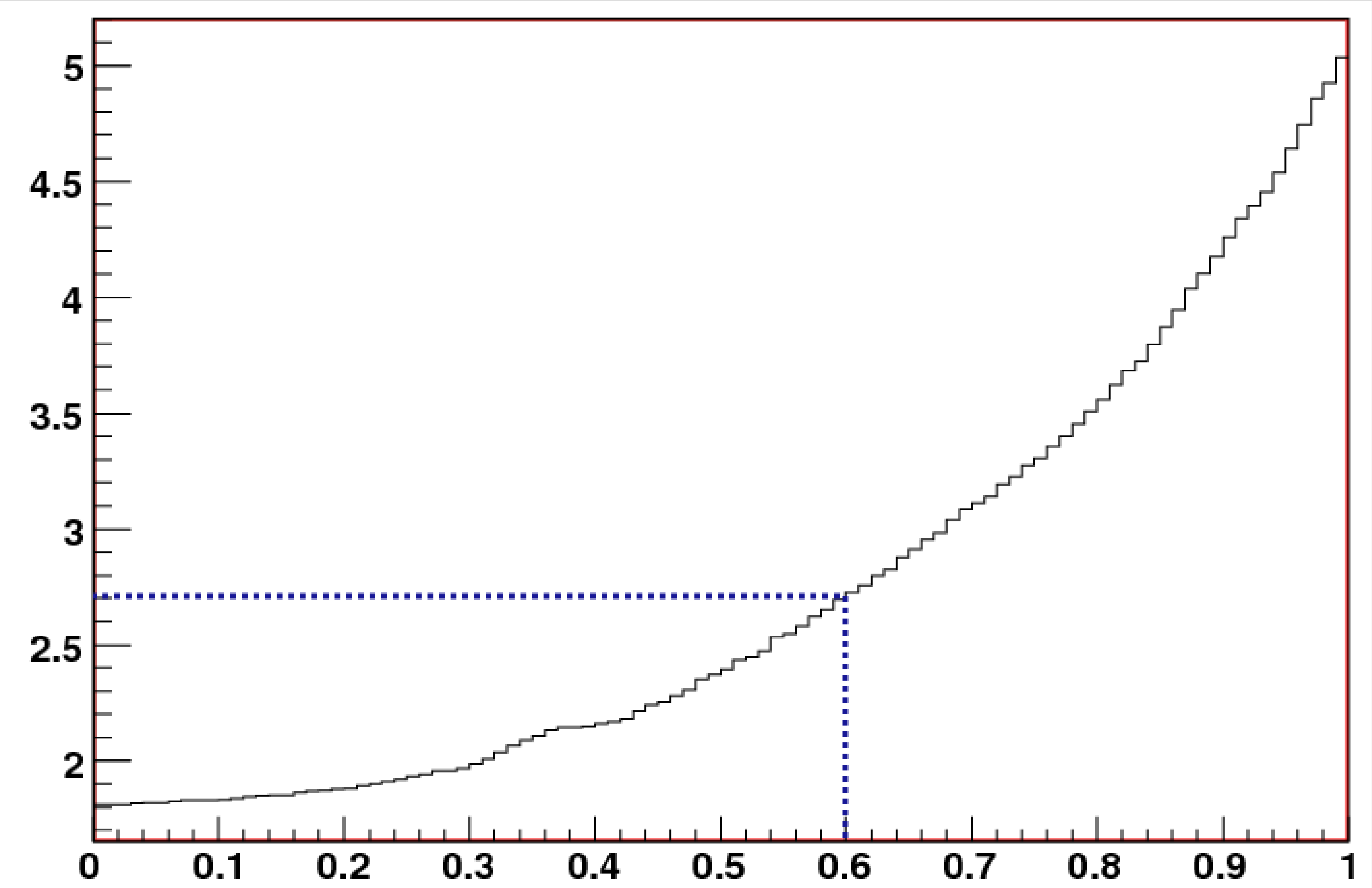
BG/S vs EMC Fwd Acceptance – Including Smearing

- Backward acceptance cut fixed at 600 mrad



BG/S vs Bwd Acc – Including Smearing

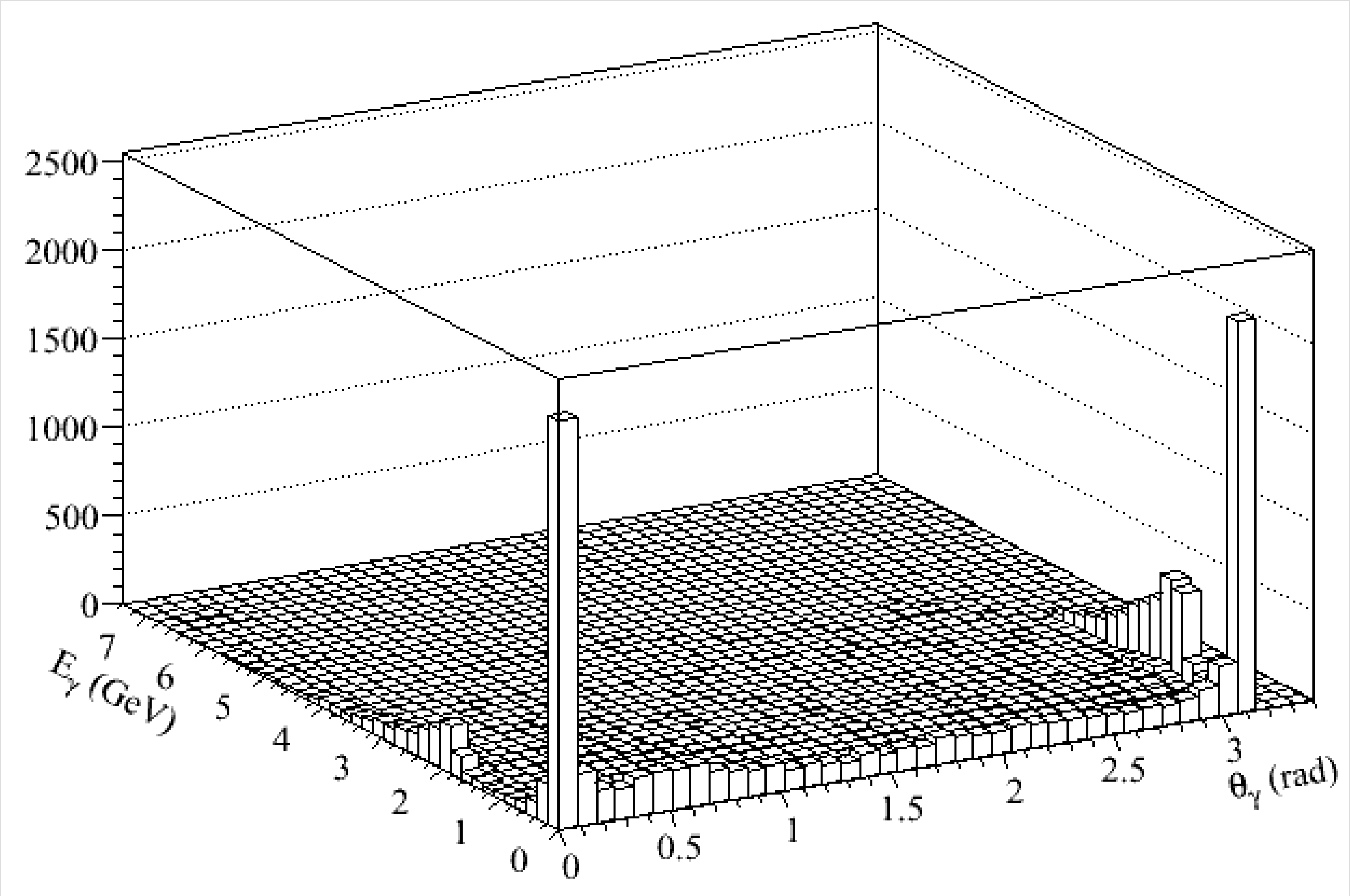
- Forward acceptance cut fixed at 300 mrad



τ Physics and Acceptance

- To search for LFV, need to reduce backgrounds as close to zero as possible
  - Just like recoil analyses, some BG channels can be eliminated kinematically if the total momentum can be reconstructed
- Benchmark LFV analysis: $\tau \to \mu\gamma$
  - BG from radiative $e^+e^- \to \mu\mu\gamma(\gamma...)$ events
  - Only ~ 1/120k $\mu\mu$ events have a photon that can fake $\tau \to \mu\gamma$
  - In these events, kinematics still closed: no missing momentum
  - Need to lose additional photons (more than one) to fake missing mass signature of a true $\tau\tau$ event (with 2 undetected neutrinos in the tag τ)

Distribution of Secondary Photons in $\mu\mu\gamma$ Events Faking $\tau \to \mu\gamma$



Total Containment in τ Events

- Most of the secondary photons are either very low energy or ~ parallel to one of the beams
- Event selection requires missing momentum to be inside the detector volume
  - If the only lost paricles are all along one beam direction (either forward or backward), event can still be vetoed
  - In order to pass this selection, need to lose a substantial amount of energy (hundreds of MeV), and need to lose particles *both* forward and backward
  - Very rare – only 7 events in 1.2 GEvt of mm generated (KK2F) pass "typical" analysis cuts
    - Statistically, we cannot afford to do detailed studies like we did for $B \to \tau\nu$
  - But, need to lose particles in both directions means we can win be improving only one direction
    - If FWD EMC can reject mm events (good efficiency and low BG for soft g), BWD becomes less critical

Conclusions and Future Studies

- Maximizing acceptance can have a large impact on the type of physics we want to do at SuperB
- Other possible studies
  - Better understanding of efficiency gains in high-multiplicity / BReco states
  - Extend E_{extra} studies to more physics channels? Is $B \rightarrow \tau\nu$ a sufficient benchmark?
  - More realistic resolution models for E_{extra} studies?
  - More detailed studies on tracking / PID acceptance?
- Cost benefit analysis
  - Acceptance costs money, makes detector integration and interaction with beamline more complicated