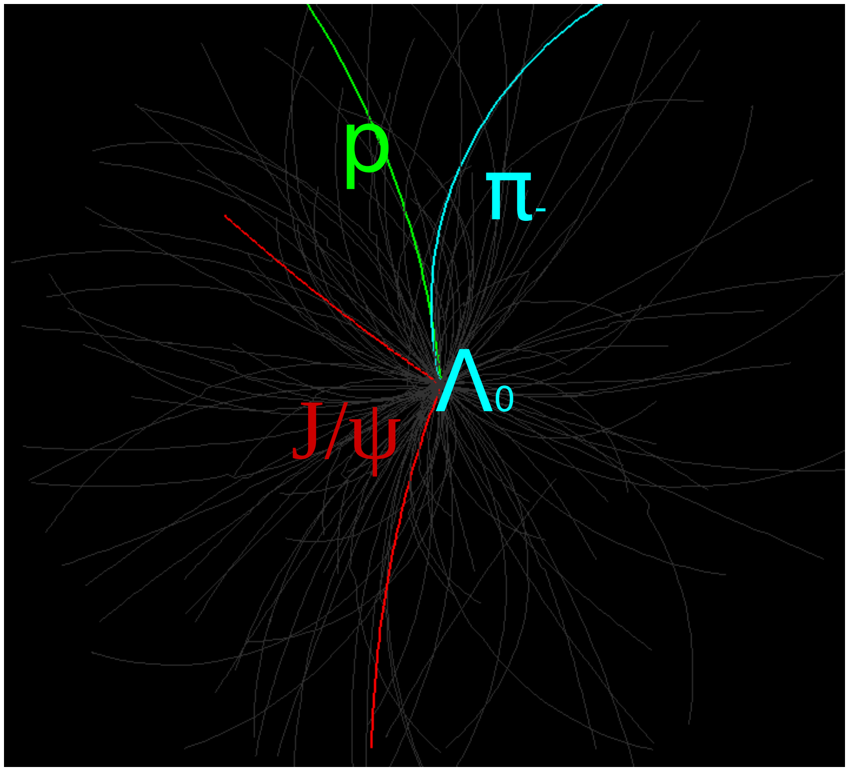
Analysis of Λ_0 polarization in 7 TeV LHC data



Λ_b decay into Λ_0 and J/Ψ
picture from Daniel Scheirich

$$p+p \longrightarrow \Lambda^0 + X$$
$$\Lambda^0 \longrightarrow p+\pi^-$$

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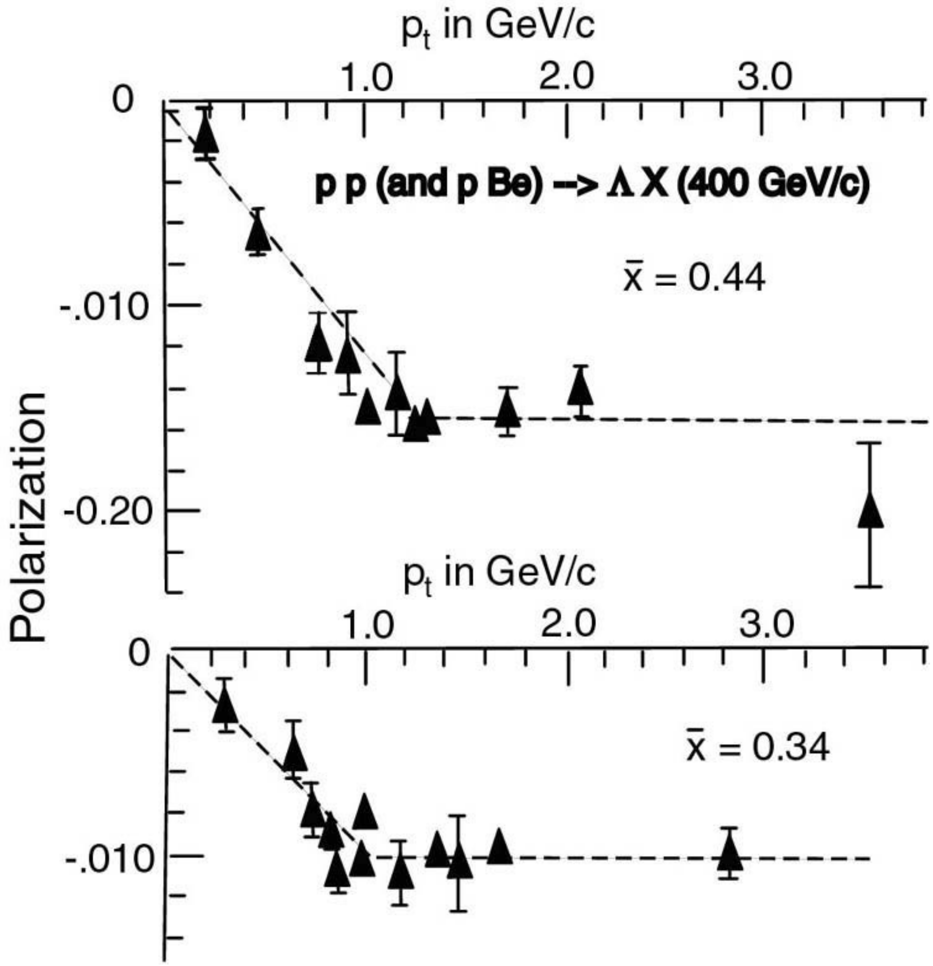
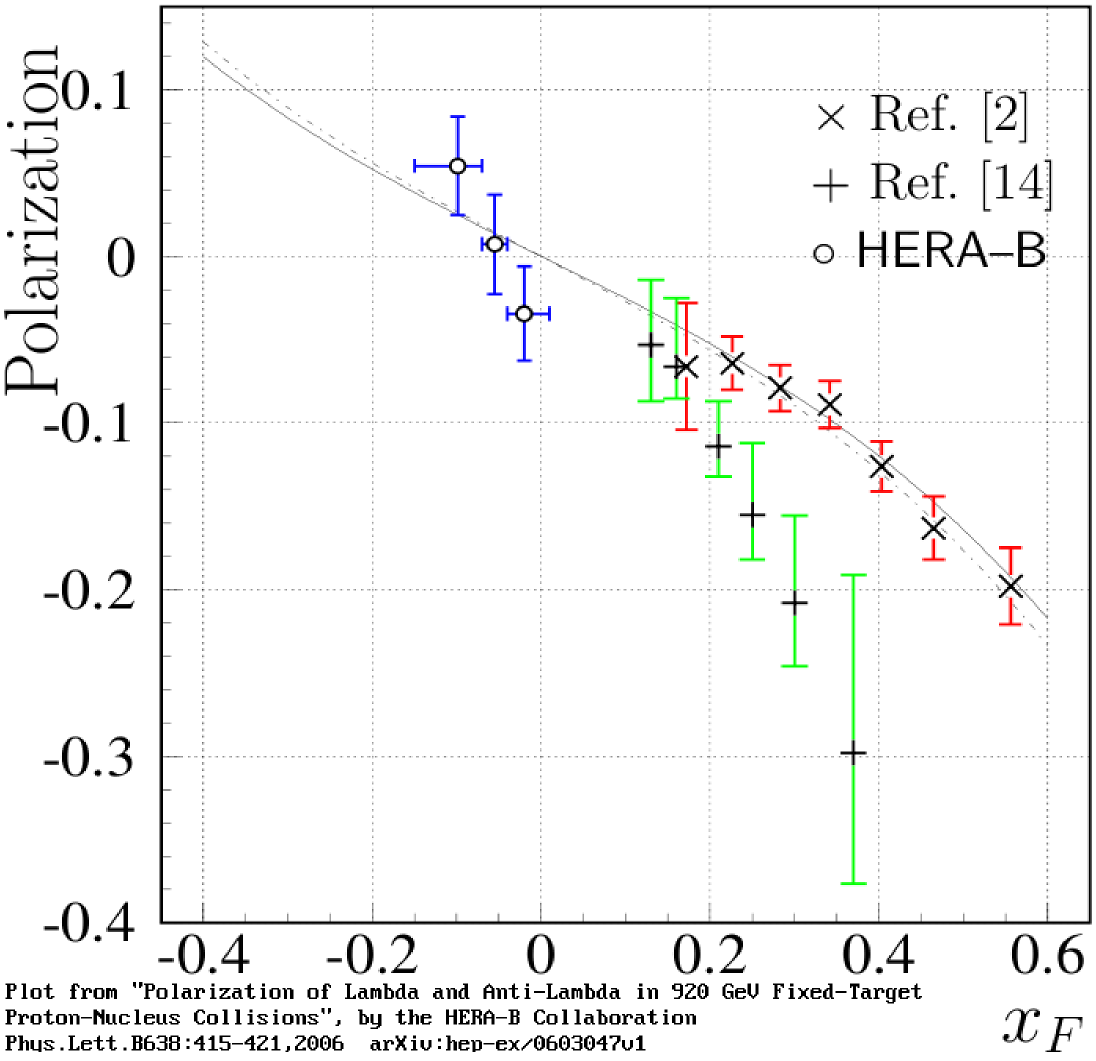
Recap



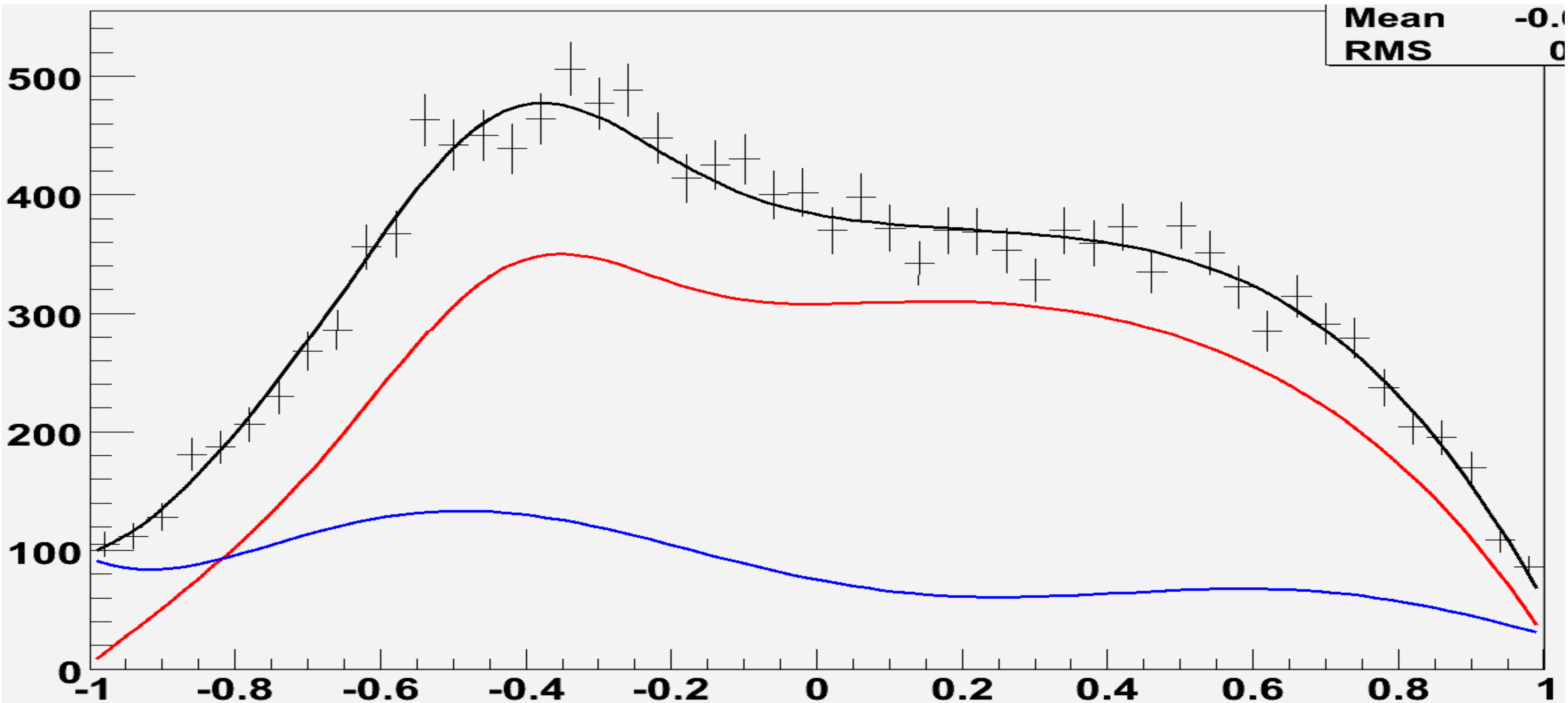


Plot from "Polarization of Lambda and Anti-Lambda in 920 GeV Fixed-Target Proton-Nucleus Collisions", by the HERA-B Collaboration
Phys.Lett.B638:415-421,2006 arXiv:hep-ex/0603047v1

Determining the polarization

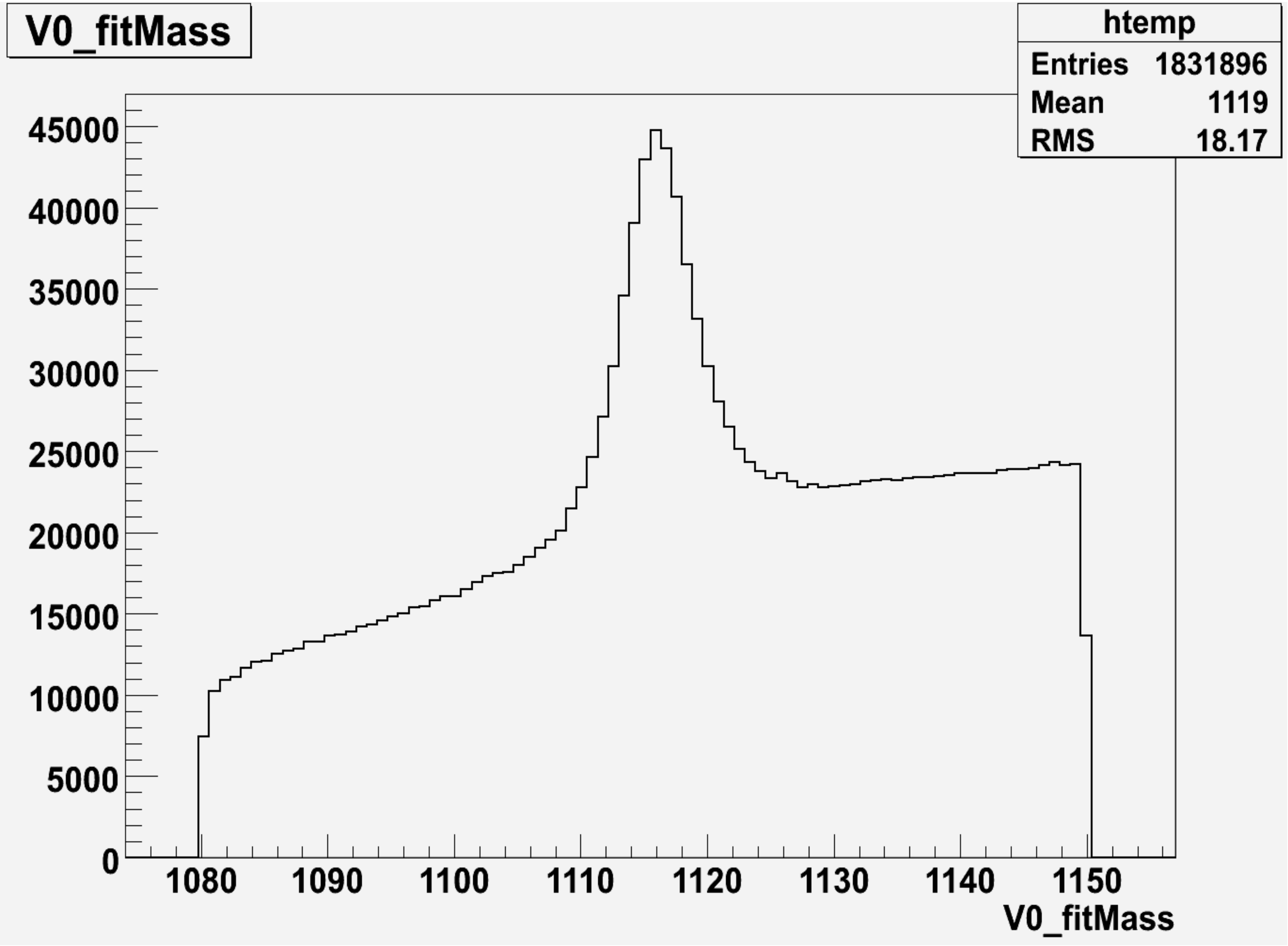
- Polarization creates a distribution ~ $1+\alpha P\cos(\theta)$. (α is a constant, ~0.642); θ is the angle between the decay proton direction and the normal of the scattering plane (which contains the two colliding protons and the Λ) in the rest frame of the Λ. In order to conserve parity in strong interactions, polarization has to be normal to the scattering plane.
- However, the actual distribution is more complicated. In addition to the signal, it includes background, efficiency function, and weighting constants. Hence, the distribution is described by $N1*B(\theta) + N2(1+\alpha P\cos(\theta)) * e(\theta)$
- Methodology: Apply cuts, then fit signal and background components (determined from MC)
- Note that due to poor angular resolution, there's a 20% relative correction factor.

First test – retrieving injected polarization (100%) in MC sample

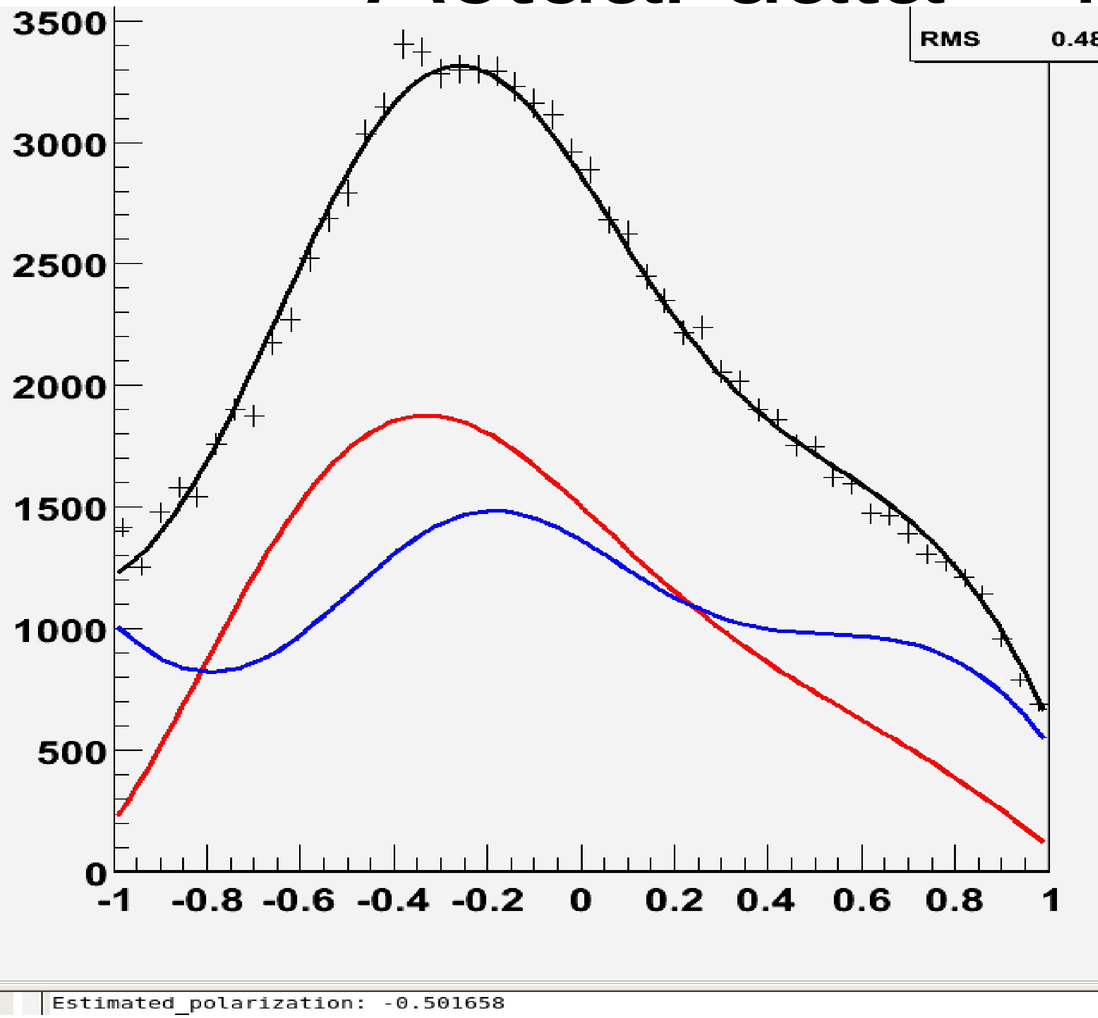


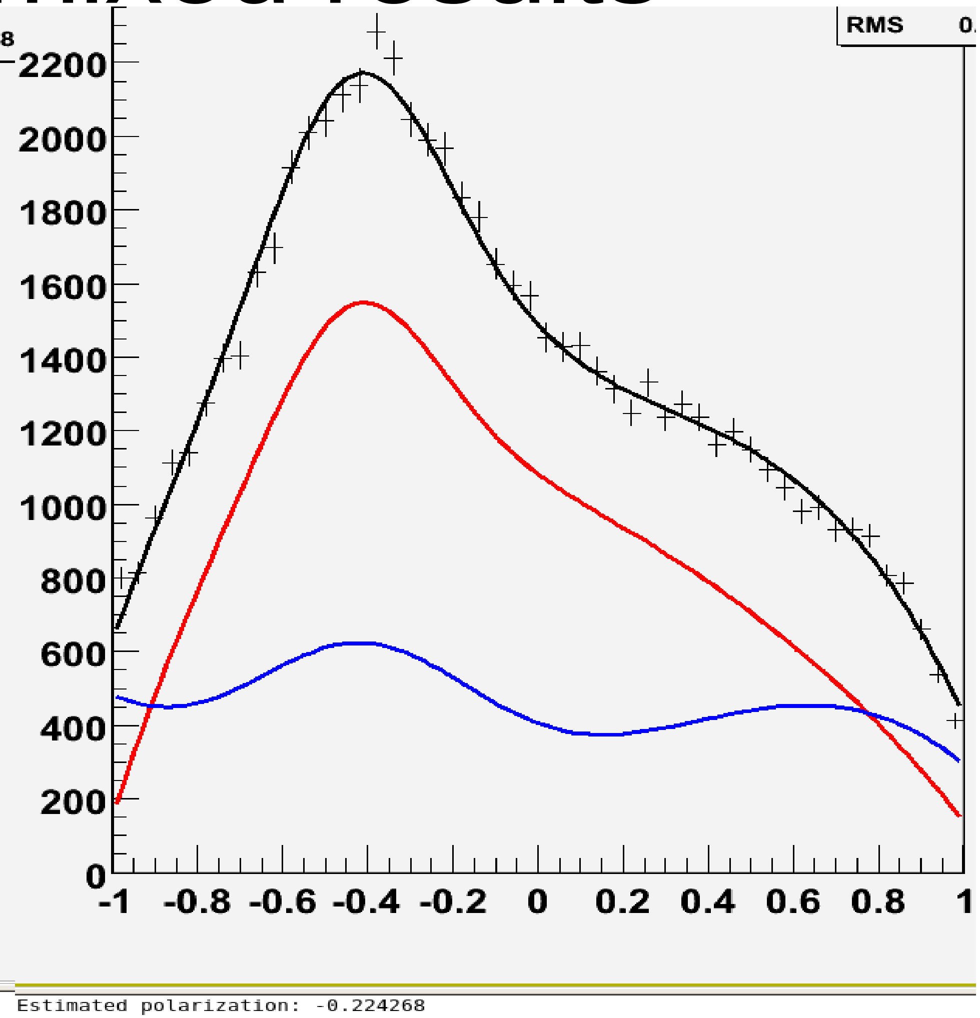
cos(θ) distribution in Monte Carlo results; the x-axis is cos(θ), the y-axis is counts, and the black line shows the fit (red and blue are signal + background components, respectively.) This extracted a polarization of 104%, within the error bars.

Mass peak in uncut data



Actual data – mixed results



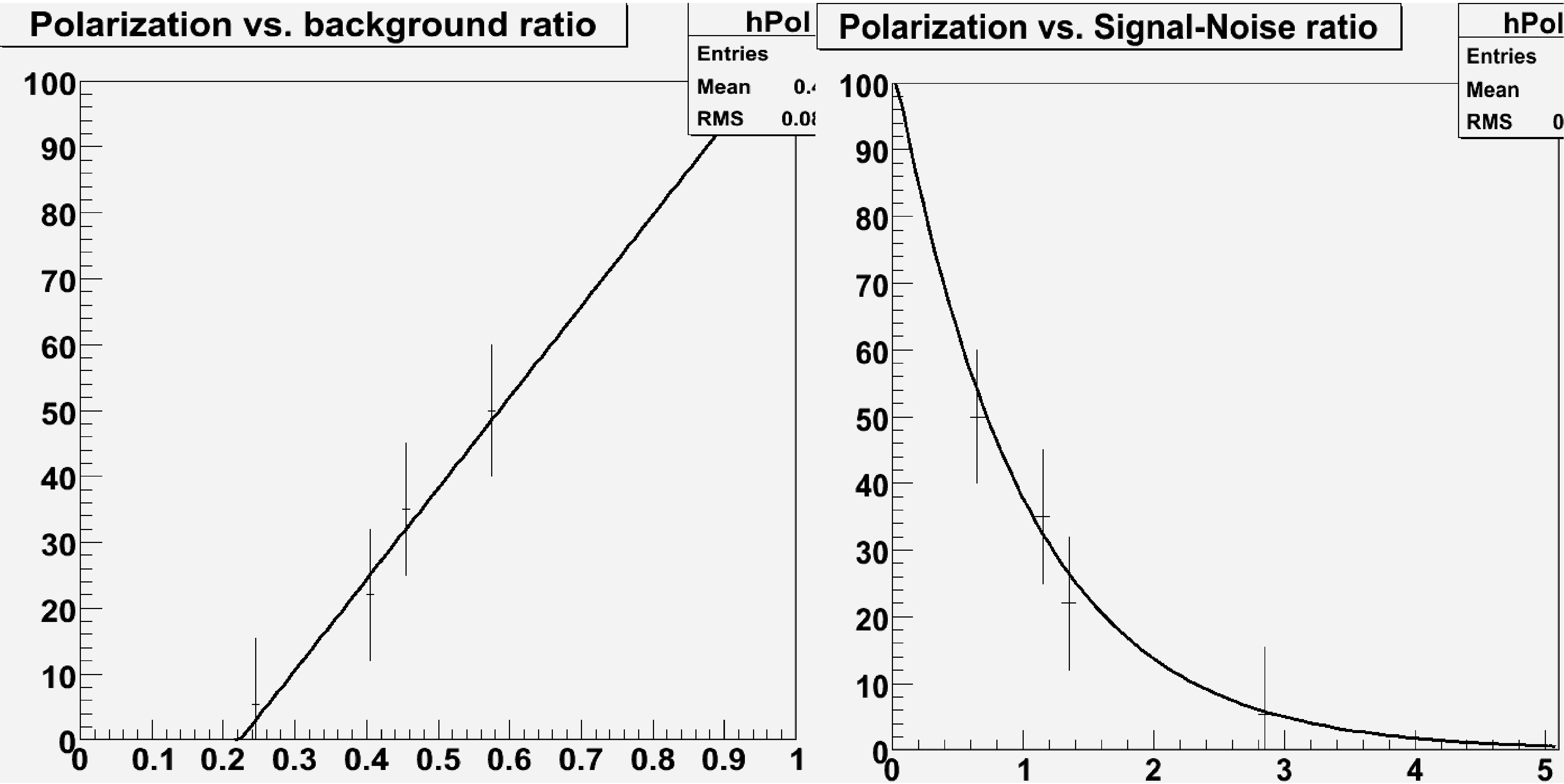


The two plots show polarization fits in data using different cut levels (the right has much tighter cuts.) Unfortunately, the left plot has an estimated polarization of -50%, and the right plot only -22%.

Polarization measurement depending on cuts? Not good...

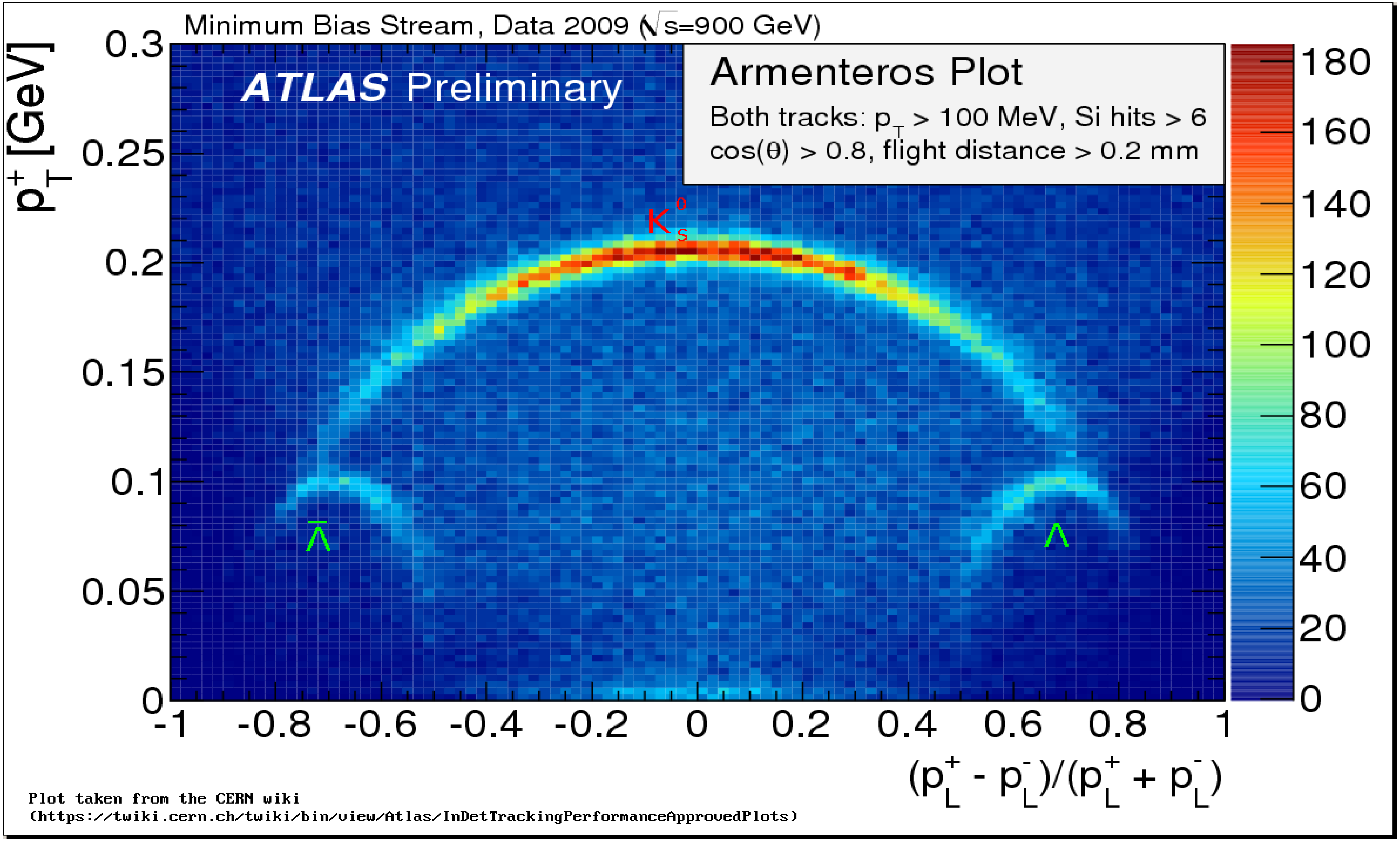
- The signal to noise ratio in the data fit differs from the MC, by a factor of 20-50% (depending on cuts), with more signal than expected.
- Using the original approach, polarization decreases as cuts increase.
- Clearly something fishy is going on with the background fit – 7 TeV is a 'new frontier' of high-energy physics and there is no guarantee the MC is accurate at describing the background – the whole basis of this analysis.
- Hence, it was decided to dramatically increase the cuts to a level where the background is relatively inconsequential. It would be preferential to use the V0 finder, but we have been running that for 2 weeks and it is still working. Additional caveat: Its creator isn't sure that it can be relied on for such an analysis.

In fact, there's an obvious relationship between the polarization measured by our approach and the background level

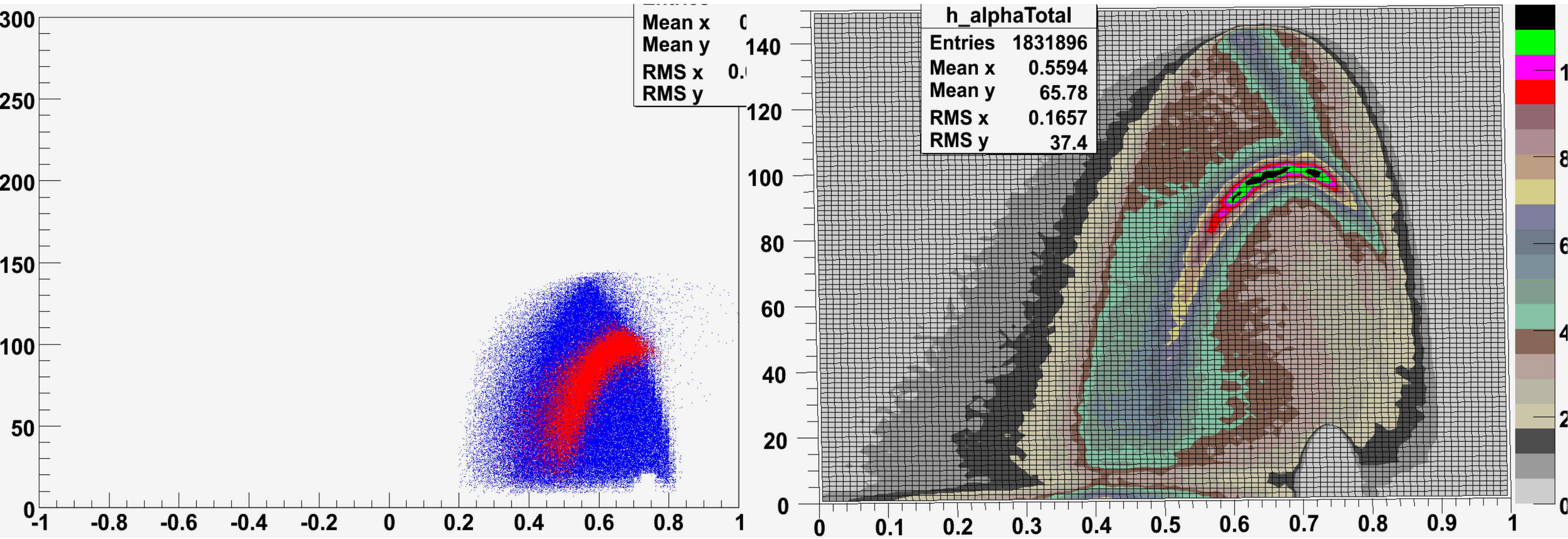


- Of course, given estimated error bars of +/- 10, the relationship depends quite a bit on how you do your fit. Left is a linear fit of polarization vs. background ratio, producing a result of 30% polarization when background is 0. Right is an exponential fit of polarization vs. the signal-noise ratio (1/(Background ratio) -1), producing a result of 0% polarization when background is 0 (and the ratio approaches infinity.) The right fit is a bit better than the left fit, but both are well within the margin of error.

The Armenteros-Podalinksi distribution



Armenteros-Podalinski cut

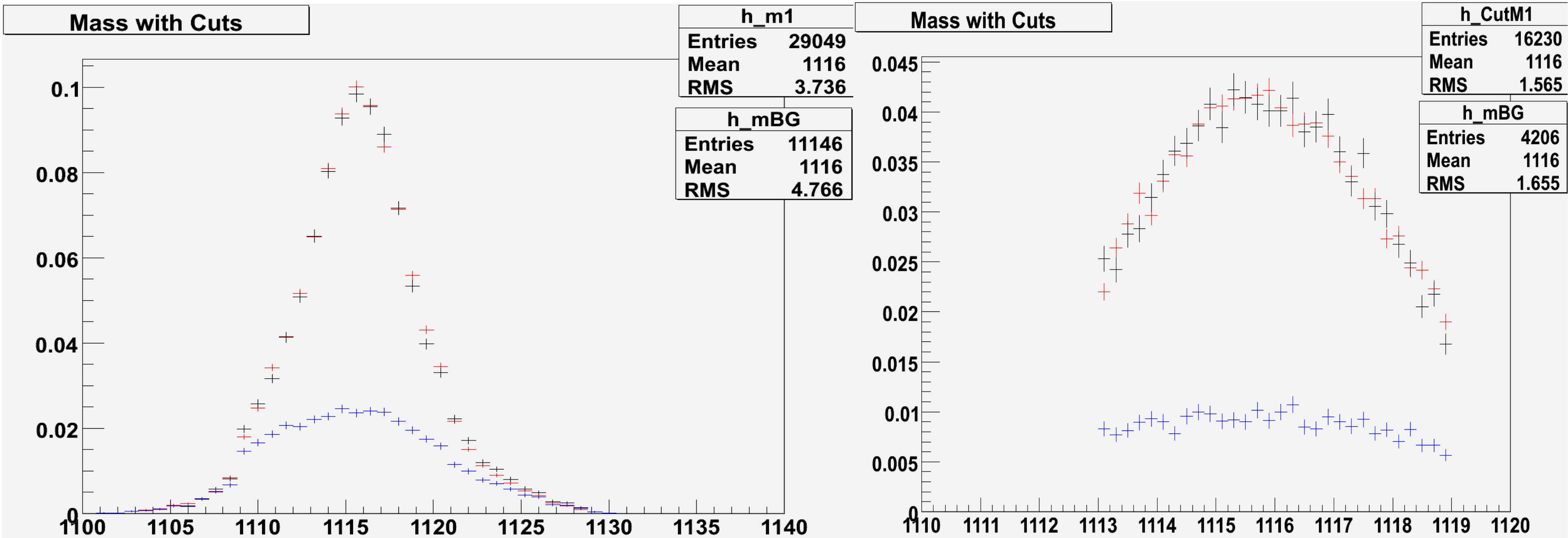


The two plots show the Armenteros-Podalinski plot in MC (left) and data (right); signal is shown in red and background in blue in the MC plot.

Overall final cuts and adjustments

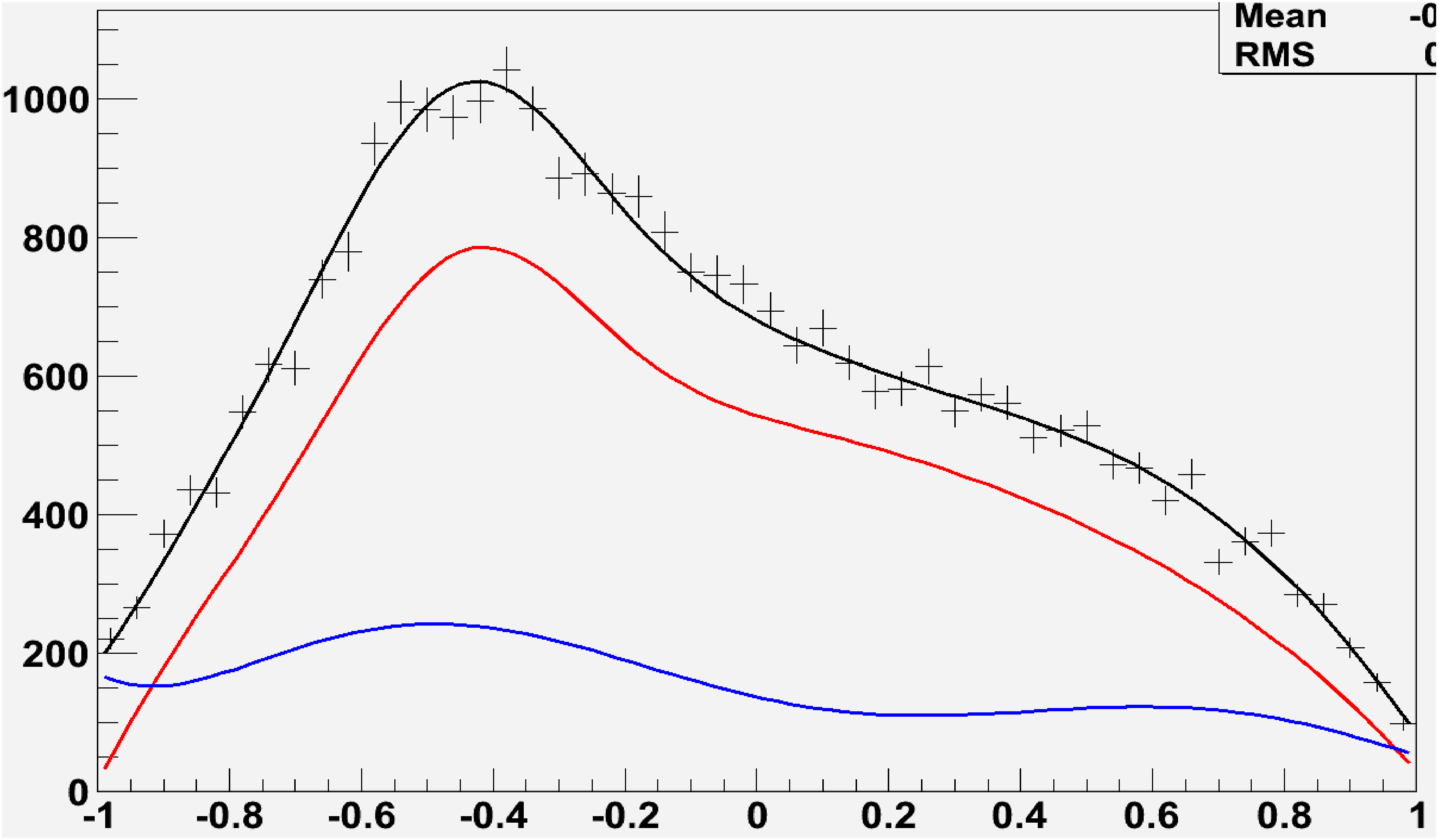
- Opening angle, Armenteros-Podalinksi contour cut (alpha-qt+ distribution) Lxy (component of the Λ's travel distance in the plane normal to the beam direction), chi^2 probability, Kaon-lambda-bar fit mass cut (to remove kaons from the background), mass distribution, etc.

- These complicated cuts result in a 4-1 signal-noise ratio in MC (25.4% background.) Notably, this result was retrieved in data (25.7%)



Left plot: Mass distribution with most of the cuts (but without mass/opening angle cuts so that there's still a clear mass peak.) Right plot: Mass distribution with all cuts included. Background is shown in blue, data in red, MC results in black

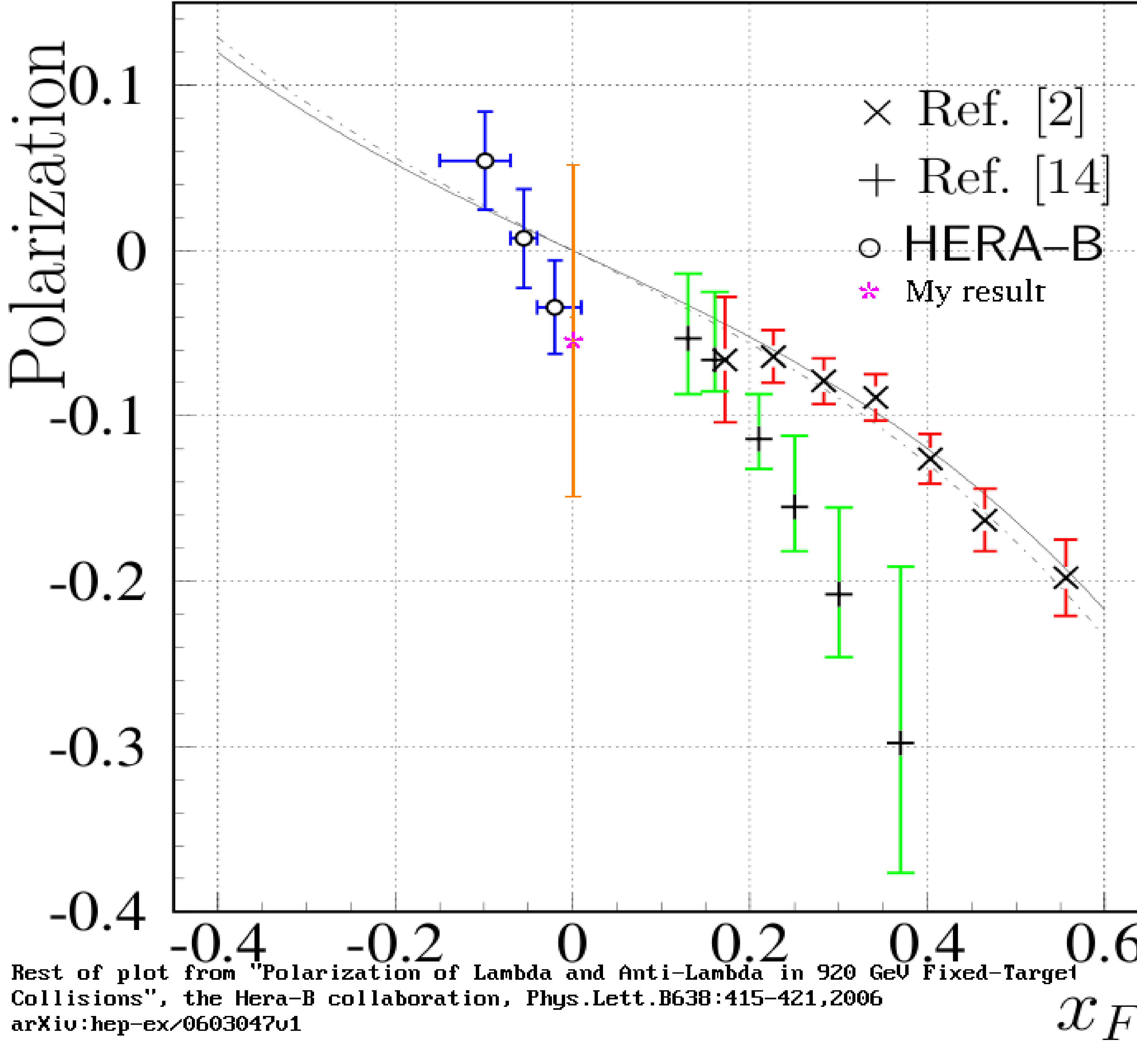
Successful fit of 7 TeV data.



- Polarization was measured to be 5.4% +/- 3% (statistical) +/- ~10% (estimated systematic.) x_F = 0.00081 +/- 0.0006. Pt = 1.3 +/- 0.67 GeV

Reasons to believe this result

- Signal to noise ratio and mass distribution agree between Monte Carlo and data.
- 25% background is quite small and shouldn't have a huge effect on the signal (though it is possible to construct such a background distribution that will.)
- Our result is in agreement with theory (predicting ~0% polarization) and work by other groups (one from Yale and another from St. Petersburg) on the same 7 TeV data.



Rest of plot from "Polarization of Lambda and Anti-Lambda in 920 GeV Fixed-Target Collisions", the Hera-B collaboration, Phys.Lett.B638:415-421,2006
arXiv:hep-ex/0603047v1

Further questions to study

- Further refine our methodology and reduce the error bars
- Use the V0 finder for selection cuts, and compare to our results
- Bin the results in Pt to see how polarization varies (or doesn't)
- Apply additional cuts to further reduce the background fraction and study changes in the polarization
- Attempt to understand the evolution of background cos(θ) with respect to mass, so that we can rely purely on the data to account for it
- Check for polarization in the scattering plane – this is a check for conservation of parity in strong interactions (believed to be true, but not studied in-depth at 7 TeV data yet.)
- Analyze Λ_b decays and polarization.