Precision Measurement of $\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}_\ell$ Branching Fraction

Chris Buchanan, Shannon Eynon, Rafi Qumsieh, Dr. Romulus Godang

Physics Department

University of South Alabama

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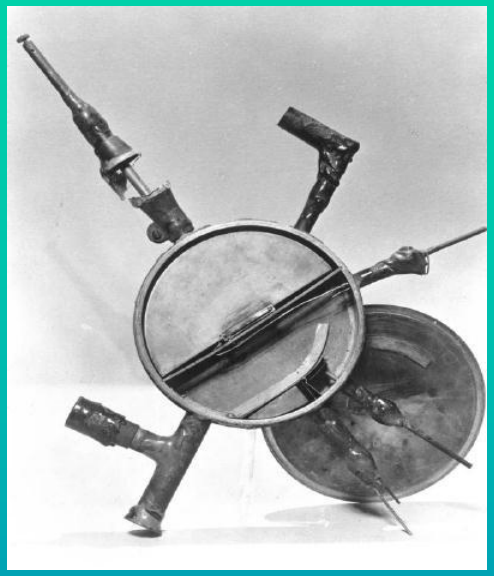
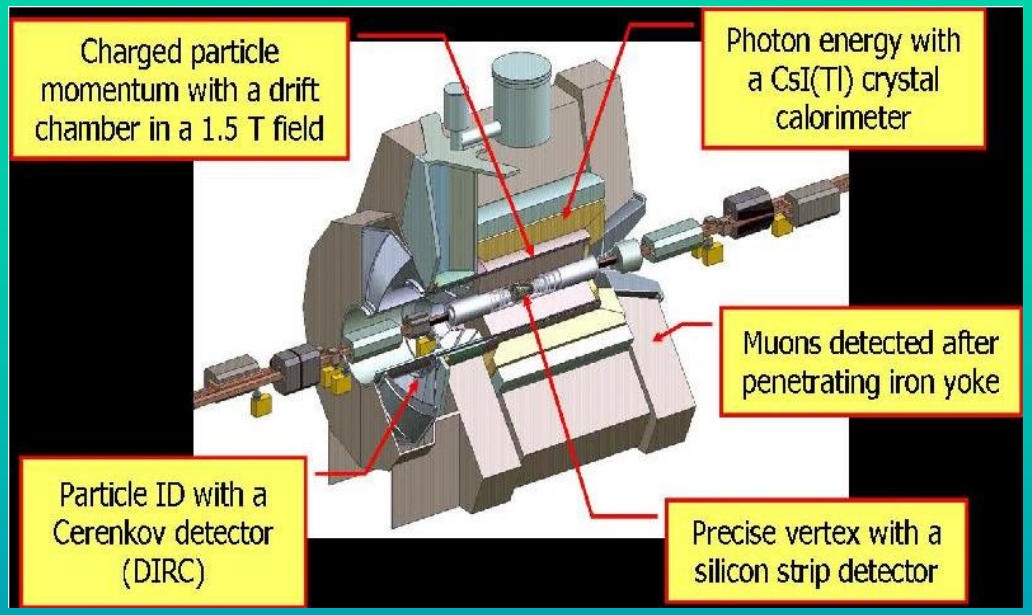
First Cyclotron

Ernest Orlando Lawrence 1929- 4.5''

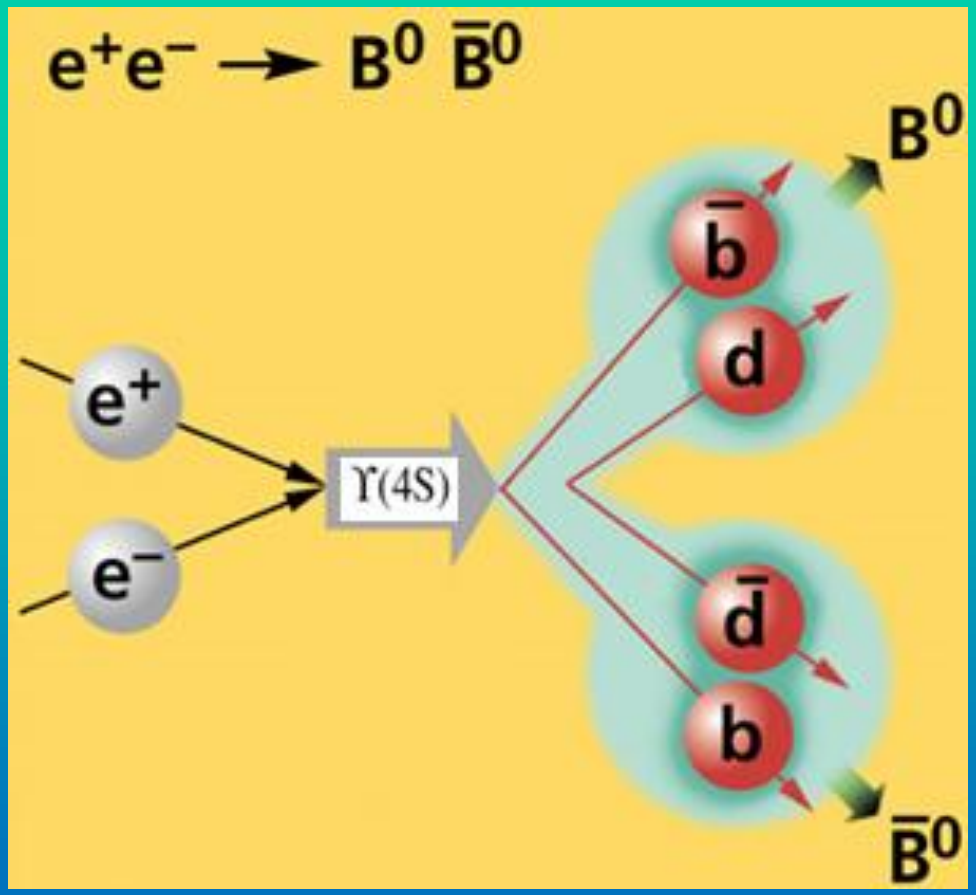


BaBar Detector at SLAC



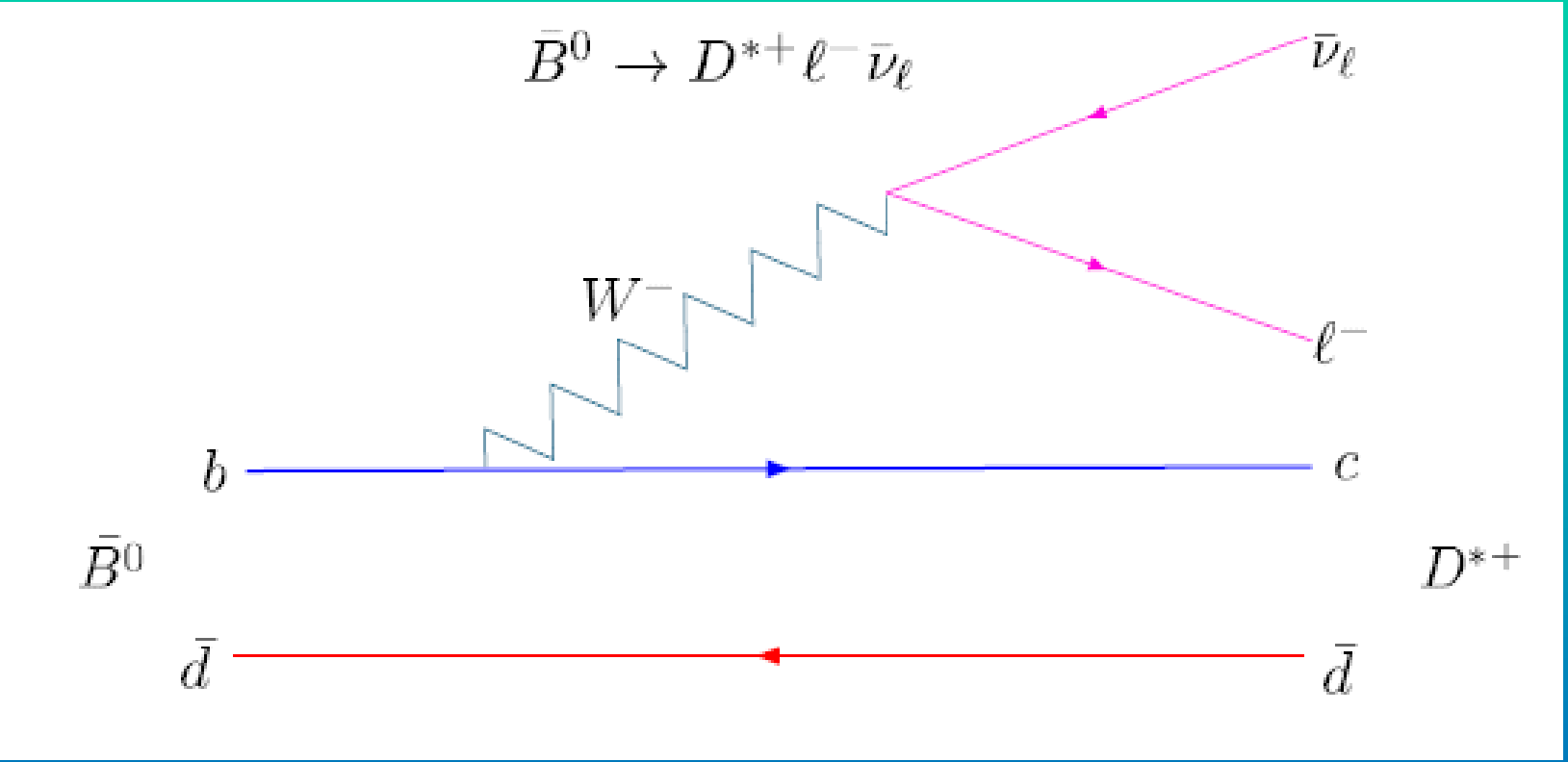
SLAC National Accelerator Laboratory (Stanford University) - 1.8 miles long

Introduction



- 9.0 GeV electrons collide with 3.1 GeV positrons
- Center of Mass at 10.58 GeV
- Other Possibility: $\Upsilon(4S) \rightarrow B^+B^-$

Semileptonic B Decay



- Looking for Branching Fraction $\mathcal{B}(\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}_\ell)$
- Largest branching fraction of any exclusive $\bar{B}^0$ decay (~5%)
- Simple Model: Spectator Diagram

Partial Reconstruction

$\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}_\ell$ $\quad$ $D^{*+} \to D^0\pi^+$

- Right Sign: $\ell^+\pi^-$, $\ell^-\pi^+$
  - For yield
- Wrong Sign: $\ell^+\pi^+$, $\ell^-\pi^-$
  - For checking

- Improvement in statistics
  - Factor of 20 compared to Full Reconstruction

- Yields Missing-Mass-Squared:

$$M_\nu^2 \equiv \left(E_{beam} - \tilde{E}_{D^*} - E_\ell\right)^2 - \left(\vec{\tilde{p}}_{D^*} + \vec{p}_\ell\right)^2$$

Single and Double Tags

Single Tags:
One neutral *B* partially reconstructed

$$N_s = 2 \times N_{B\bar{B}} f_{00} \times \mathcal{B}\left(\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}_\ell\right) \times \mathcal{B}\left(D^{*+} \to D^0\pi^+\right) \times \epsilon_s$$

Double Tags:
Two neutral *B* partially reconstructed

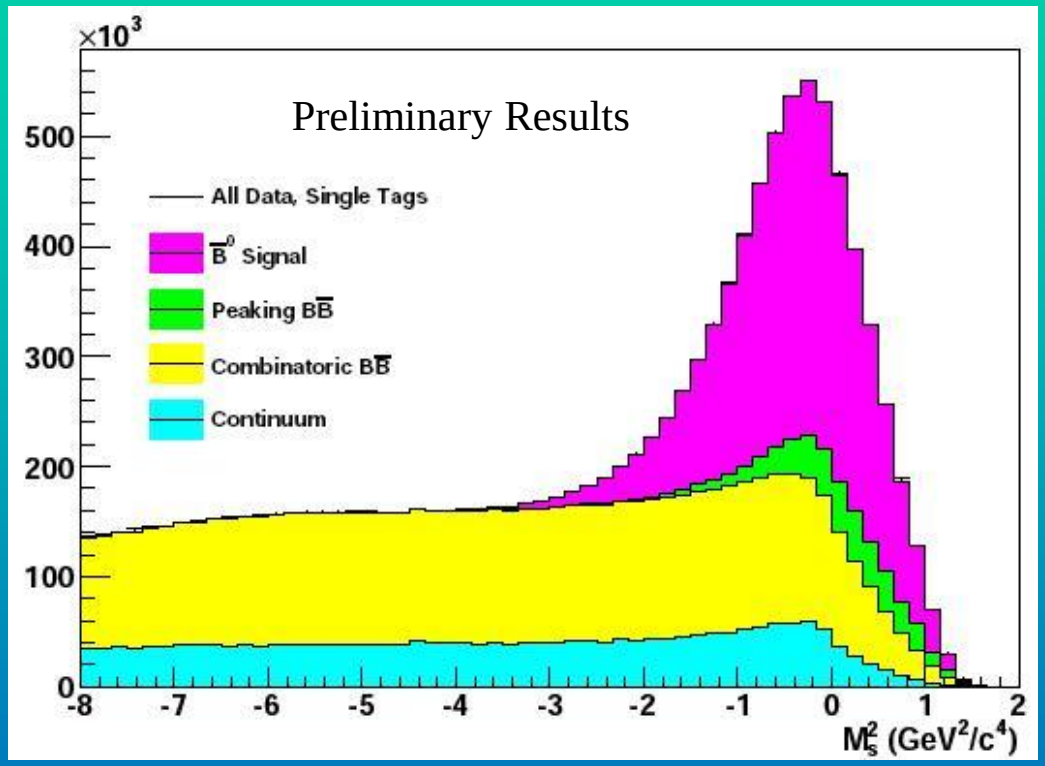
$$N_d = N_{B\bar{B}} f_{00} \times \left[\mathcal{B}\left(\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}_\ell\right) \times \mathcal{B}\left(D^{*+} \to D^0\pi^+\right)\right]^2 \times \epsilon_d$$

Solved for Branching Fraction:

$$\mathcal{B}(\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}_\ell) = 2 \times \frac{N_d}{N_s} \times \frac{\epsilon_s}{\epsilon_d} \times \frac{1}{\mathcal{B}(D^{*+} \to D^0\pi^+)}$$

Data Sample: 476 million $B\bar{B}$ pairs

Understanding the Backgrounds



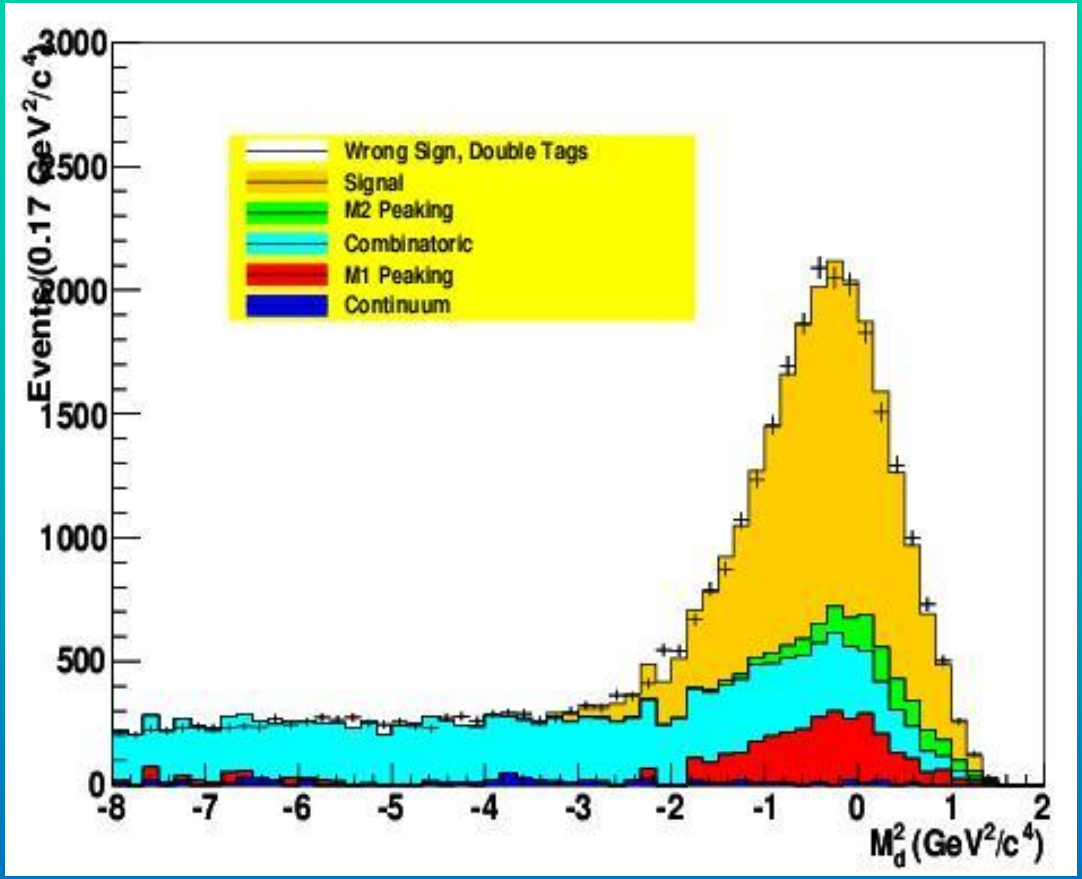
Sideband Region: -8 to -4 GeV^2/c^4

Signal Region: -2 to 2 GeV^2/c^4

Backgrounds

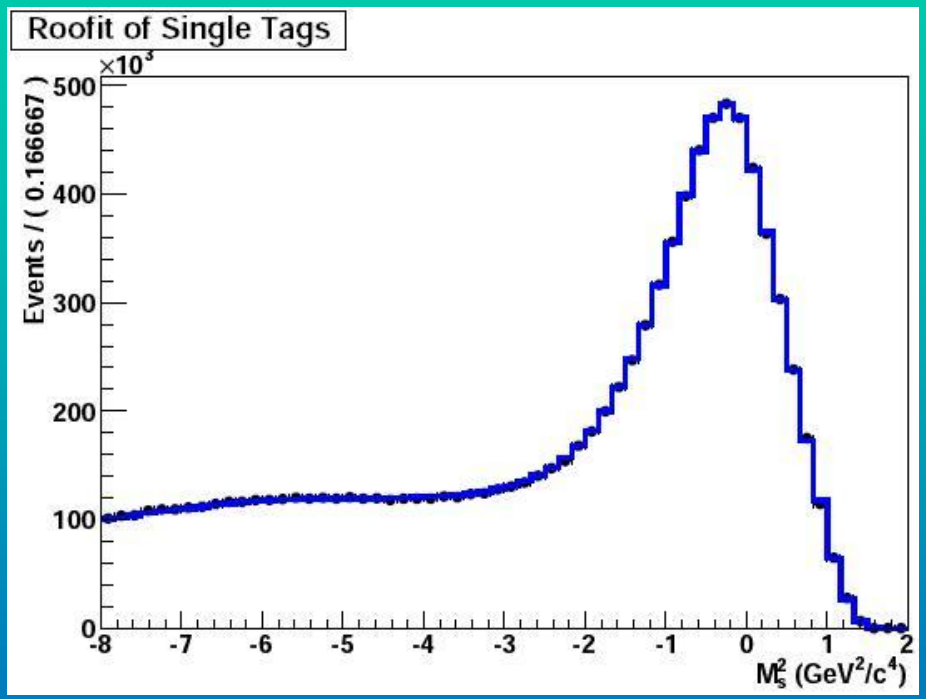
- Continuum
  - -Off-resonant Y(4S) decays
  - -Using off-resonant data
- Combinatoric
  - -Random combination of reconstructed leptons and soft pions.
  - -Using Monte Carlo
- Peaking
  - -From decays of $\bar{B}^0 \rightarrow D^* n(\pi) \ell \bar{\nu}_\ell$
  - -Using Monte Carlo

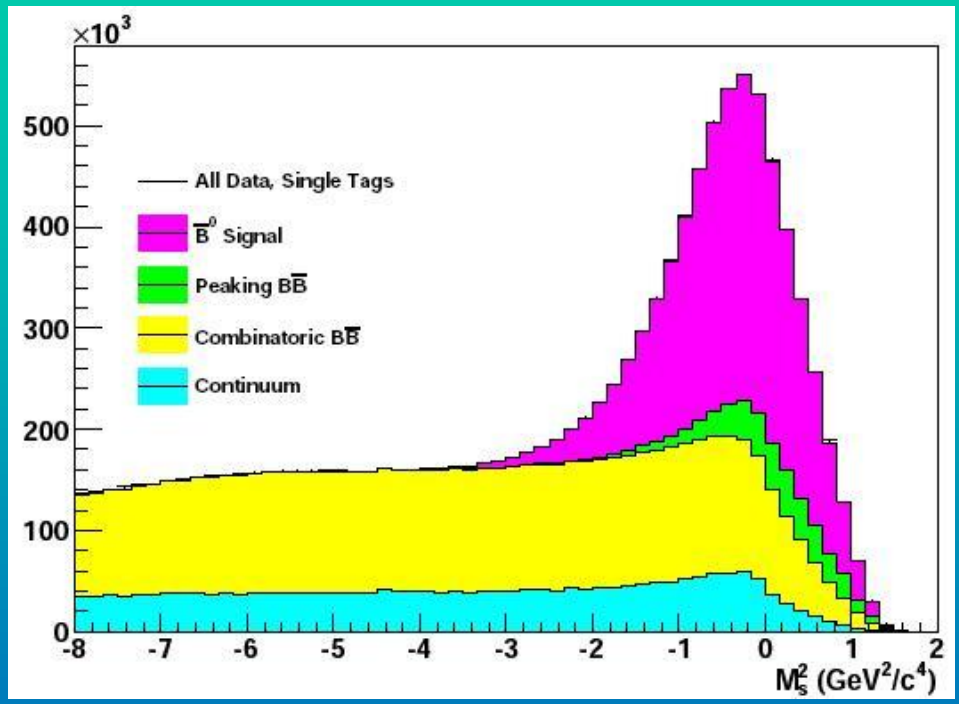
Double Tag – Finding N_d



- Unique Background:
  $M1_d^2$ background distribution in M_d^2
- First Candidate — Peaking Background
- Second Candidate — Signal

Tools:
Root and Roofit

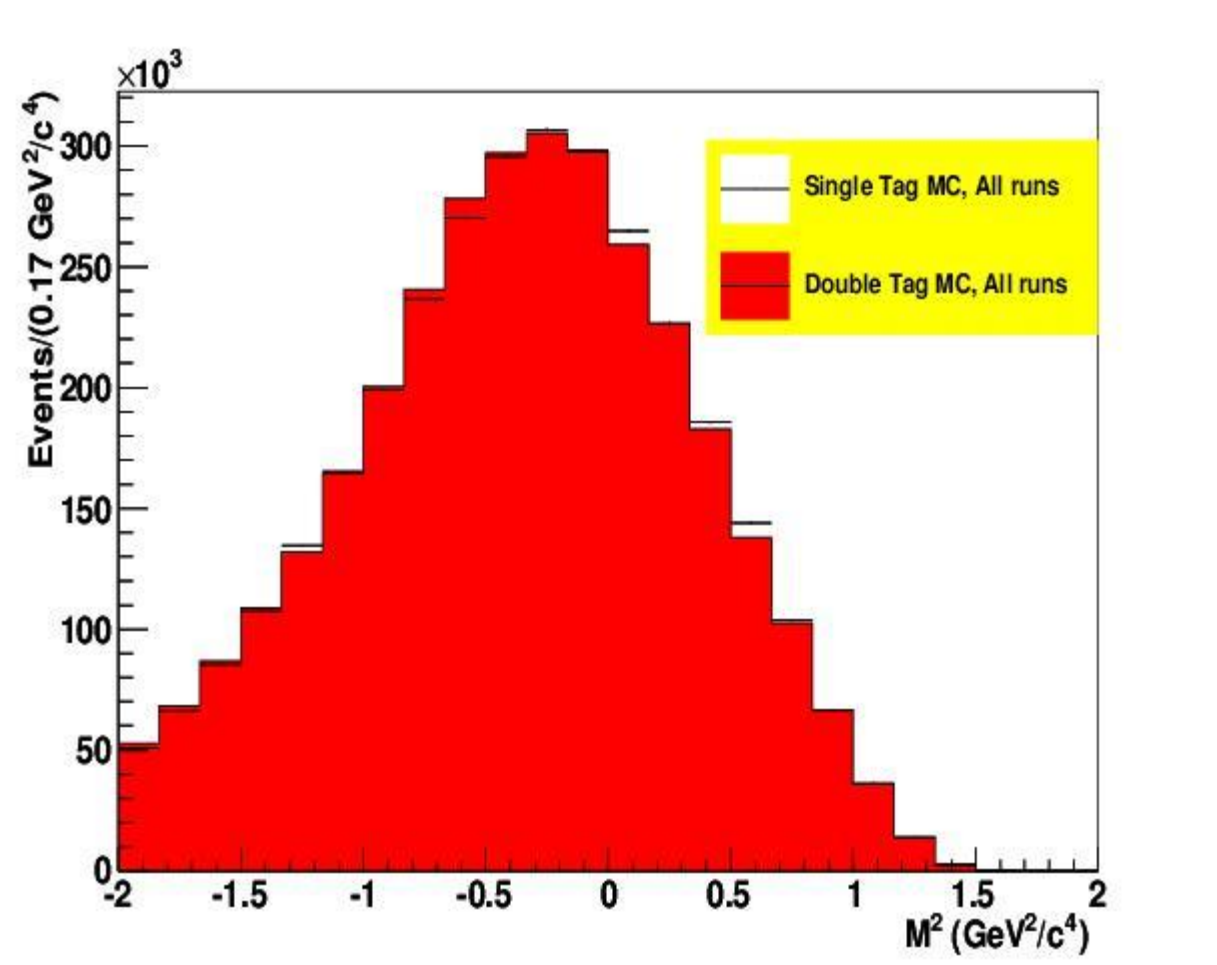




Roofit

- Consists of all backgrounds and MC Signal
- Fits to the Missing-Mass-Squared Data

Calculating the Efficiency Ratio



- Signal Region events generated by MC

Conclusions & Plan

- The branching fraction $\mathcal{B}(\bar{B}^0 \to D^{*+}\ell^-\overline{\nu}_\ell)$ has been previously measured:

$$(5.01 \pm 0.12)\ \%$$

(K. Nakamura *et al.* (Particle Data Group),

J. Phys. G **37**, 075021 (2010))

- Should expect better uncertainty than published results
- Improvement in Double Tag results
- Plan to publish this result soon.

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References

R. Godang, L. Cremaldi, and D. Summers, BABAR Analysis Document 731,(2005)

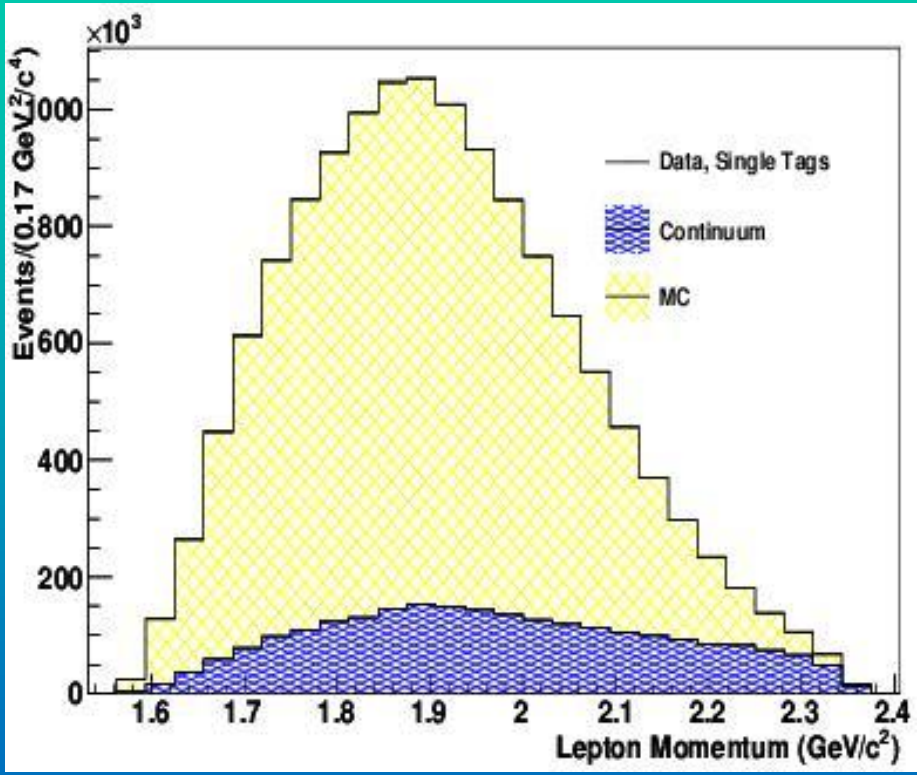
R. Godang, C. Buchanan, S. Eynon, BABAR Analysis Document 2168 (2010)

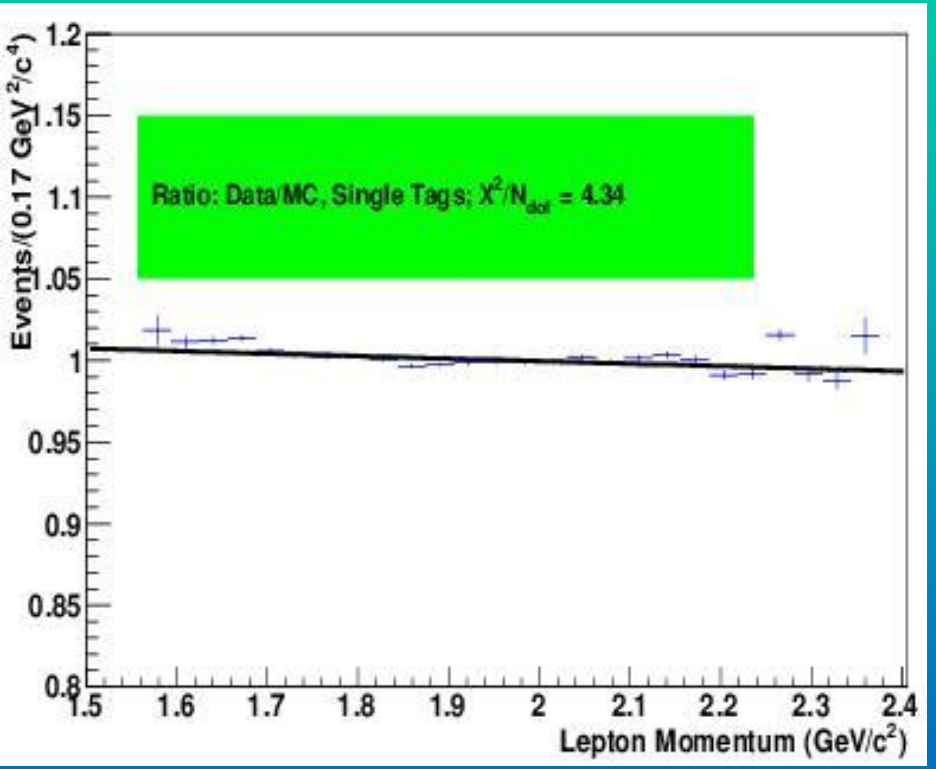
K. Nakamura *et al.* (Particle Data Group), J. Phys. G **37**, 075021 (2010)

Systematic Error Contributions

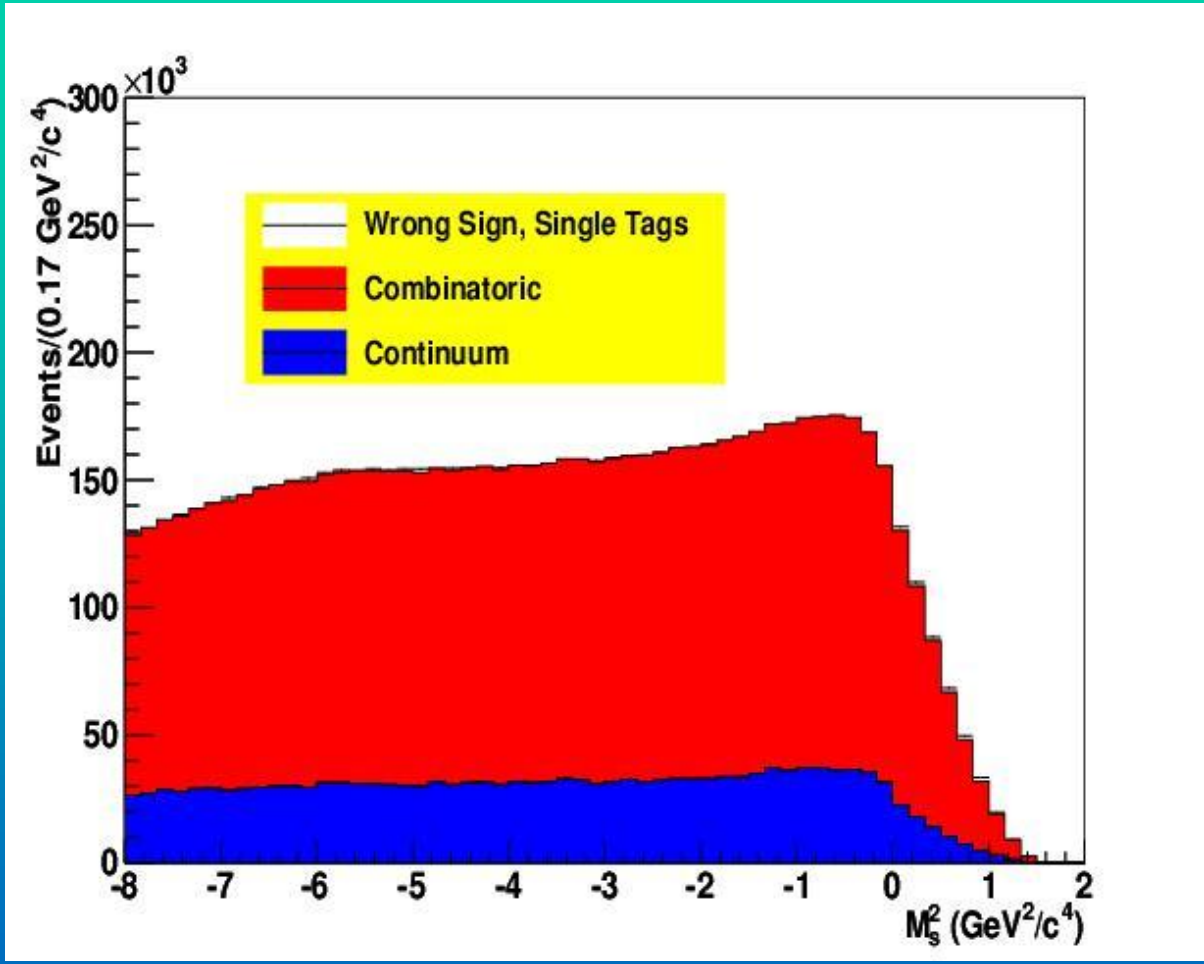
- Peaking background composition
- Monte Carlo Modeling of combinatoric
- Monte carlo statistics
- Efficiency correlation
- Other peaking events
- Lepton momentum spectrum
- Pion momentum spectrum

Lepton Momentum



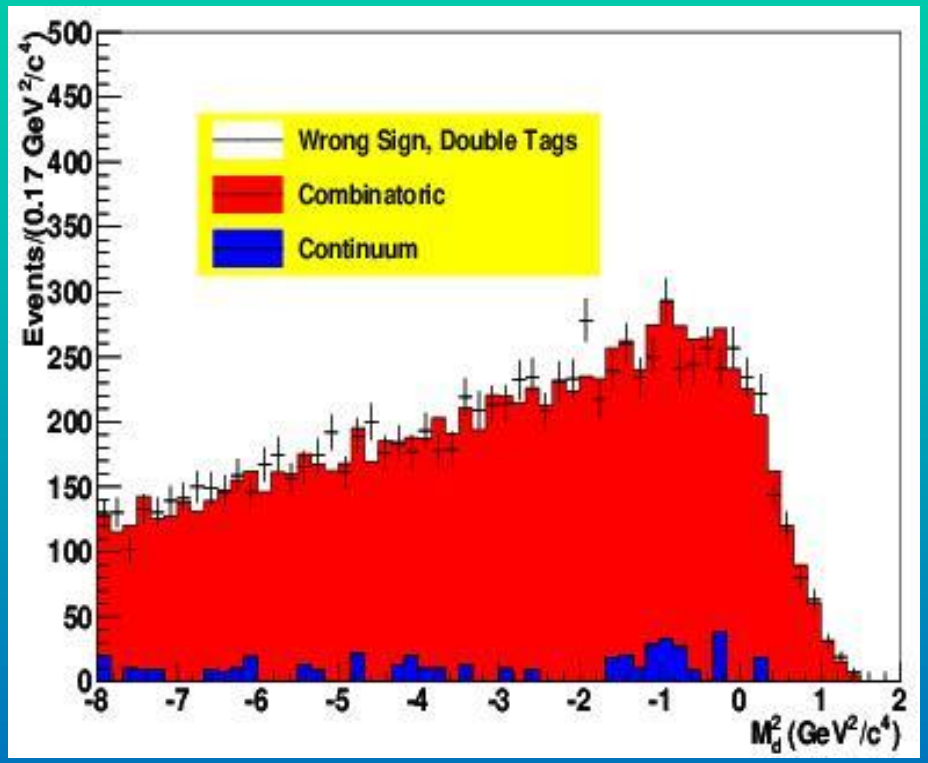


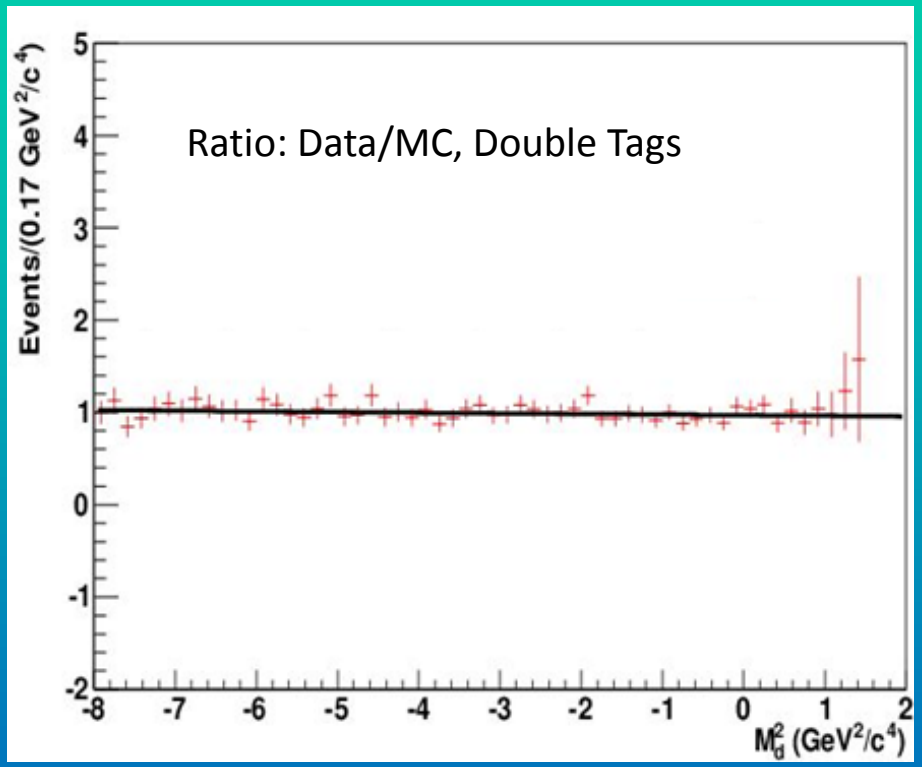
Wrong Sign



- Consists of $\ell^+\pi^+$ or $\ell^-\pi^-$
- No yield expected in Signal Region

Wrong Sign – Double Tag

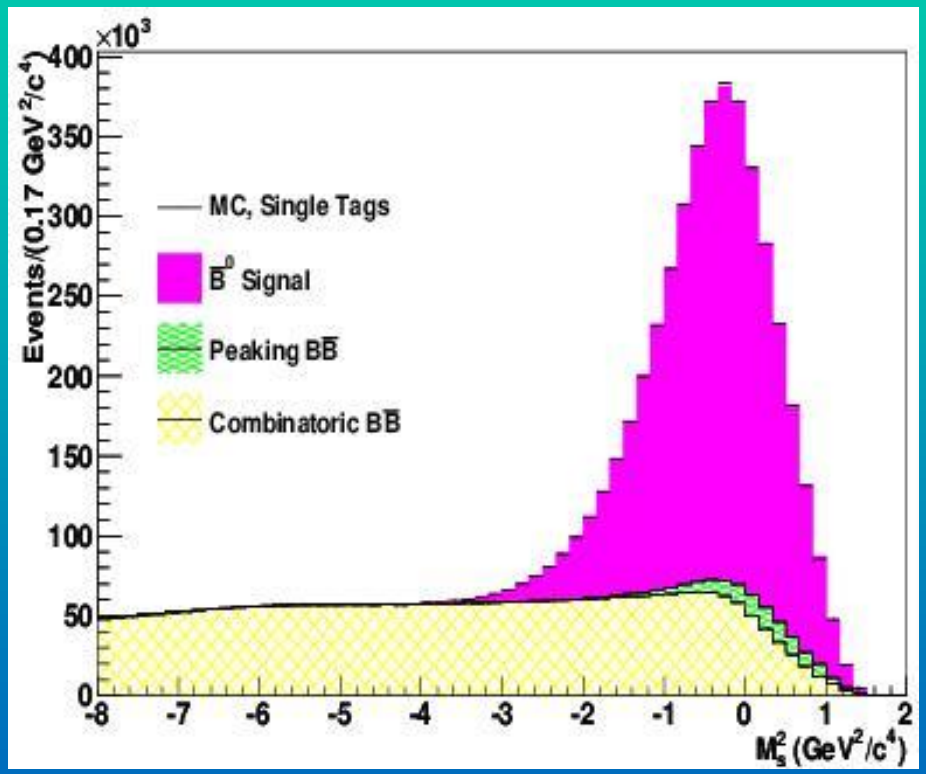




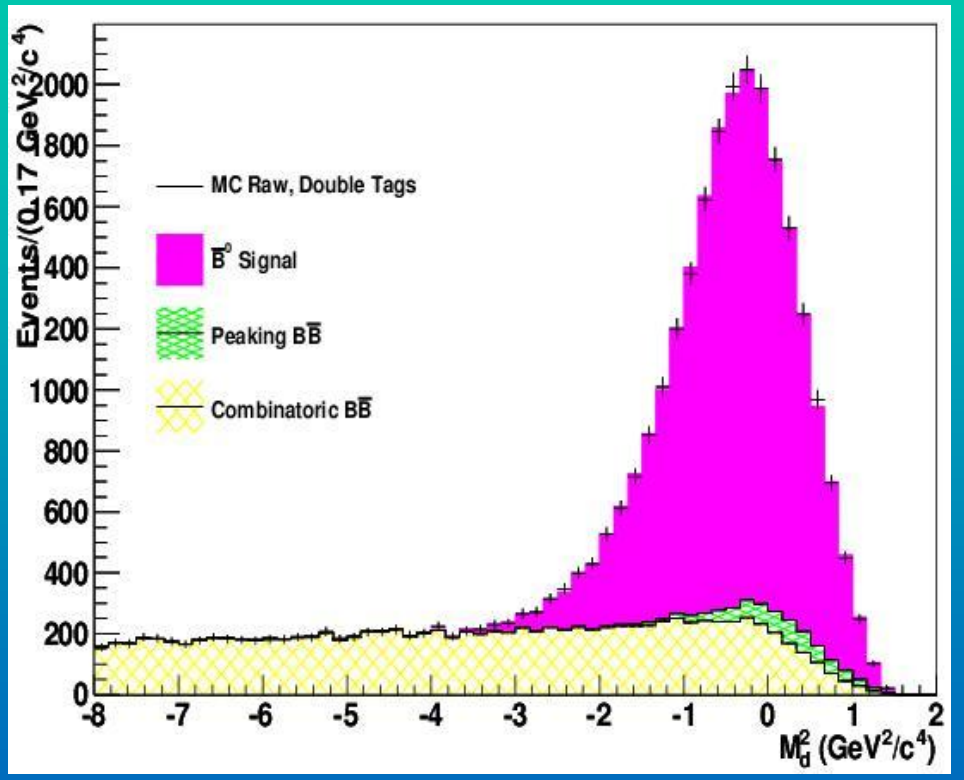
As expected Data/MC ratio is around one

Using Monte Carlo Only

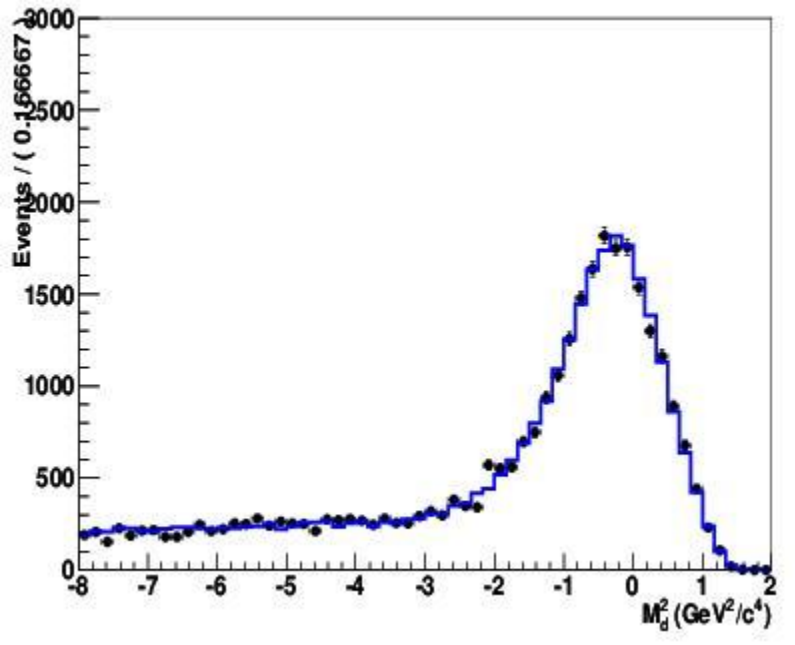
Single Tag

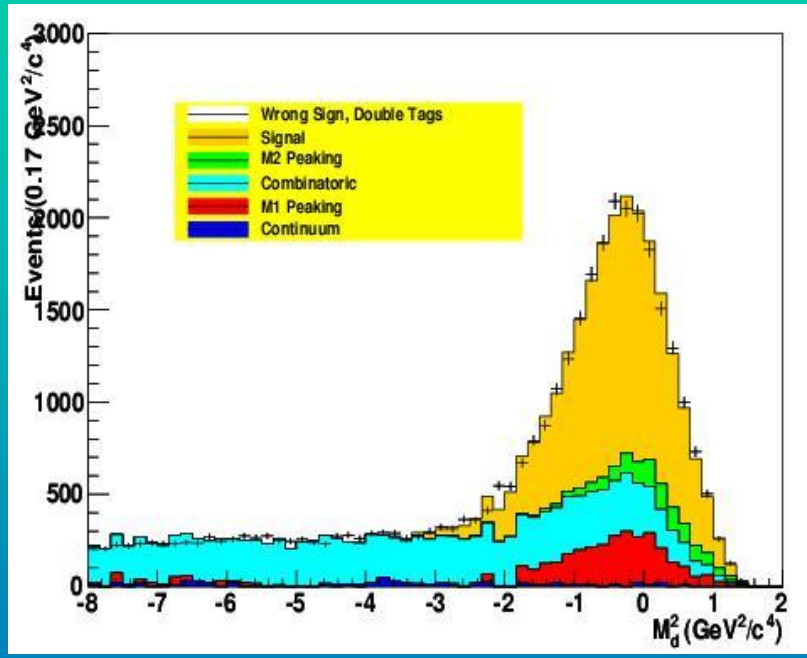


Double Tag



- Double-Checking the Monte Carlo
- Expect the yield and the signal to match


Events / (0.166667)
3000
2500
2000
1500
1000
500
0
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
M_d^2 (GeV^2/c^4)


Events/(0.17 GeV^2/c^4)
3000
2500
2000
1500
1000
500
0
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
M_d^2 (GeV^2/c^4)
Wrong Sign, Double Tags
Signal
M2 Peaking
Combinatoric
M1 Peaking
Continuum