LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

Study of Time Dependent CP Asymmetry of $B^0 \to K_S K_S K_S$ with one $K_S \to \pi^0\pi^0$

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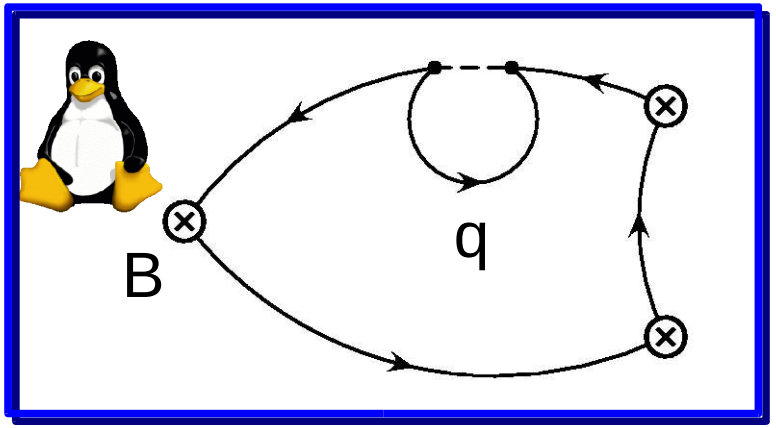
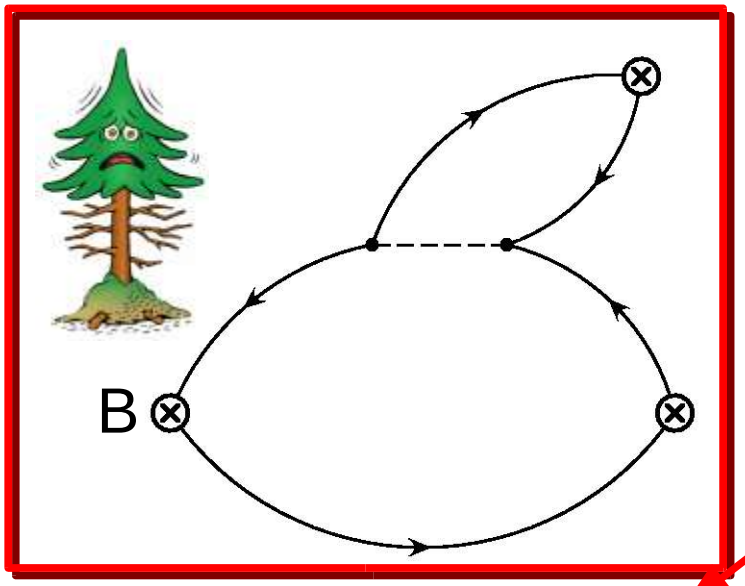
b→s transitions and NP

Penguin dominated amplitudes
Sensitive to NP

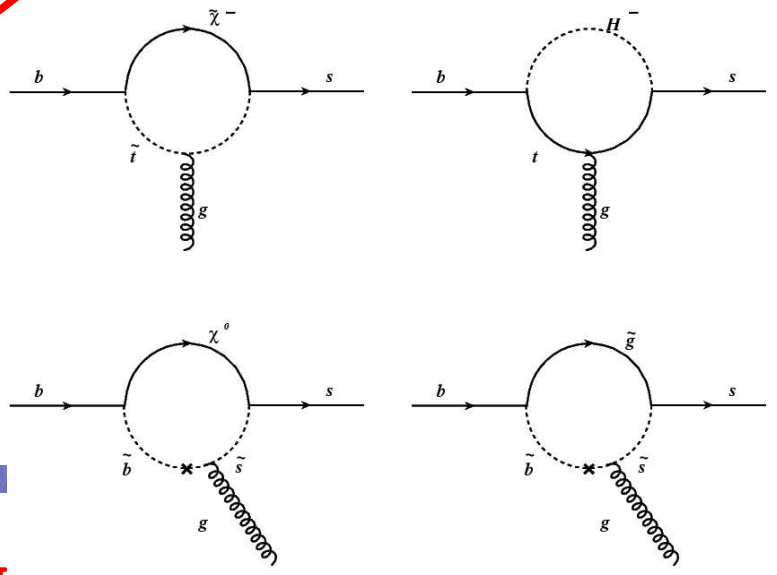


$$\mathcal{A}(B^0 \to X\, K^0) = -V_{ts}\, V_{tb}^* \times \boldsymbol{P_1}(c) - V_{us}\, V_{ub}^* \times \{\boldsymbol{E_2} + \boldsymbol{P_1}^{GIM}(u\text{-}c)\}$$

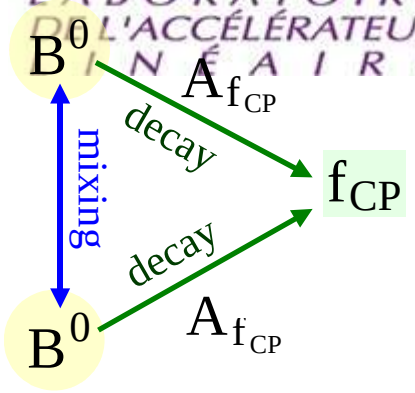


No sensitivity to NP.
Not always present

SUSY contributions



CP asymmetry in b→s (I)



$$\lambda_{f_{CP}} = \underbrace{\frac{q}{p}}_{\text{mixing}} \cdot \underbrace{\frac{\bar{A}_{f_{CP}}}{A_{f_{CP}}}}_{\text{decay}} = |\lambda_{f_{CP}}| \cdot e^{-2i\phi_{CP}}$$

$$S_{f_{CP}} = -\frac{2\,\Im\,\lambda_{f_{CP}}}{1+|\lambda_{f_{CP}}|^2}$$

$$C_{f_{CP}} = \frac{1-|\lambda_{f_{CP}}|^2}{1+|\lambda_{f_{CP}}|^2}$$

$$A_{f_{CP}}(t) = \frac{\Gamma(B^0_{phys}(t) \to f_{CP}) - \Gamma(B^0_{phys}(t) \to f_{CP})}{\Gamma(B^0_{phys}(t) \to f_{CP}) + \Gamma(B^0_{phys}(t) \to f_{CP})} = -C_{f_{CP}} \cos(\Delta m_d t) + S_{f_{CP}} \sin(\Delta m_d t)$$

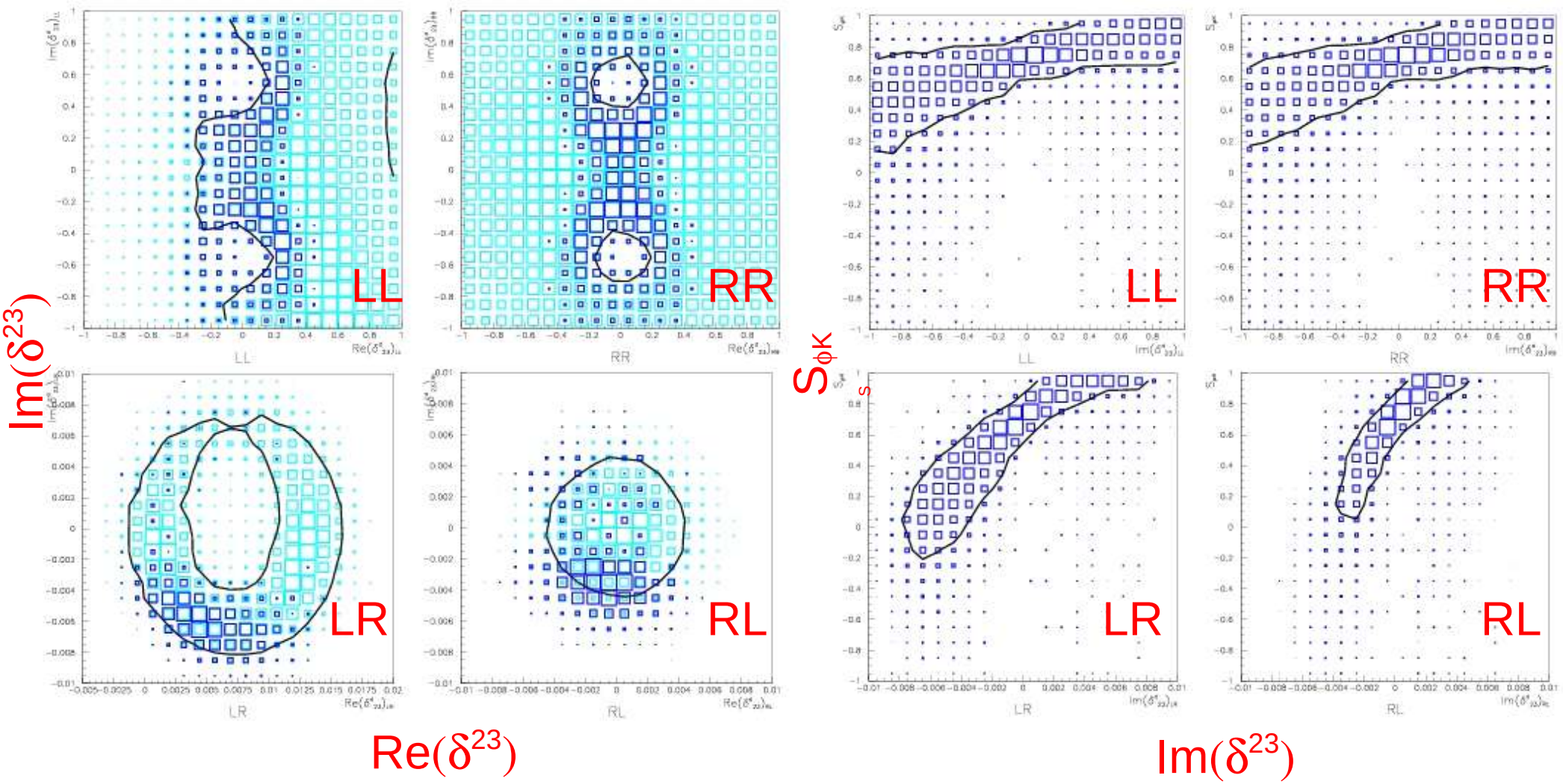
If there is only one CKM ($A = \bar{A}$)

$$C = 0 \quad ; \quad S = \sin(2\beta)$$

One can use S and C from these channels to test the consistency of the Standard Model or...

CP asymmetry in b→s (II)

... even to quantify New Physics



The case of KsKsKs

Two penguins contributions to decay amplitudes, with strong CKM herarchy

- expected |S| ~ sin2b & C ~0

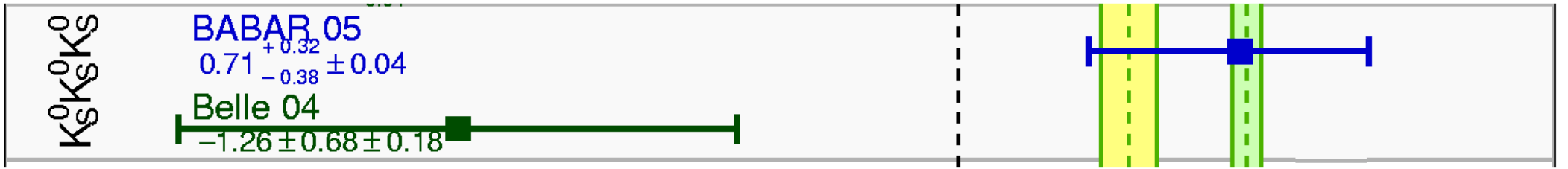
No tree contribution

- in principle as cleas as ϕK_S

BaBar and Belle already published first results.

BaBar analysis uses ~90 events reconstructing 3 $K_S \to \pi^+\pi^-$

Adding events with one $K_S \to \pi^0\pi^0$ it is possible to increase the signal yield by 50% (but more background)



Even Selection (I)

We start from **BksKsKs03a3body** skim:

- $|m_{ES}-m_B^{PDG}| < 0.1$ GeV
- $|\Delta E| < 0.45$ GeV
- $|\cos\theta_T|<0.95$
- Total Energy < 20 GeV
- ≥ 1 track in the Rest Of Event

We define a fit region in terms of four variables to be used in the likelihood:

- 5.1 GeV < m_{Miss} < 5.3 GeV
- 5.13 GeV < m_{Rec} < 5.43 GeV
- $l_2=L_2/L_0$ in [0,1]
- $|\Delta t| < 20$ ps && $\sigma(\Delta t) < 3.5$ ps

Even Selection (II)

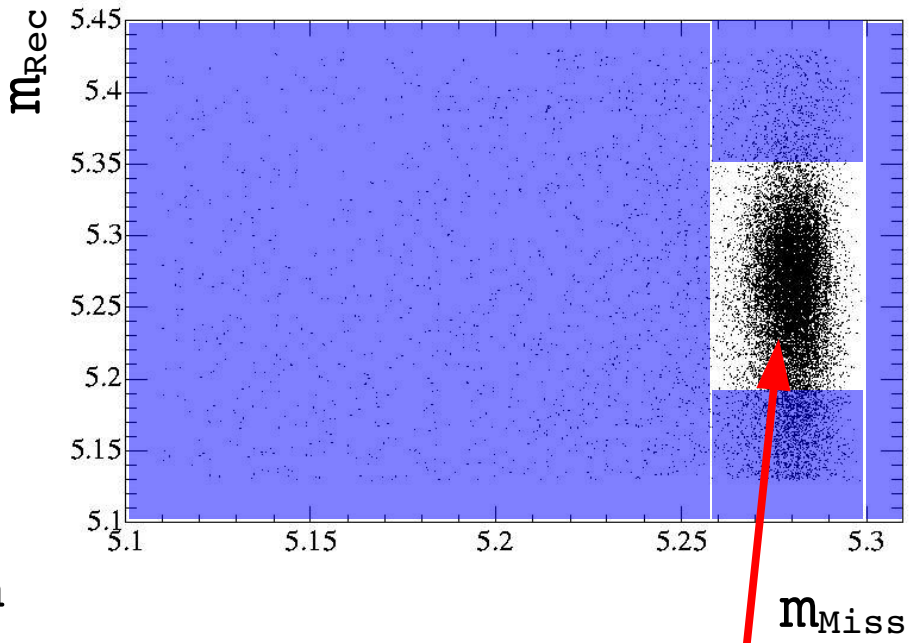
We optimize additional cuts to remove $\bar{q}q$ background

For $K_S \to \pi^0\pi^0$ selection

- LAT
- E_γ
- π^0 mass
- $K_S(\pi^0\pi^0)$ mass

For $K_S \to \pi^+\pi^-$

- $K_S(\pi^+\pi^-)$ mass
- K_S lifetime significance
- K_S transverse decay length



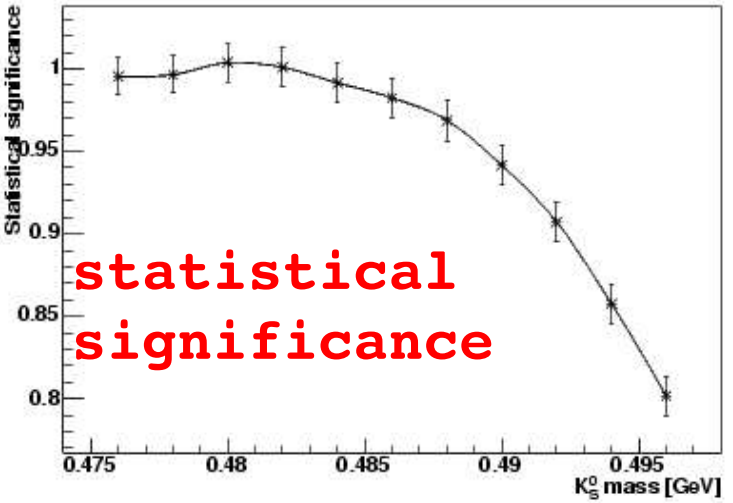
We optimize these cuts maximizing Ns/sqrt(Ns+Nb) simultaneously, estimating signal from Monte Carlo and background from on-resonance sidebands

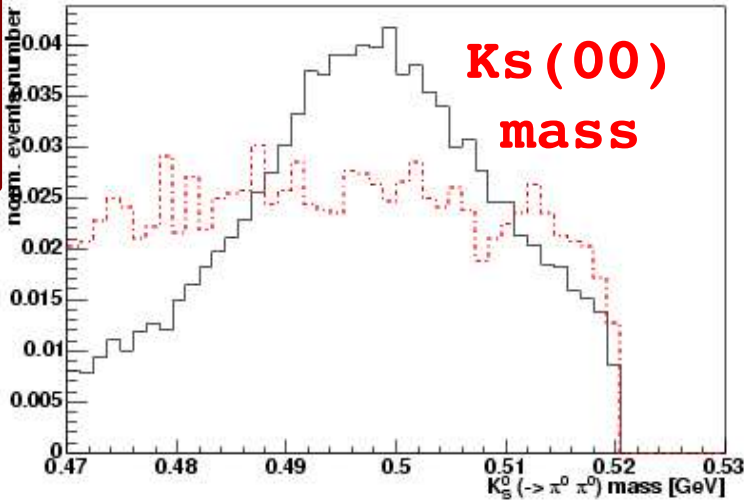
Optimal cuts & Efficiency

optimized cuts

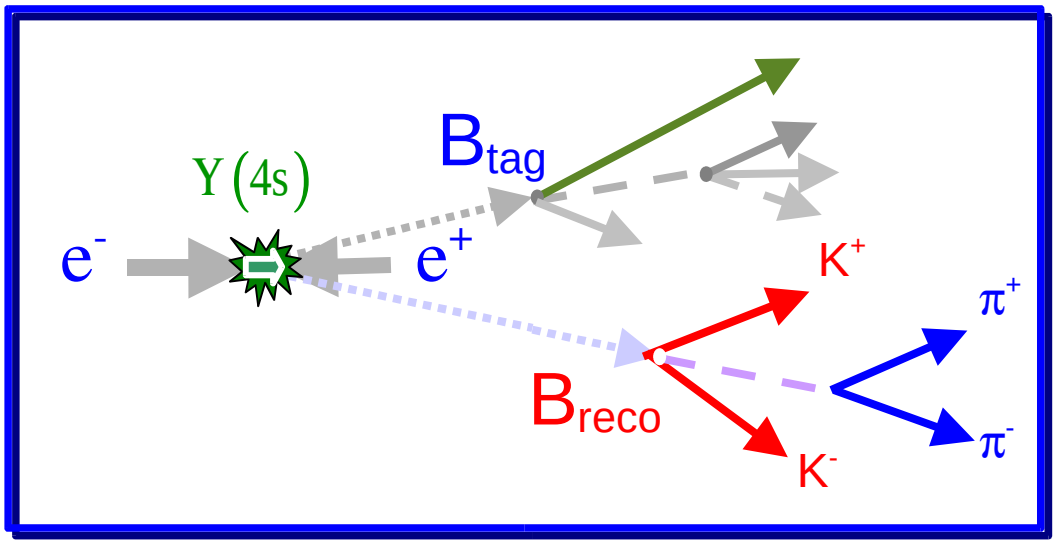
Selection	Efficiency(%)
pre-selection	10.513 ± 0.034
$\lvert m_{REC} - m_{B^0}^{PDG} \rvert < 150$ MeV	85.05 ± 0.12
$(5.11 < m_{MISS} < 5.31)$ GeV	99.491 ± 0.026
$LAT < 0.55$	91.65 ± 0.10
$(480 < m_{K^0_{S^{00}}} < 520)$ MeV	83.76 ± 0.14
$mass_{\pi_0} < 141 MeV$	89.81 ± 0.13
$\gamma energy > 50$ MeV	85.90 ± 0.16
$\lvert m_{K^0_{S^{+-}}} - m_{K^0_{S^{PDG}}} \rvert < 11 MeV$	89.16 ± 0.15
K^0_S life time significance > 5	89.99 ± 0.15
$(0.15 < K^0_S$ transverse decay length $< 60)$ cm	99.354 ± 0.043
$\chi^2(B^0) < 20$	92.88 ± 0.14
veto on χ^0_c and χ^2_c	83.78 ± 0.21
Total efficiency	3.268 ± 0.020

$\overline{BB}$ rejection cuts (next slides)





B vertexing and Δt shape(I)

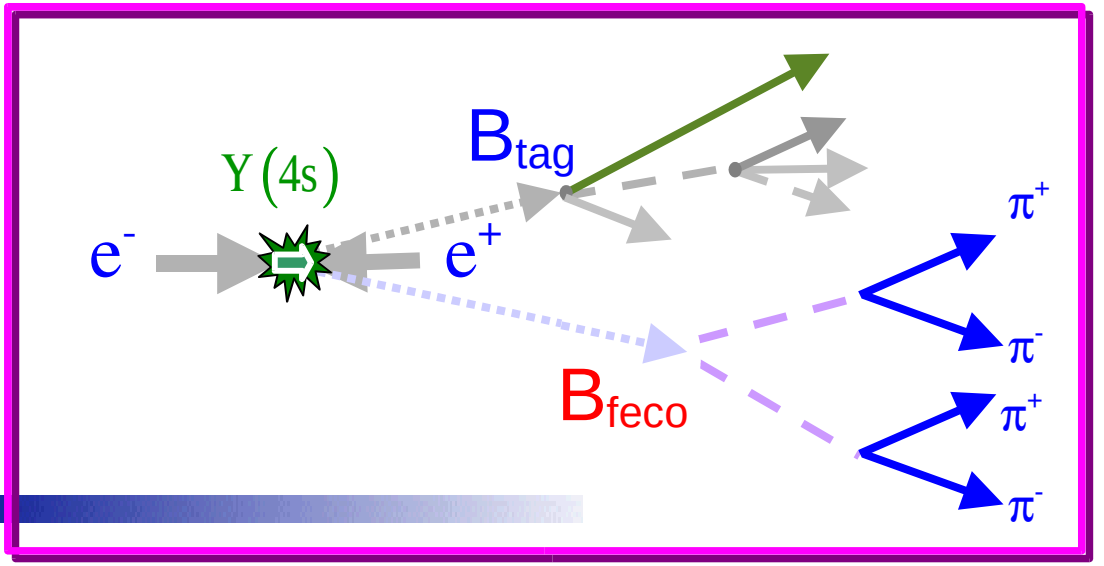


standard case: charged particles from primary vtx

direct determination of Δt

this case: charged particles from (secondary) K_S vertex

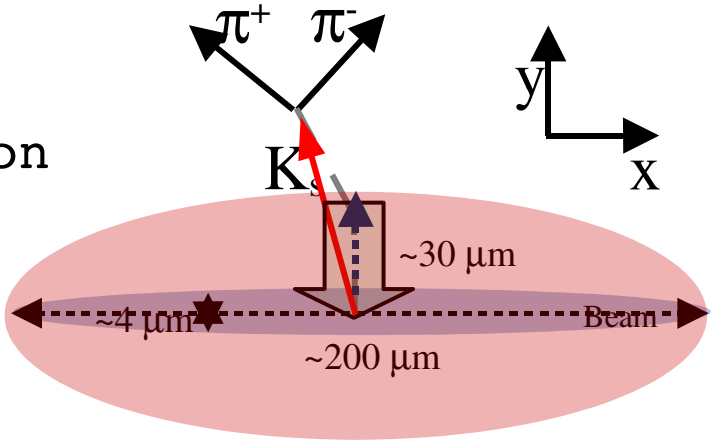
Beam Spot constrained vertex

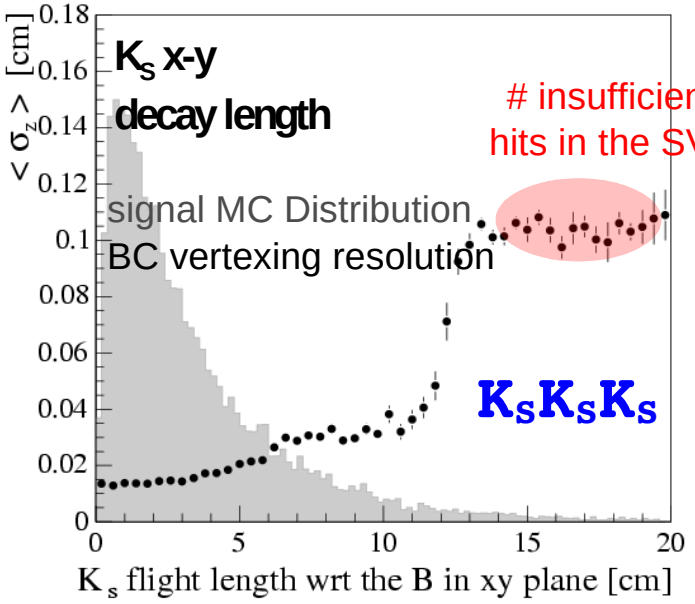


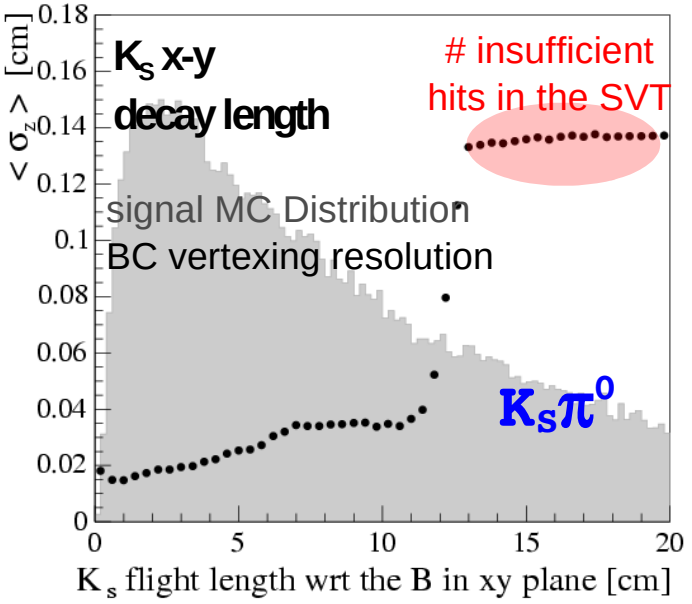
B vertexing and Δt shape(II)

We use the new (TreeFitter) based Beamspot Constrained Vertexing:

- we force the B to come from the beamspot in the transverse plain
- The intersection of the "new" K_S direction with the z axis gives the B decay vertex
- We fit the tag side (standard BaBar)
- We fit Y(4s) tree with a constraint on $\tau(B_{tag})+\tau(B_{reco}) = 2\tau(B^0)$
- We have $2K_S \rightarrow \pi^+\pi^-$. Δt better determined

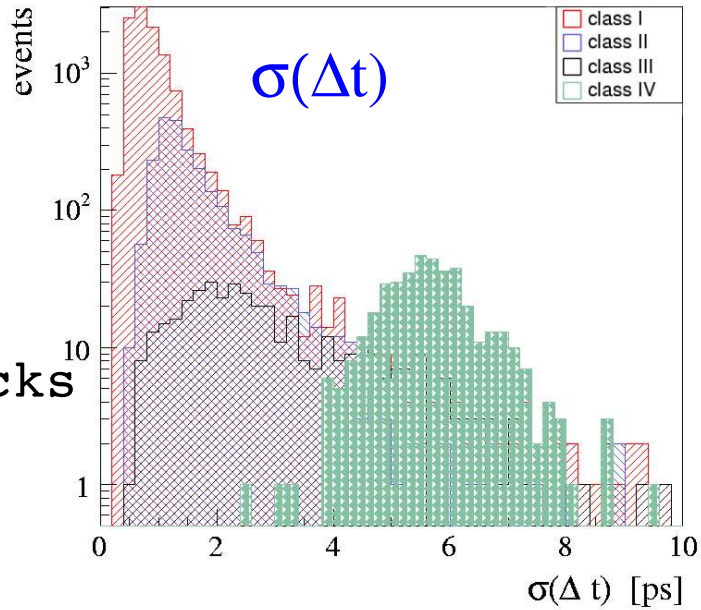






B vertexing and Δt shape(III)

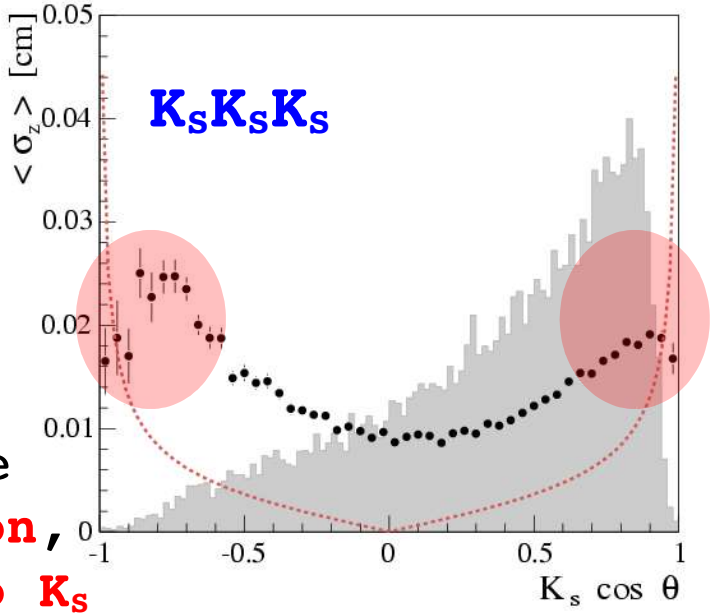
- We define 4 different classes of K_S
  - Class I : 1 z & 1 ϕ hit in layer 1-3
  - on both bions
  - Class II : others with 1 z & 1 ϕ hit
  - in SVT on both pions
  - Class III : only 1 SVT hit on both tracks
  - Class IV : no SVT hits
- The B is associated to the class of the best K_S
- We use Class I and II (all) events for S (C)

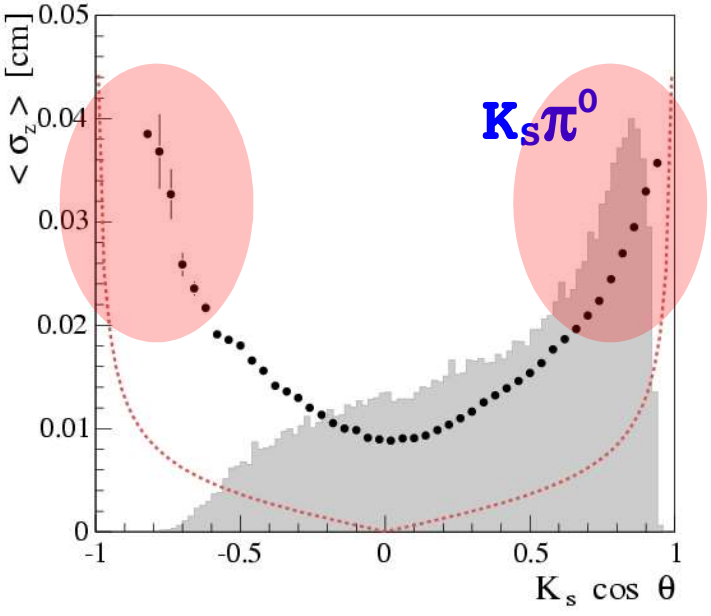


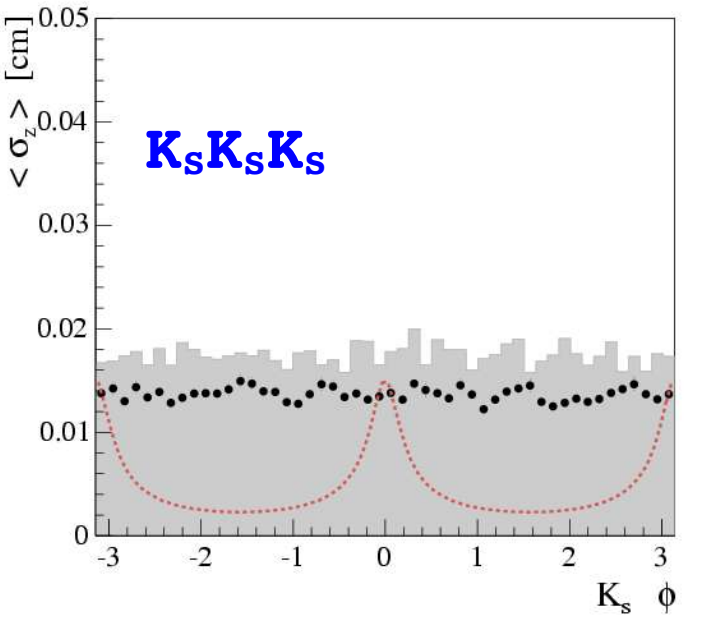
class	K_S^0	B^0
I	0.531 ± 0.002	0.791 ± 0.002
II	0.225 ± 0.002	0.156 ± 0.002
III	0.053 ± 0.001	0.023 ± 0.001
IV	0.190 ± 0.002	0.030 ± 0.001

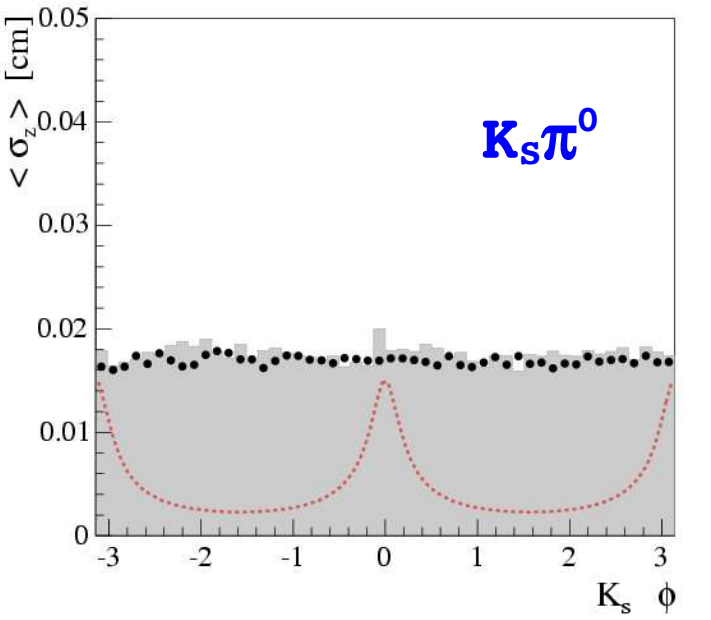
B vertexing and Δt shape(IV)

- We qualitativly reproduce $K_S\pi^0$ behavior
- We have in average **a better resolution**, because of the **two K_S**







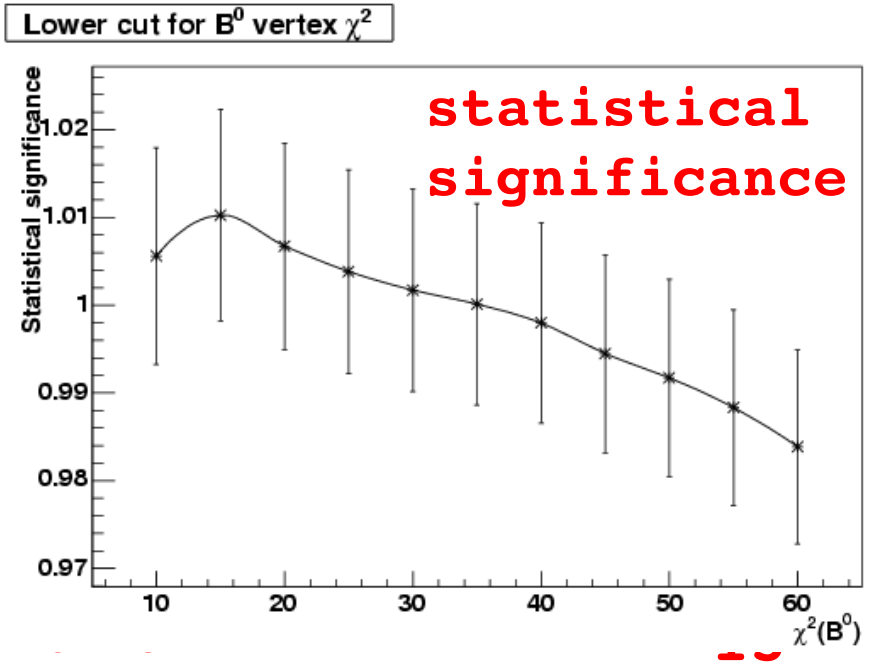


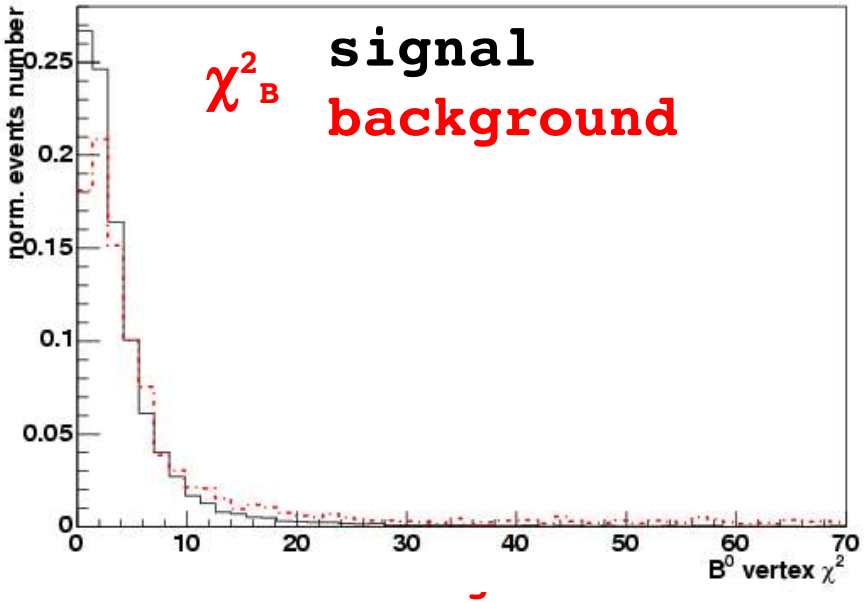
$\overline{BB}$ background(I)

All the charmless intermediate resonaces giving $3K_S$ final state are considered as signal

The $\overline{cc}$ resonances are considered background, since we are interested to $b \to s$ transitions

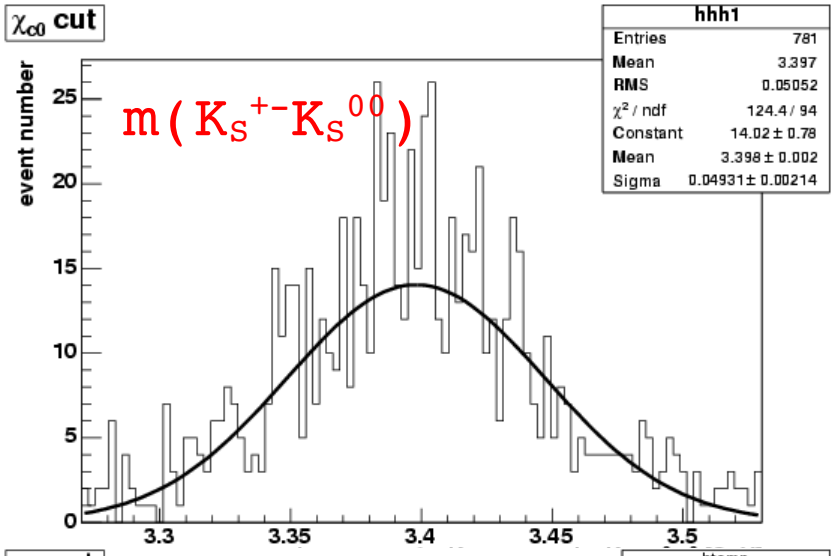
The largest part of $\overline{BB}$ background is combinatoric, having in general a bad vertex. We remove it cutting on B vtx χ^2

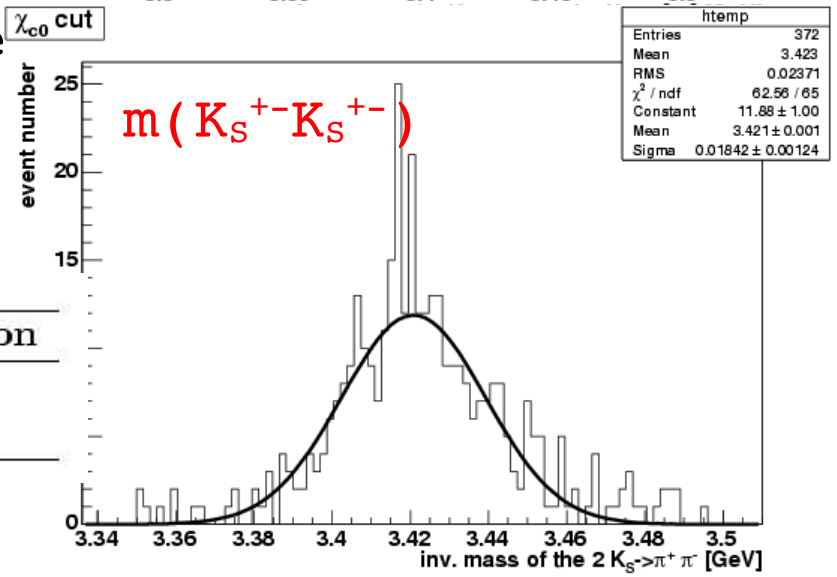




$\overline{BB}$ background(II)

- 2σ veto on $\chi_{c0}(K_SK_S)K_S$ mass:
  - $m(K_S^{+-}K_S^{00})<3.300$ GeV &&
  - $m(K_S^{+-}K_S^{00})>3.496$ GeV
  - $m(K_S^{+-}K_S^{+-})<3.385$ GeV &&
  - $m(K_S^{+-}K_S^{00})>3.475$ GeV





- Peacking background is negligible
- We add to the fit a non peacking $\overline{BB}$ component

Background kind	Events in fit region	Events in signal region
not peaking	208 ± 14 (51.4 ± 3.5)	23 ± 4.8 (5.7 ± 1.2)
peaking	21 ± 4.5 (5.2 ± 1.1)	5 ± 2.2 (1.2 ± 0.6)

from a sample of 850fb^{-1} generic $\overline{BB}$ Monte Carlo

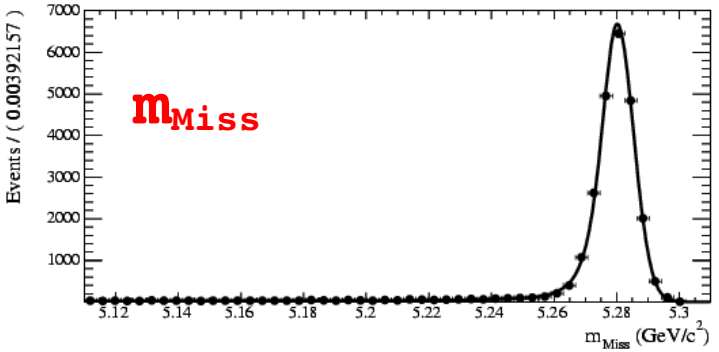
Maximum Likelihood fit

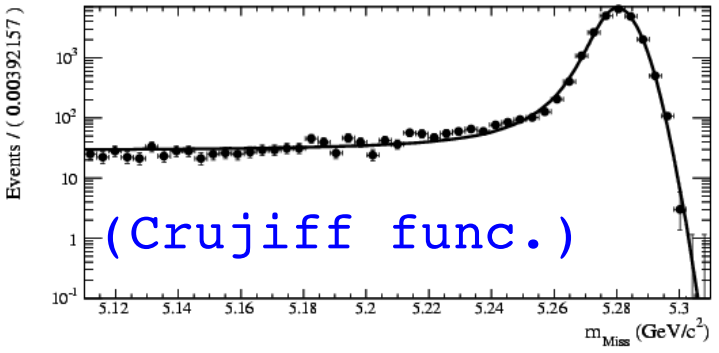
Likelihood for good events
(to fit for yield, S and C)

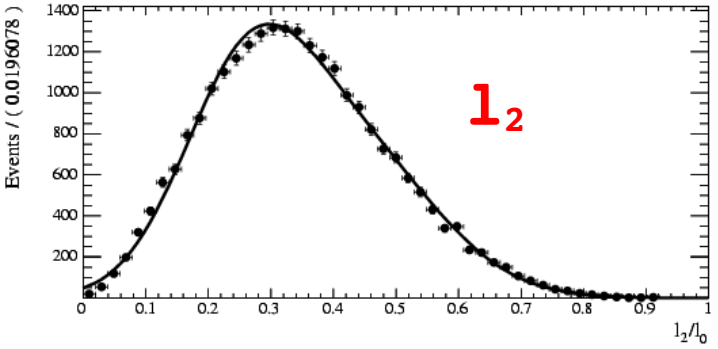
$$L = \frac{e^{-(N_S+N_B)}}{(N_S+N_B)!} \prod_{i\in\text{good}}^{N_{\text{good}}} \{ N_S f^S_{\text{good}} \epsilon^S_{c_i} \cdot P_S(m_{REC,i}) P_S(m_{MISS,i}) P^c_S(l_{2i}) P^c_S(\delta t_i, T|\sigma_{\delta t_i}) +$$
$$N_B f^B_{\text{good}} \epsilon^B_{c_i} \cdot P_B(m_{REC,i}) P_B(m_{MISS,i}) P_B(l_{2i}) P^c_B(\delta t_i, T|\sigma_{\delta t_i}) +$$
$$N_{BB} f^{BB}_{\text{good}} \epsilon^{BB}_{c_i} \cdot P_{BB}(m_{REC,i}) P_{BB}(m_{MISS,i}) P^c_{BB}(l_{2i}) P^c_{BB}(\delta t_i, T|\sigma_{\delta t_i}) \} +$$
$$\prod_{i\in\text{bad}}^{N_{\text{bad}}} \{ N_S(1-f^S_{\text{good}}) \epsilon^S_{c_i} \cdot P_S(m_{REC,i}) P_S(m_{MISS,i}) P_S(l_{2i}) P^c_S(T) +$$
$$N_B(1-f^B_{\text{good}}) \epsilon^B_{c_i} \cdot P_B(m_{REC,i}) P_B(m_{MISS,i}) P_B(l_{2i}) +$$

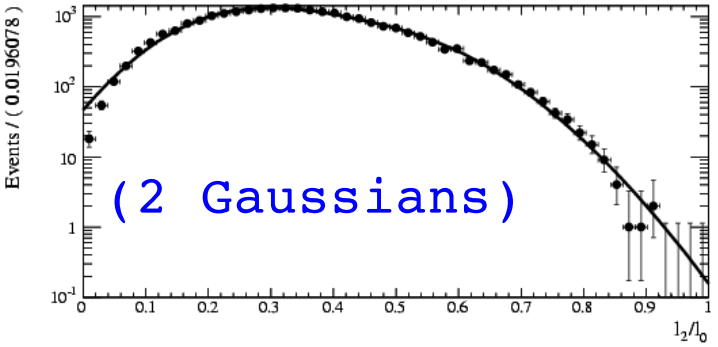
Likelihood for bad events
(to fit for yield and C)

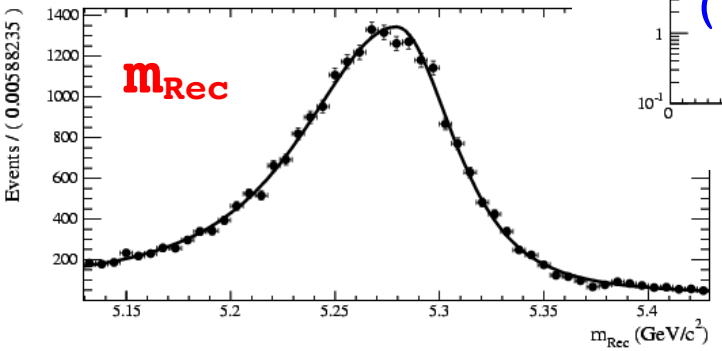
Signal parameterizations

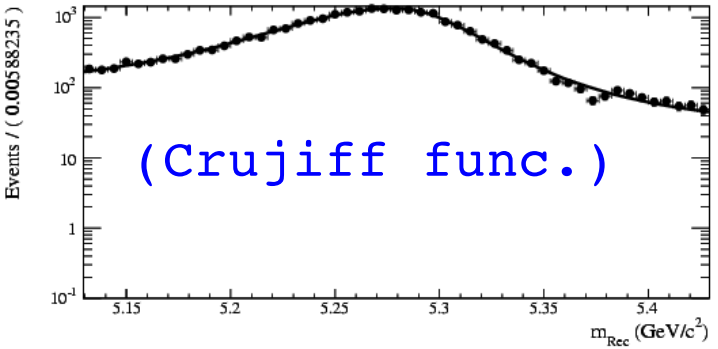




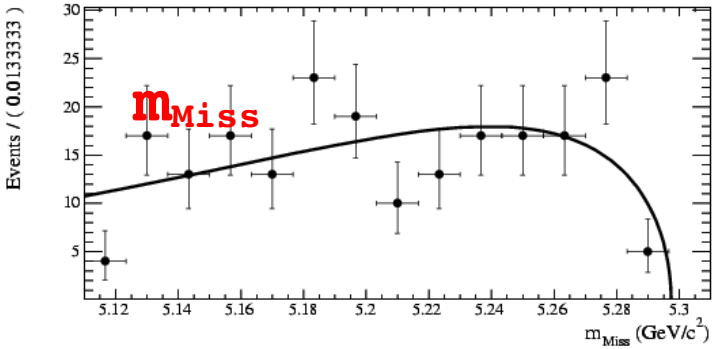


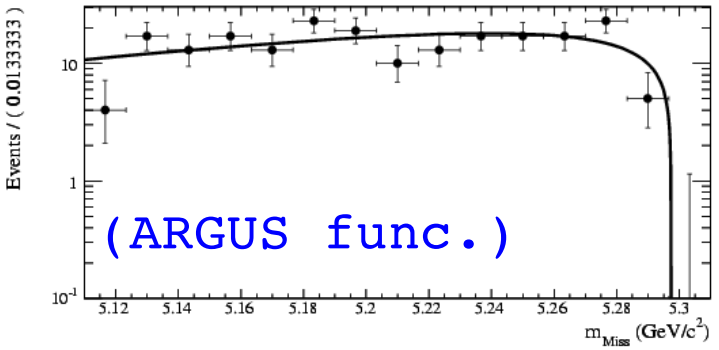


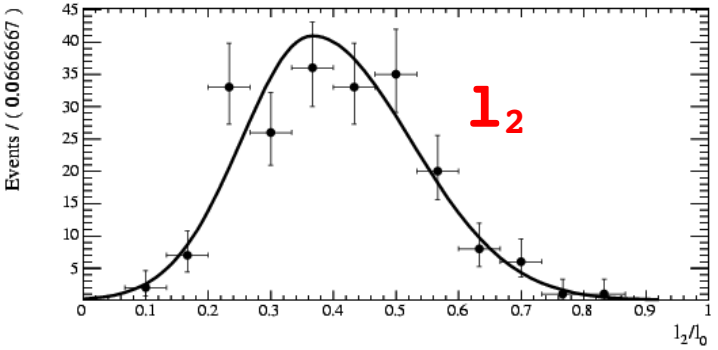


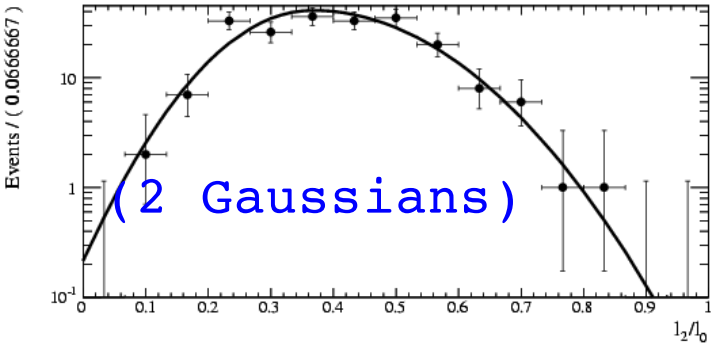


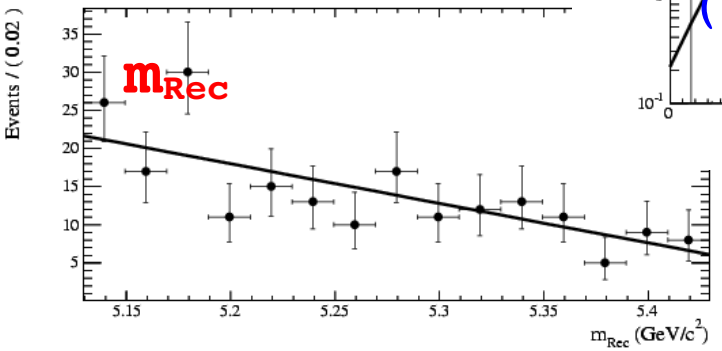
$\overline{B}B$ Bkg. parameterizations

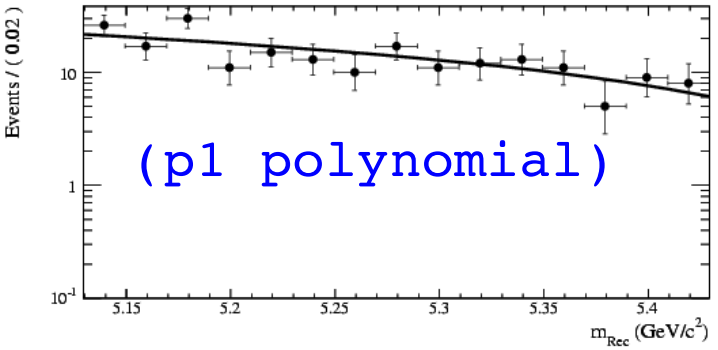




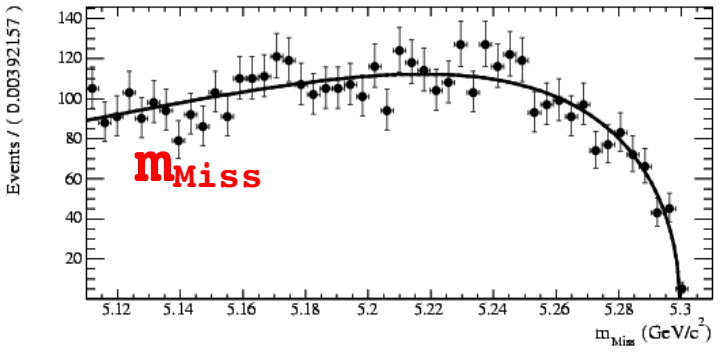


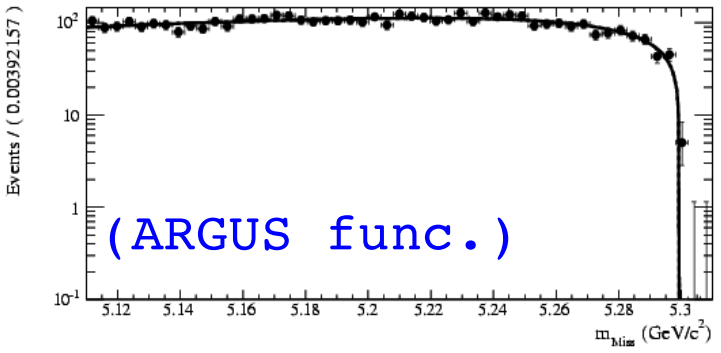


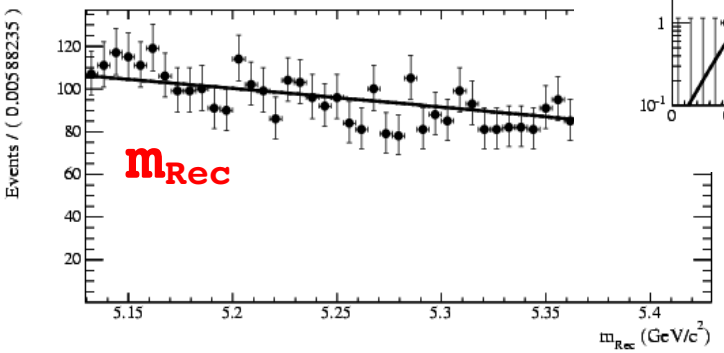


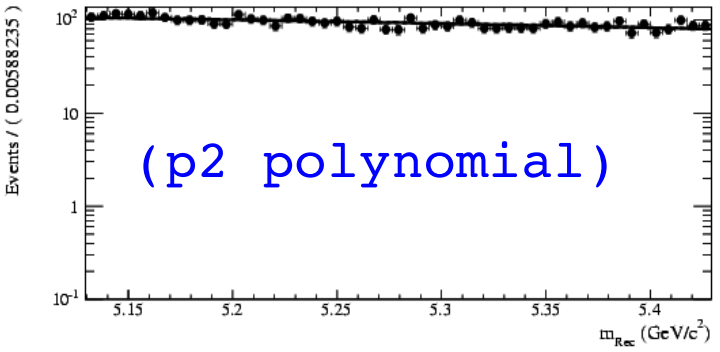


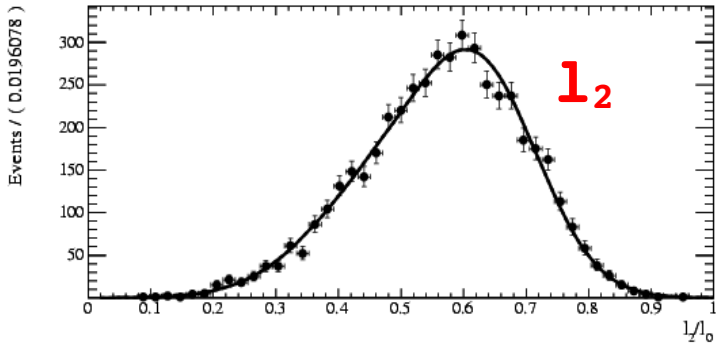
$\bar{q}q$ Bkg. parameterizations

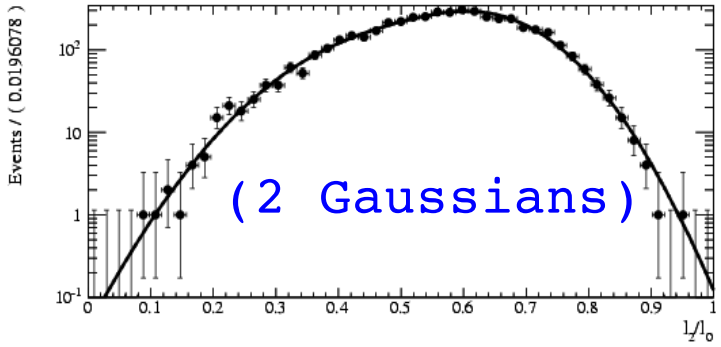






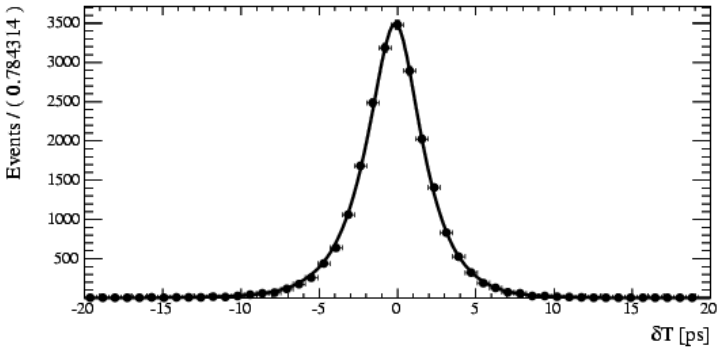


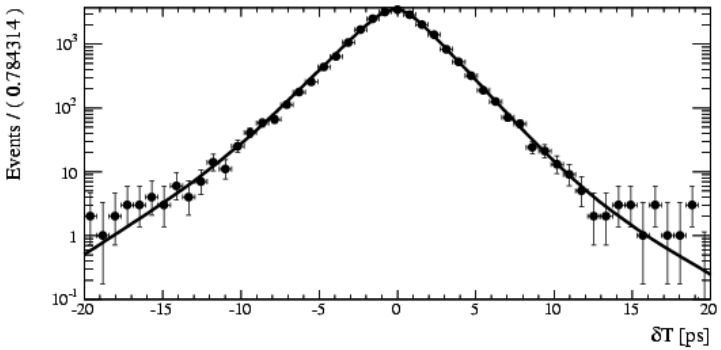




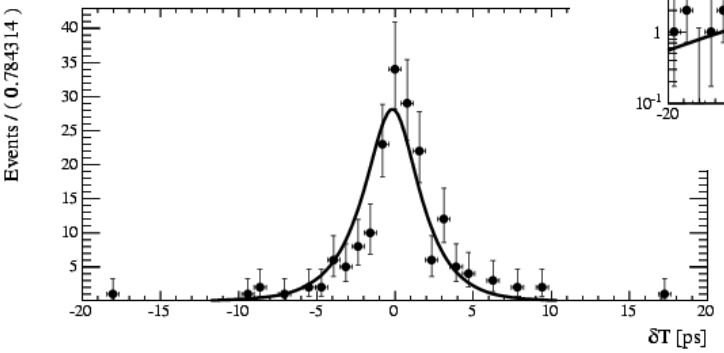
All parameters are floated in the nominal fit

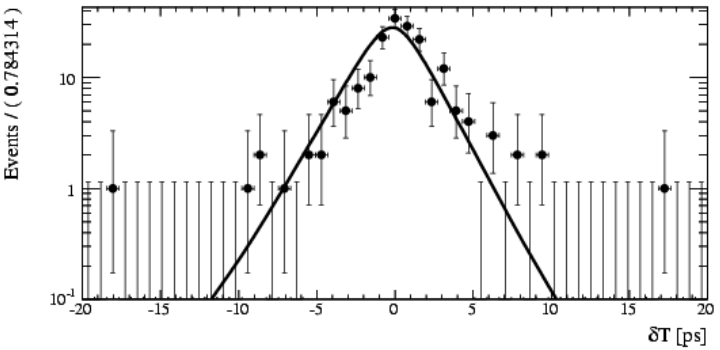
Resolution Function

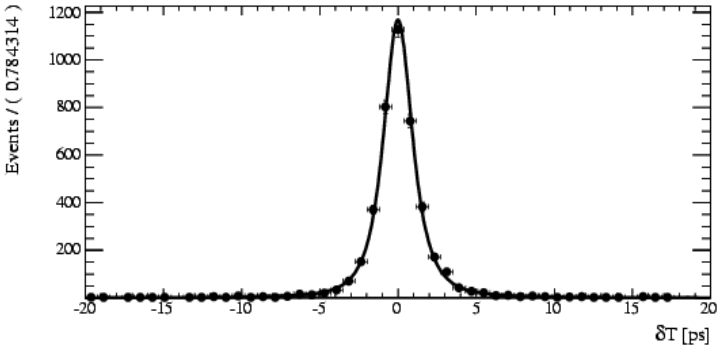


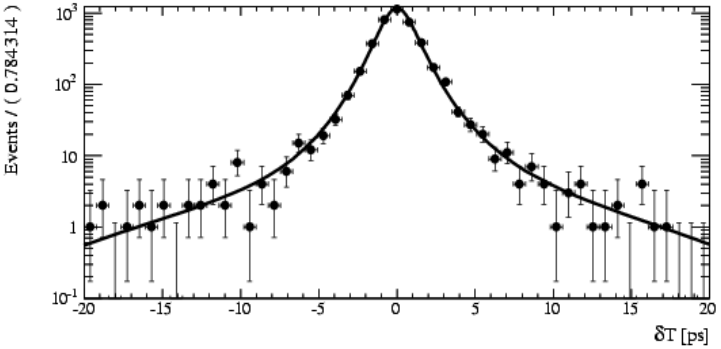


Breco parameters for signal and $\overline{BB}$ bkg









3 Gaussians for $\overline{qq}$ bkg

Validation(I)

LABORATOIRE DE L'ACCÉLÉRATEUR L I

Fit on control samples OK

	N_{sig}	N_{bkg}	N_{bb}	S	C
signal MC ($S=0$ $C=0$)	23970 ± 159	$37.21^{+21.2}_{-18.8}$	763.94 ± 48.7	-0.002 ± 0.026	-0.025 ± 0.016
signal MC ($S=-0.7$ $C=0$)	19021 ± 141	$22.43^{+19.4}_{-17.4}$	589.3 ± 43.1	-0.713 ± 0.027	-0.012 ± 0.018
continuum background MC	$29.7^{+22.0}_{-19.5}$	5092.6 ± 73.5	$-33.6^{+19.2}_{-13.7}$	-13 ± 12	–
$B\ \bar{B}$ background MC	$11.84^{+5.41}_{-4.57}$	$7.33^{+10.8}_{-9.63}$	$188.84^{+17.8}_{-17.1}$	–	–

Toys and Mock fits give problems with pulls on S and C

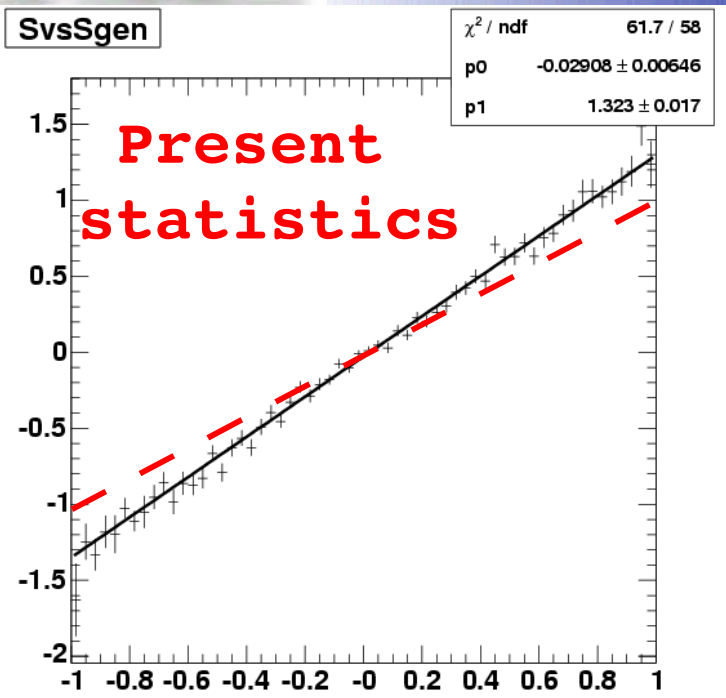
	μ_{Pull}	σ_{Pull}	Average error
$N_{K^0_S K^0_S K^0_S}$	-0.048 ± 0.021	1.02 ± 0.02	10.2
$N_{q\bar{q}}$	0.058 ± 0.021	1.01 ± 0.02	56.5
$N_{B\bar{B}}$	-0.1825	1.051 ± 0.018	23.9
C	0.008 ± 0.022	1.089 ± 0.017	0.48
S	-0.142 ± 0.025	1.173 ± 0.019	0.81

The size of the bias depends on the distance from physical boundary

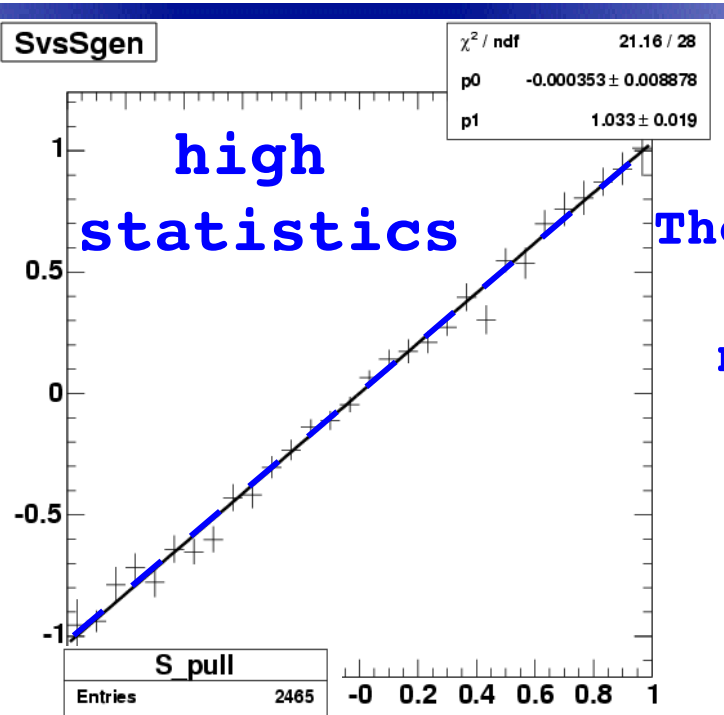
S=-0.7 C=0

	μ_{Pull}	σ_{Pull}	Average error
$N_{K^0_S K^0_S K^0_S}$	0.015 ± 0.021	0.991 ± 0.016	10.21
$N_{q\bar{q}}$	0.003 ± 0.021	1.012 ± 0.015	56.56
$N_{B\bar{B}}$	-0.1733	1.062 ± 0.019	24.01
C	0.003 ± 0.023	1.098 ± 0.019	0.481
S	-0.000 ± 0.023	1.114 ± 0.019	0.799

Validation(II)

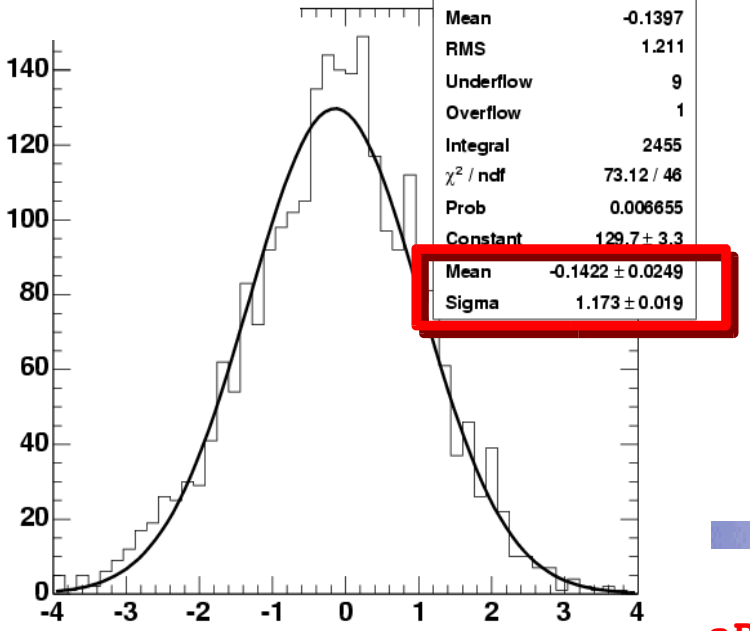


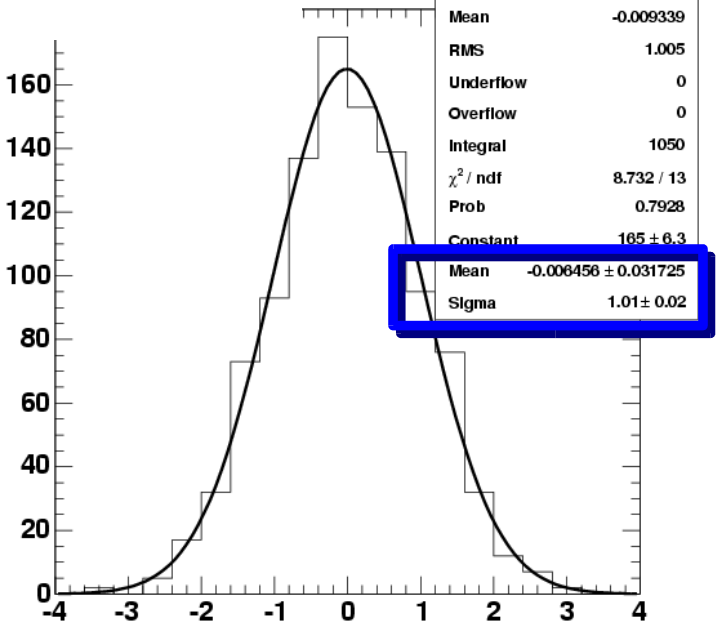
Present statistics



high statistics

The effect will disappear merging to 3Ks(+-) analysis





The maximum of the likelihood is not always an unbiased estimator We can correct for it after the unblinding

aBa

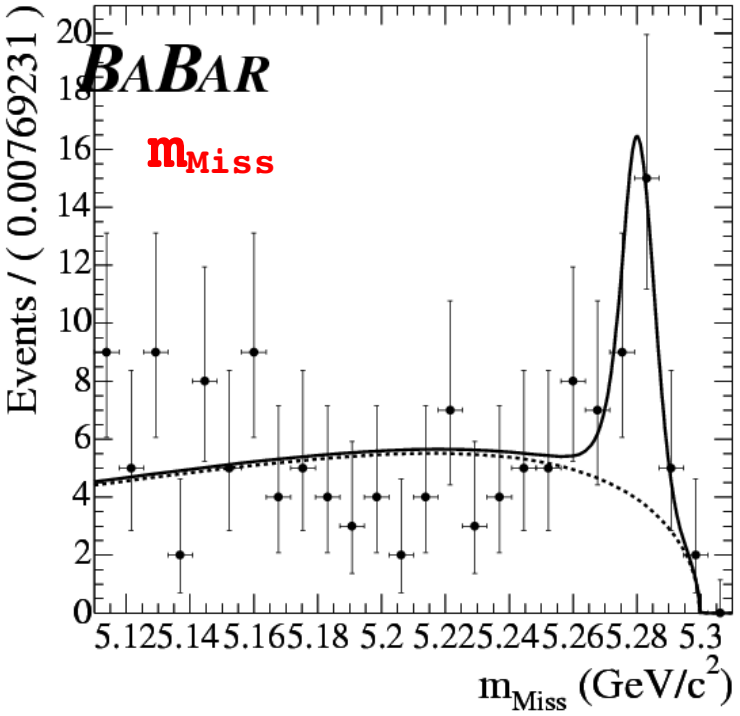
Blind Fit on data

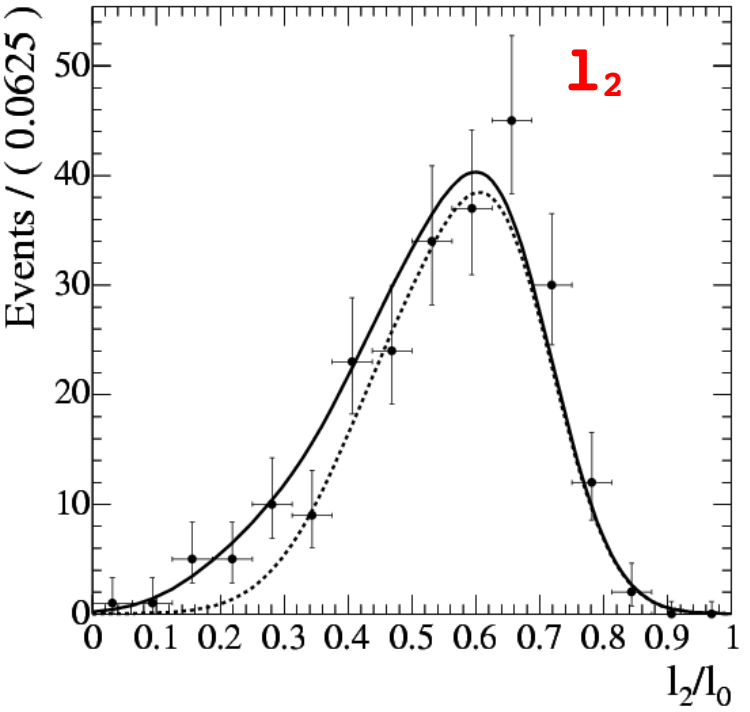
LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

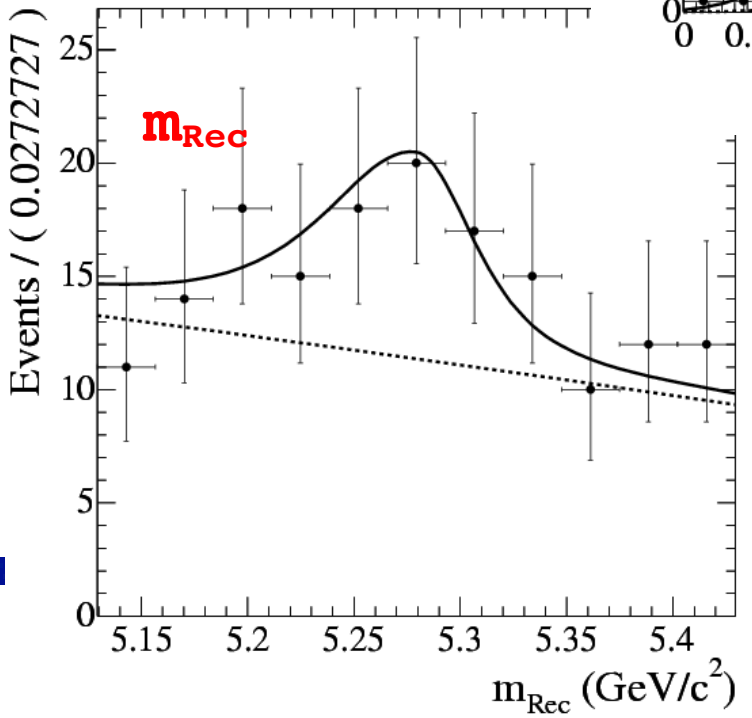
N = 45 ± 9

S = XXX $^{+0.72}_{-0.63}$

C = YYY $^{+0.39}_{-0.44}$







To do list

Waiting to meet the reviewers, we have to

- Finish few studies asked by AWG reviewer (S.Wagner)
- Complete a study of J/ψ $K_S(00)$ to do data/MC comparison
- Complete systematics (the largest part is done)
- Fix few plots on the BAD