Preparations for Λ_b Polarization Measurements and Higgs Searches at ATLAS

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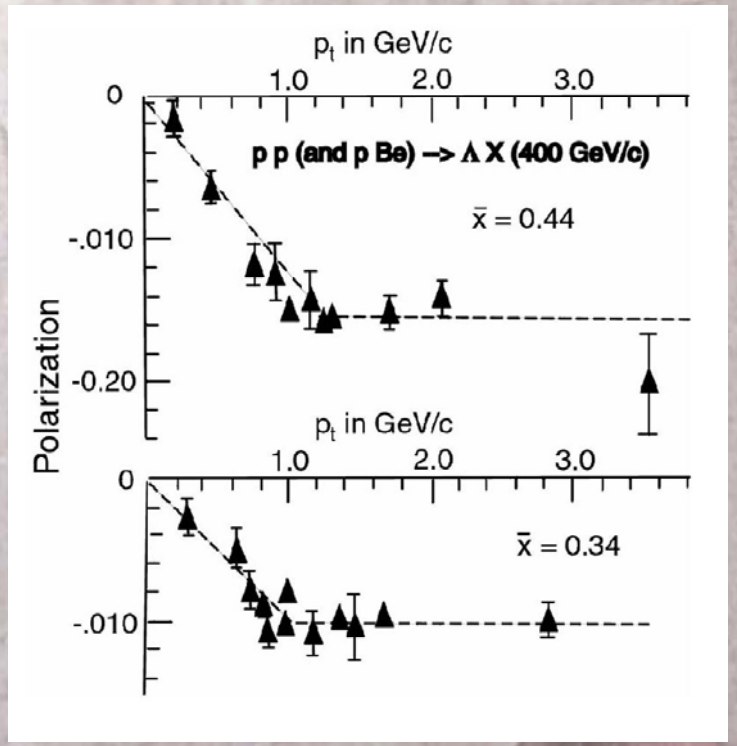
Outline

- Background on Λ_b polarization
- Preparations for LHC measurements
- Extraction of $\alpha_b P$ product from DØ data
- Separation of α_b and P

- Angular correlations in Higgs decay at generation level

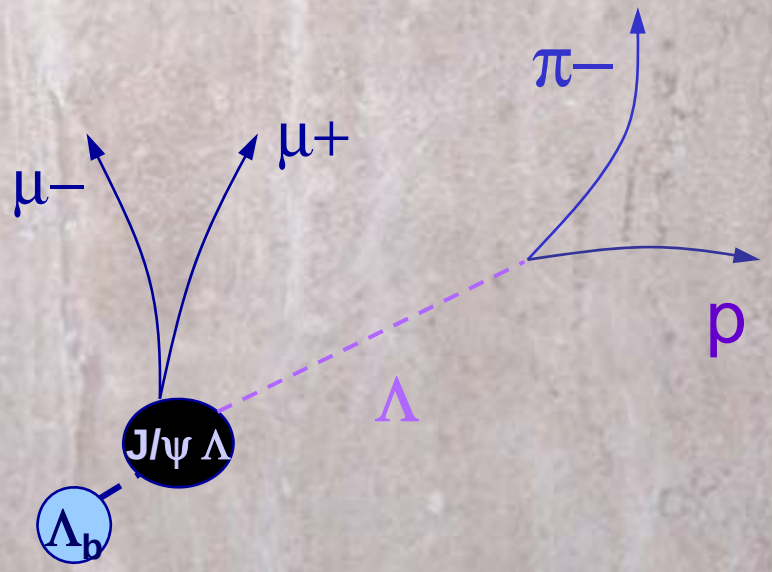
Motivation

- Mysterious Λ^0 polarization plateau
- Studying Λ_b will provide insight
- Expect 75,000 of Λ_b, $\overline{\Lambda}_b$ at LHC
- Need parity-violating α_b to measure polarization
- Initial estimate from Tevatron data



Λ_b Properties

- Baryon (udb)
- Mass: 5624 MeV
- Targeted decay channel in inclusive Λ_b production:

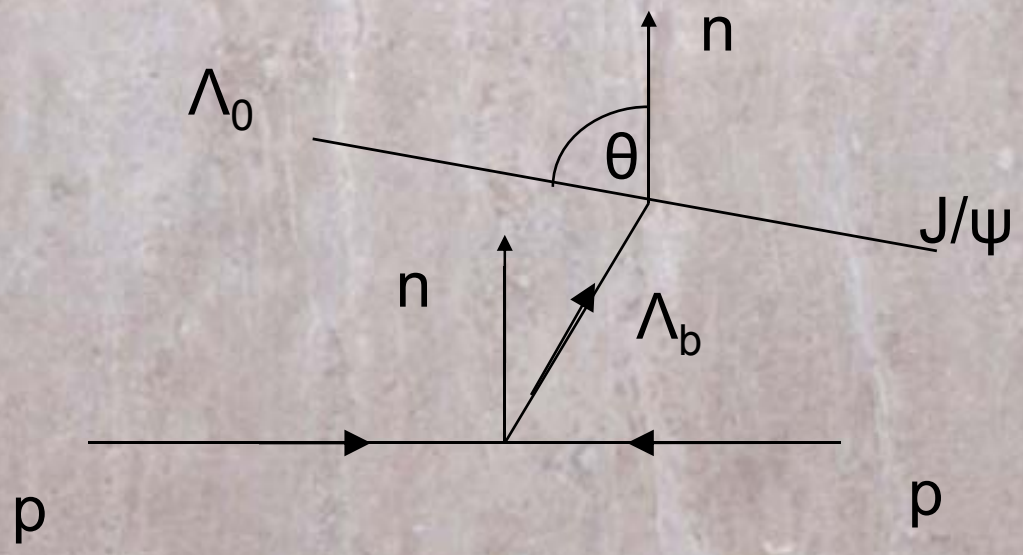


$$p + p \rightarrow \Lambda_b + X$$

where $\Lambda_b \rightarrow J/\psi\,(\mu^+\mu^-)\,\Lambda^0\,(p\pi^-)$

Λ_b Polarization

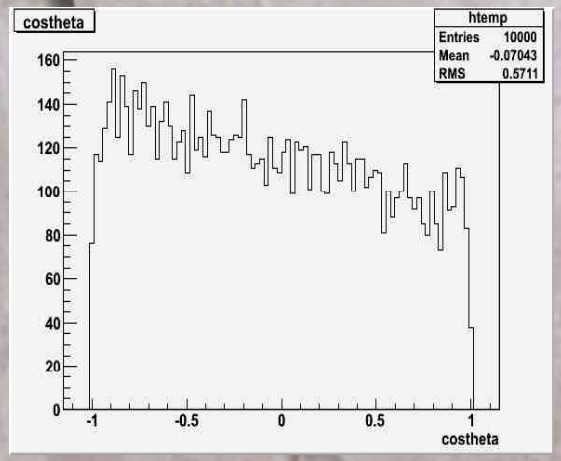
- Spin 1/2
- $P = (N_{up}-N_{down}) / (N_{up}+N_{down})$
- $\alpha_b = \Lambda_b$ asymmetry parameter
- PDF: $w(\cos\theta)=1/2*(1+\alpha_b P\cos\theta)$



Toy Monte Carlo

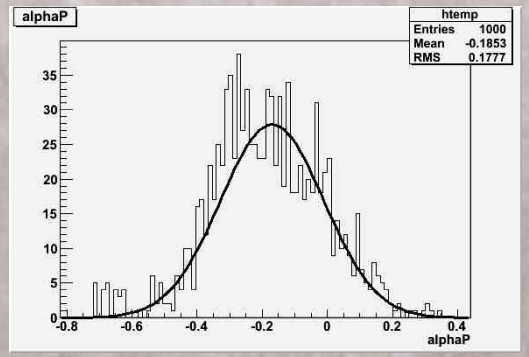
- Generation, reconstruction directly from angular distribution

Generation--one experiment with $\alpha_b P = -0.183$

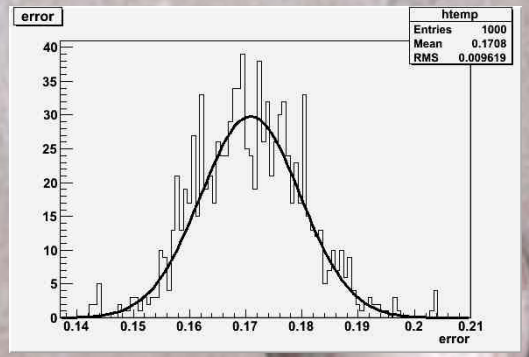


Reconstruction--1000 experiments of 100 events

Mean $\alpha_b P = -0.185$



Mean error= 0.17



Maximum Likelihood Fit

- Find parameters that make the data most likely with the following PDF

$$w = f_{sig}\, S + f_{bkgd}\, B$$

$$Acc * S_{mass} * S_{angle}$$

$B_{mass} * B_{angle}$

(Determined empirically)

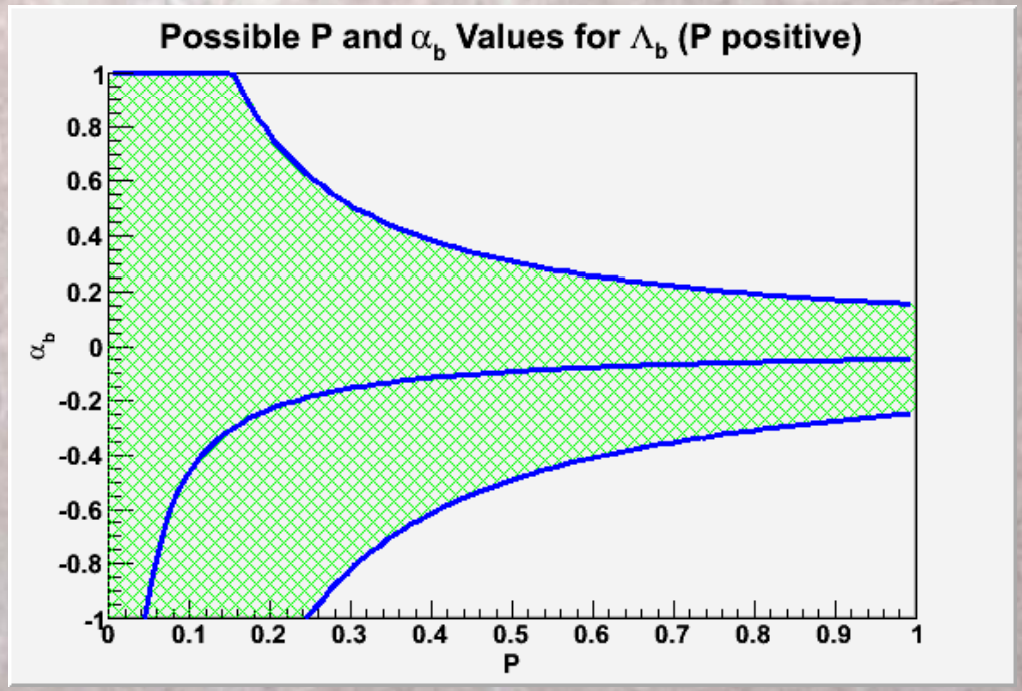
(From reconstruction level Monte Carlo, no polarization)

Gauss(μ,σ)

Angular distribution

Measurement of $\alpha_b P$ from DØ data

- 80 signal events
- $\alpha_b P = -0.046 \pm 0.2$



Fit includes acceptance, background, mass information

Addition of $\overline{\Lambda}_b$ Events

- 55 signal events
- By CP conservation,
  $w(\cos\theta)=1/2*(1-\alpha_b P\cos\theta)$
- $\alpha_b P= -0.054 \pm 0.26$

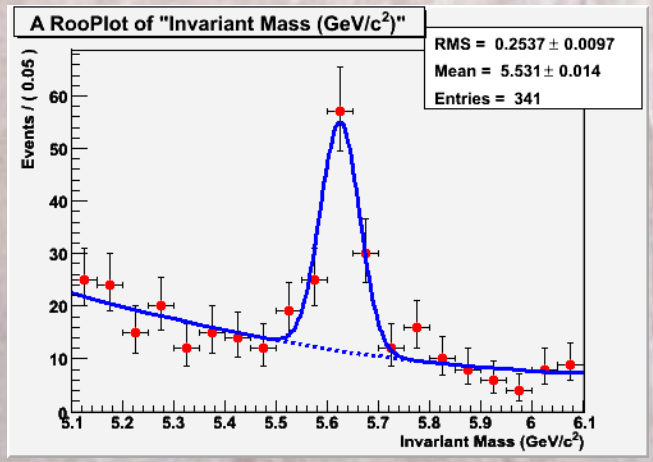
Expected error for combined sample?

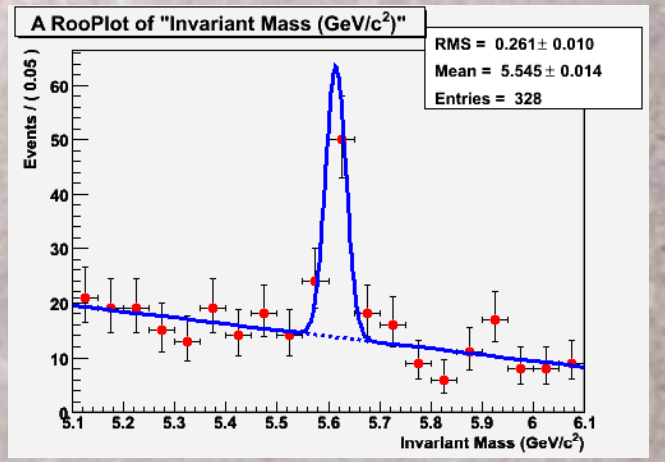
$\sigma_M=\sigma/\mathrm{Sqrt}(N)$ ⟶ Error ≈ 0.16

Simultaneous Fit Results

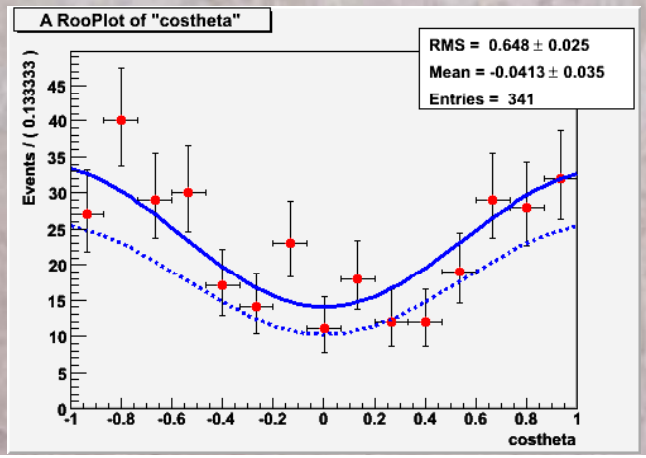
Λ_b $\overline{\Lambda}_b$

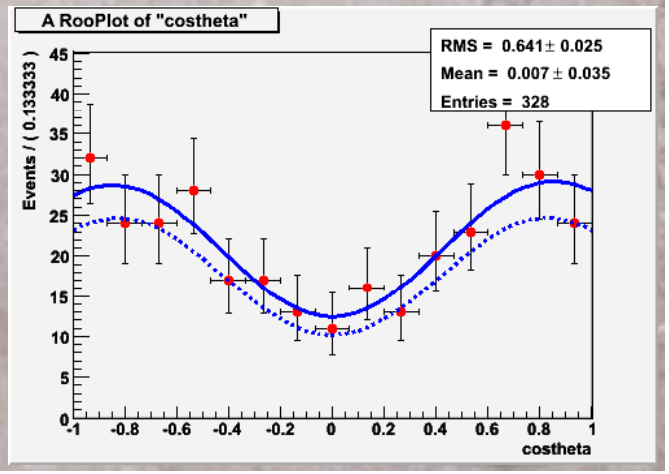
Mass





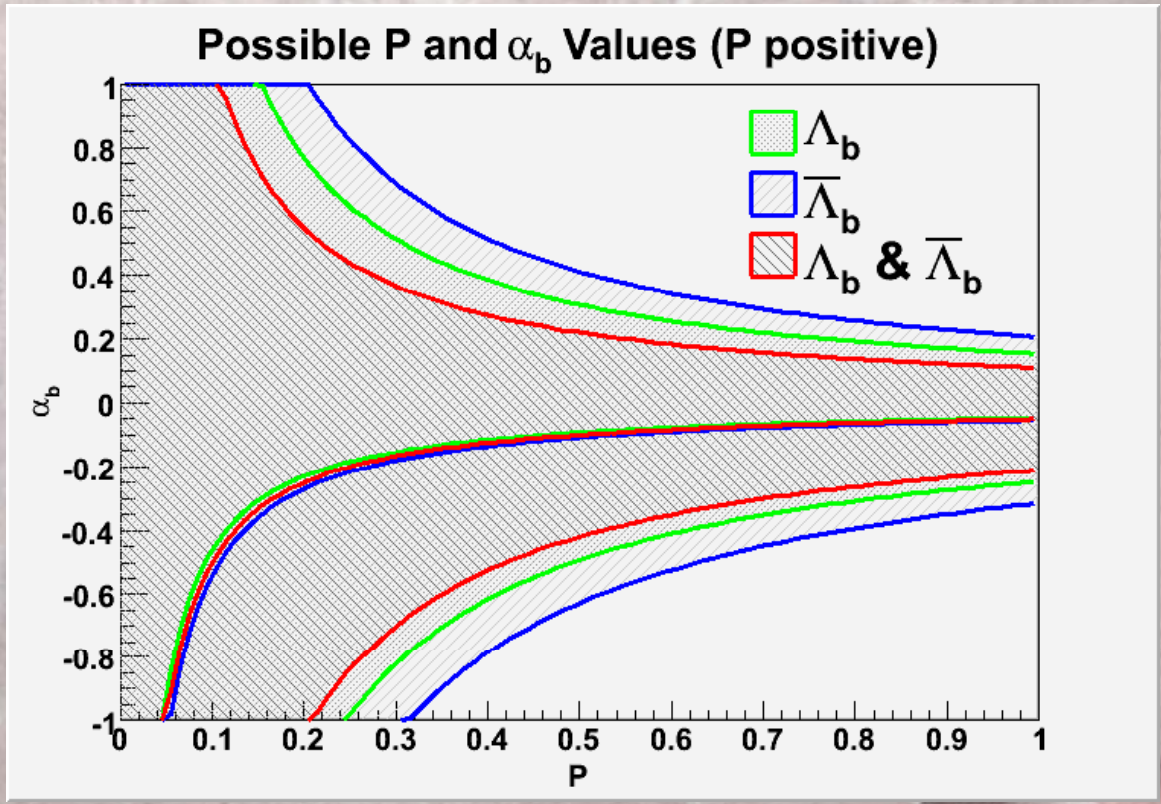
Cos(theta)





Updated Measurement

- Around 135 signal events
- $\alpha_b P = -0.05 \pm 0.16$
- Narrowed possible parameter space



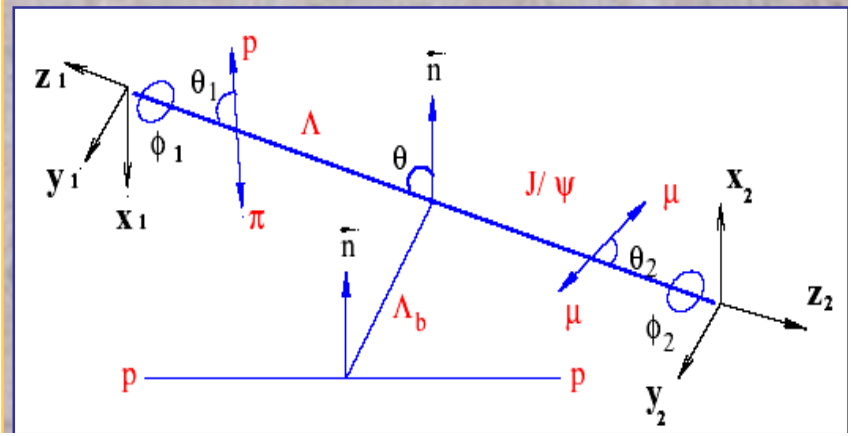
Attempt to increase data sample → Ξ_b discovery!

Full Angular Distribution

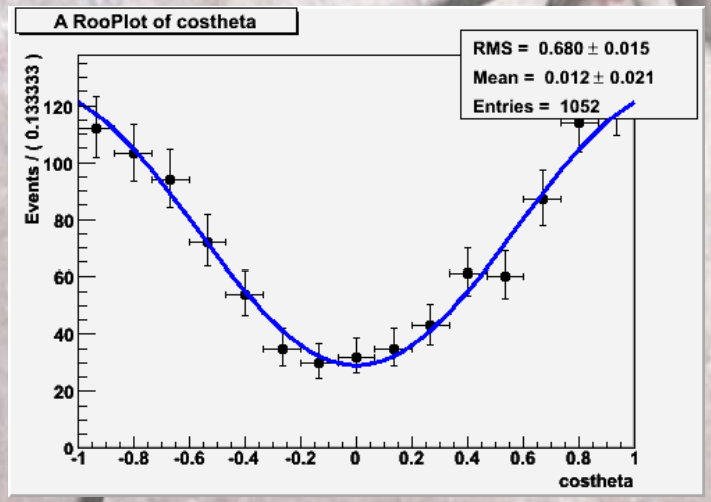
$$w(\Omega,\Omega_1,\Omega_2)=\frac{1}{(4\pi)^3}\sum_{i=0}^{i=19} f_{1i}f_{2i}(P_b,\alpha_\Lambda)F_i(\theta,\theta_1,\theta_2,\phi_1,\phi_2)$$

i	f_{1i}	f_{2i}	F_i
0	1	1	1
1	α_b	P_b	$\cos\theta$
2	$2r_1-\alpha_b$	α_Λ	$\cos\theta_1$
3	$2r_0-1$	$P_b\alpha_\Lambda$	$\cos\theta\cos\theta_1$
4	$\frac{1}{2}-\frac{3}{2}r_0$	1	$d^2_{00}(\theta_2)$
5	$\frac{1}{2}\alpha_b-\frac{3}{2}r_1$	P_b	$d^2_{00}(\theta_2)\cos\theta$
6	$-\frac{1}{2}(\alpha_b+r_1)$	α_Λ	$d^2_{00}(\theta_2)\cos\theta_1$
7	$-\frac{1}{2}(1+r_0)$	$P_b\alpha_\Lambda$	$d^2_{00}(\theta_2)\cos\theta\cos\theta_1$
8	$-3Re(a_+a_-^*)$	$P_b\alpha_\Lambda$	$\sin\theta\sin\theta_1\sin^2\theta_2\cos\phi_1$
9	$3Im(a_+a_-^*)$	$P_b\alpha_\Lambda$	$\sin\theta\sin\theta_1\sin^2\theta_2\sin\phi_1$
10	$-\frac{3}{2}Re(b_-b_+^*)$	$P_b\alpha_\Lambda$	$\sin\theta\sin\theta_1\sin^2\theta_2 cos(\phi_1+2\phi_2)$
11	$\frac{3}{2}Im(b_-b_+^*)$	$P_b\alpha_\Lambda$	$\sin\theta\sin\theta_1\sin^2\theta_2 sin(\phi_1+2\phi_2)$
12	$-\frac{3}{\sqrt{2}}Re(b_-a_+^*+a_-b_+^*)$	$P_b\alpha_\Lambda$	$\sin\theta\cos\theta_1\sin\theta_2\cos\theta_2\cos\phi_2$
13	$\frac{3}{\sqrt{2}}Im(b_-a_+^*+a_-b_+^*)$	$P_b\alpha_\Lambda$	$\sin\theta\cos\theta_1\sin\theta_2\cos\theta_2\sin\phi_2$
14	$-\frac{3}{\sqrt{2}}Re(b_-a_-^*+a_+b_+^*)$	$P_b\alpha_\Lambda$	$\cos\theta\sin\theta_1\sin\theta_2\cos\theta_2\cos(\phi_1+\phi_2)$
15	$\frac{3}{\sqrt{2}}Im(b_-a_-^*+a_+b_+^*)$	$P_b\alpha_\Lambda$	$\cos\theta\sin\theta_1\sin\theta_2\cos\theta_2\sin(\phi_1+\phi_2)$
16	$\frac{3}{\sqrt{2}}Re(a_-b_+^*-b_-a_+^*)$	P_b	$\sin\theta\sin\theta_2\cos\theta_2\cos\phi_2$
17	$-\frac{3}{\sqrt{2}}Im(a_-b_+^*-b_-a_+^*)$	P_b	$\sin\theta\sin\theta_2\cos\theta_2\sin\phi_2$
18	$\frac{3}{\sqrt{2}}Re(b_-a_-^*-a_+b_+^*)$	α_Λ	$\sin\theta_1\sin\theta_2\cos\theta_2\cos(\phi_1+\phi_2)$
19	$-\frac{3}{\sqrt{2}}Im(b_-a_-^*-a_+b_+^*)$	α_Λ	$\sin\theta_1\sin\theta_2\cos\theta_2\sin(\phi_1+\phi_2)$

Integrating over 4 angles leaves only the first 2 terms. Integrating over 2 angles leaves 8 terms.

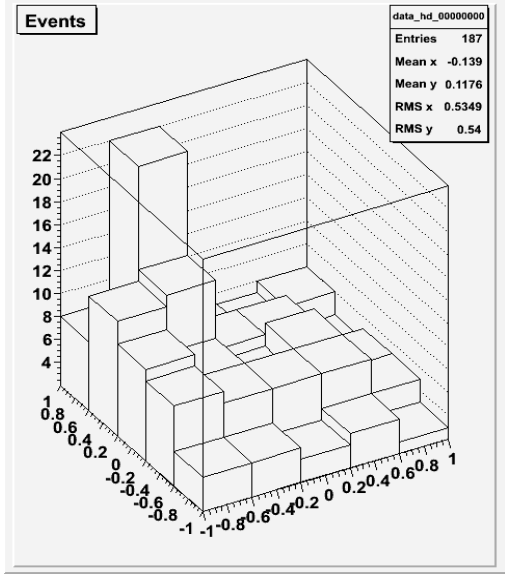


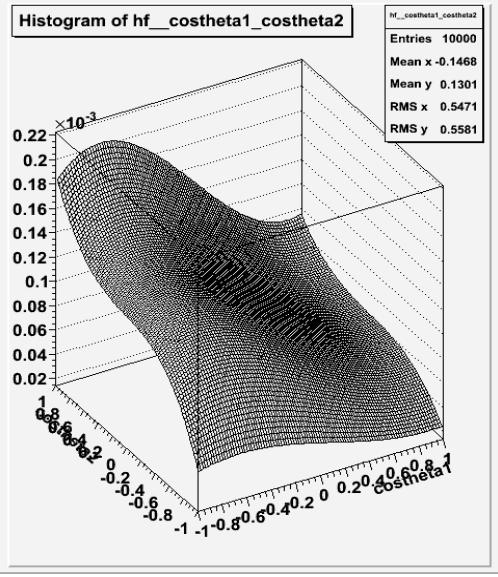
Modeling Acceptance, Background

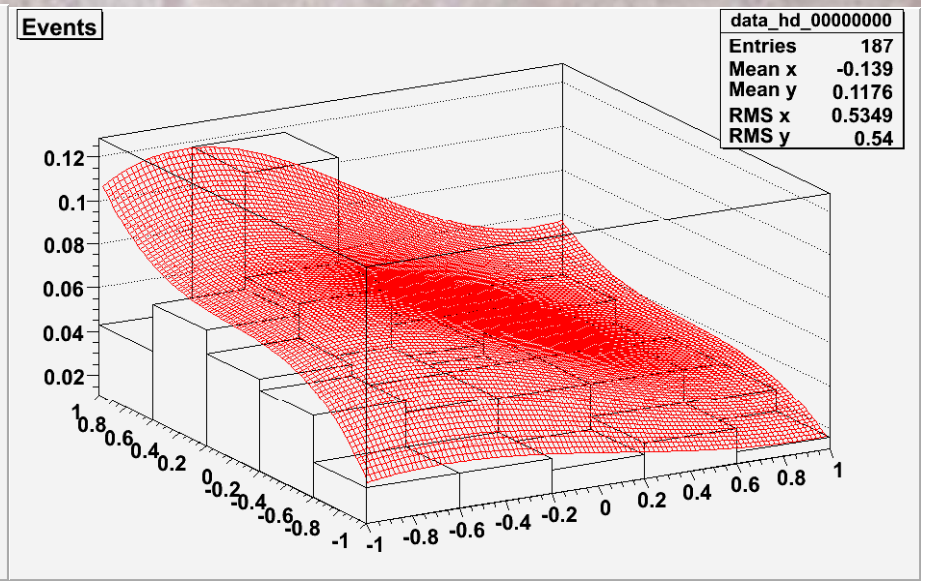


Costheta acceptance

Costheta1 vs. Costheta2 background







α_b Measurement for Λ_b Particles

- Allows separation of α_b and P
- Generation, reconstruction level simulations

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 GNU nano 1.2.4

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  EXT PARAMETER                                          STEP         FIRST
  NO.   NAME      VALUE            ERROR                 SIZE      DERIVATIVE
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   2  r0           8.26958e-01   2.18758e-01   8.99854e-05   5.55147e-04
   3  r1          -2.94767e-01   3.73348e-01  -8.45112e-04  -2.75016e-03
   4  P           -2.95065e-01   4.93915e-01  -3.63972e-04  -5.09475e-04
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   6  massback2    2.61422e-02   4.74194e-03  -1.63503e-07   1.46884e+02
   7  mean         5.62014e+00   7.07695e-03  -1.90862e-05   3.27350e-02
   8  sigma        4.26638e-02   8.76201e-03   6.91147e-06  -3.31988e-02
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  13  cos1back_2   3.88050e-03   2.14712e-01   8.97575e-07  -1.49727e-01
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                               ERR DEF= 0.5
 EXTERNAL ERROR MATRIX.    NDIM=  25    NPAR= 15    ERR DEF=0.5
 ELEMENTS ABOVE DIAGONAL ARE NOT PRINTED.
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Summary of Results

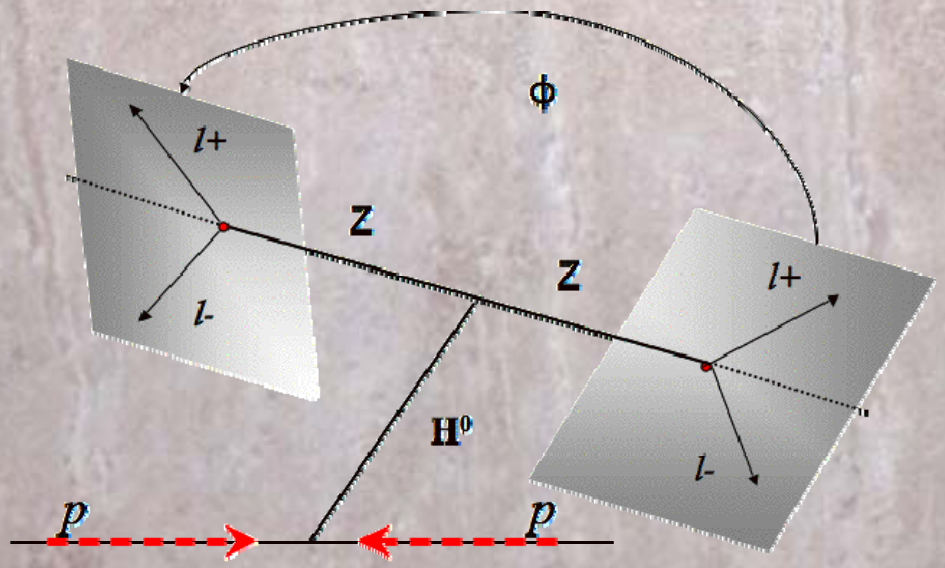
- First measurement of separated α_b and P
- Developed a framework for future analysis

- Large errors on measurements
- Better to keep particles, antiparticles apart

- Differences between Λ_b and $\overline{\Lambda}_b$ event numbers, mass peaks?
- Can we include $\overline{\Lambda}_b$ sample in the α_b measurement?

Correlation Between Final State Angles in Higgs Decay

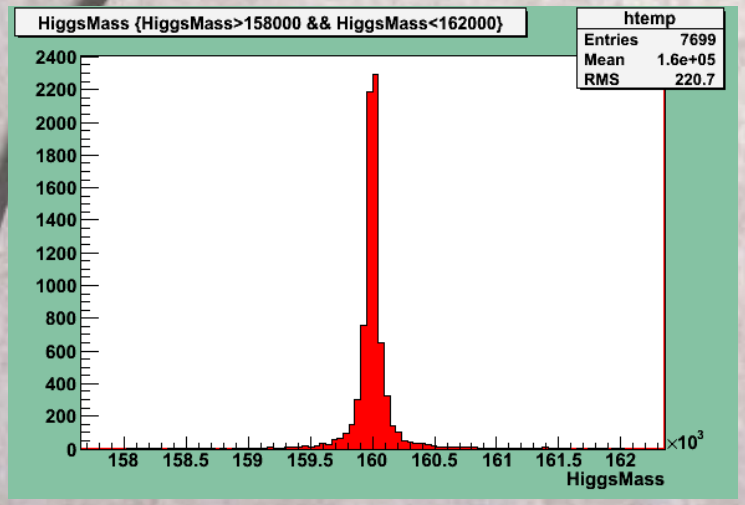
$H^0 \rightarrow Z\ (l^+l^-)\ Z^*\ (l^+l^-)$



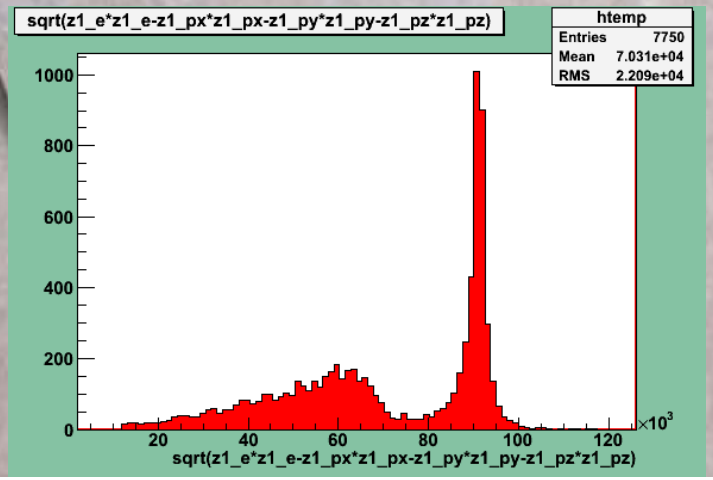
- Debate over whether one should exist
- Check at generation level

Higgs plots

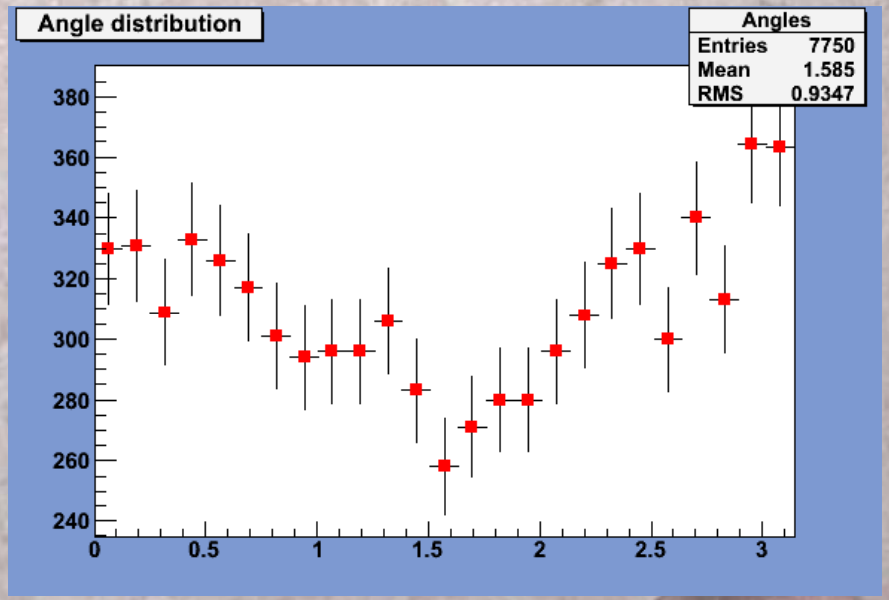
Higgs mass



Z and Z* mass



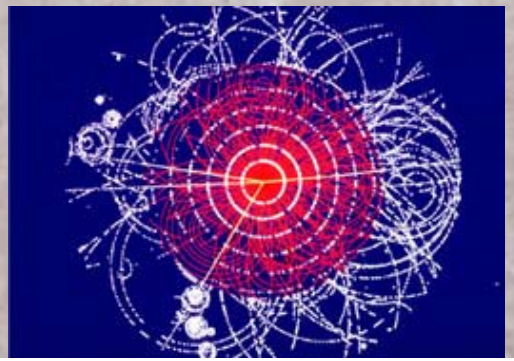
Angles between decay planes



Clear correlation in this version of Pythia!

Higgs Summary

- Found angular correlation at generation level in H to 4l channel
  - Possible use for background rejection, measurement of Higgs spin
- Extensive Monte Carlo simulations, analysis of Pythia versions remains
- Experience with Λ_b gives us an edge



Sardinia! woo!

Thank you

- Homer Neal
- Eduard De La Cruz Burelo
- Natasha Panikashvili

- Jean Krisch, Jeremy Herr, Steven Goldfarb
- REU program
- CERN