Radiative decays of beauty hadrons at LHCb

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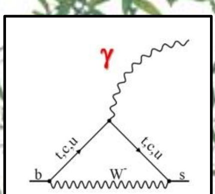
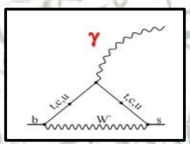


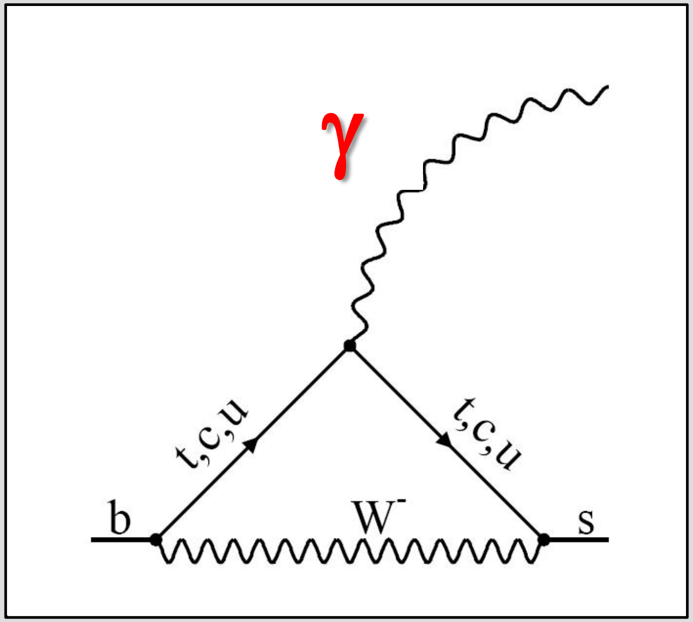
Outline

- (Exclusive) radiative penguin decays of beauty hadrons
  - Why they are interesting?
    - "The standard candle…"
- LHC collider and LHCb experiment
- Selected measurements with the radiative decays at LHCb:
  - Measurement of photon polarization in $b\to s\gamma$ transitions:
    - Time dependent *CP*-asymmetry in $B_s\to\phi\gamma$
    - Angular correlations in decays of polarized baryons $\Lambda_b\to\Lambda\gamma$
    - Dalitz-analysis of $B^{\pm}\to\phi K^{\pm}\gamma$
  - Direct *CP*-asymmetry in $B^0\to K^{*0}\gamma$
  - Extra rare decays: $b\to d\gamma$ transitions
  - …
- Summary

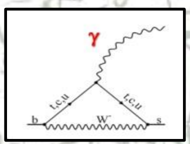


Radiative decays

- Radiative decays in Standard Model occurs through "penguin" diagram:

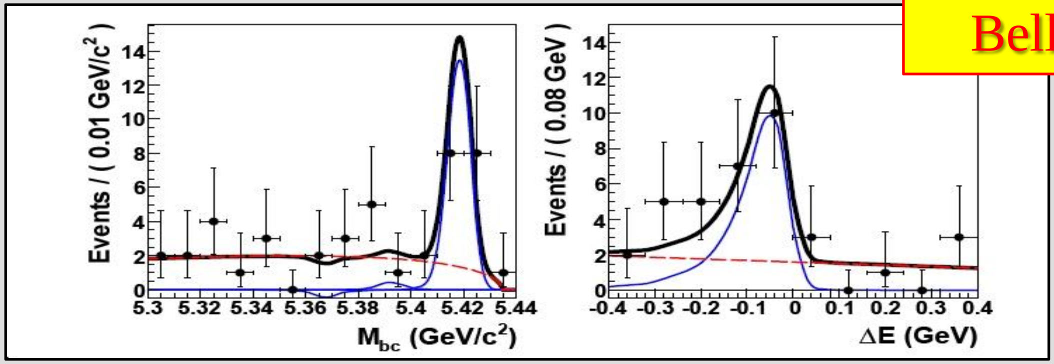


- The simple example of *Flavor Changing Neutral Current* FCNC
  - Absent on the tree level
  - Appears in the loop : "*rare decay*"

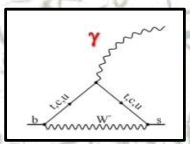


"Loop" decays

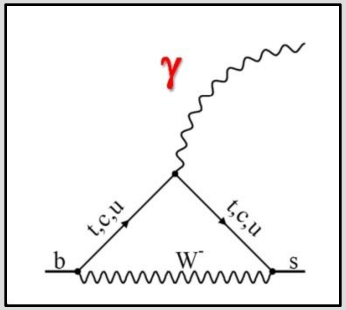
- Actually they are not so rare:
  - *Br* ($B^0 \to K^{*0} \gamma$) = $(40.1 \pm 2.0)\ 10^{-6}$ PDG'08
- First measured by CLEO'93, and later studies in great details by BaBaR and Belle
- Recently also the radiative decays of B_s
  - *Br* ($B_s \to \phi\gamma$) = $(57^{+18}_{-12}{}^{+12}_{-11})\ 10^{-6}$ Belle'08



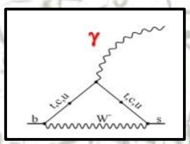
Belle: *O*(1 $B_s \to \phi\gamma$)/day at Υ(5S)



Why penguins are attractive?



- Very clear picture in standard model
  - 1-diagram dominance
  - Reliable theoretical description at (N)NLO allows the numerically precise predictions
    - the prerequisite for addressing NP
- "*Loop*":
  - New Physics contribution can be comparable and even dominating to (small) SM amplitudes
  - NP appears not only in modifications of Br, but also in asymmetries and the angular effects
    - "*Sensitive also to spin structure of NP*"



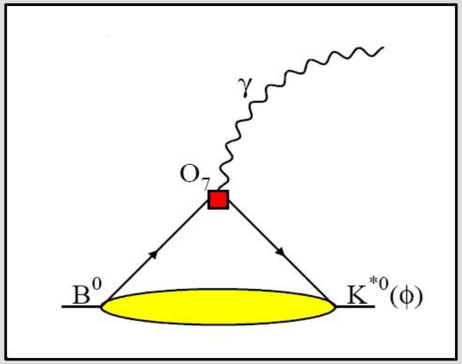
ΔB=1 effective Hamiltonian

$$\mathcal{H}_{\mathrm{eff}} = \frac{\mathrm{G_F}}{\sqrt{2}} \sum_{\mathrm{p=u,c}} \lambda_{\mathrm{p}}^{(\mathrm{q})} \left(\mathcal{C}_1(\mu)\mathcal{Q}_1^{\mathrm{p}}(\mu) + \mathcal{C}_2(\mu)\mathcal{Q}_2^{\mathrm{p}}(\mu) + \sum_{\mathrm{i=3}}^{8} \mathcal{C}_{\mathrm{i}}(\mu)\mathcal{Q}_{\mathrm{i}}(\mu) \right),$$

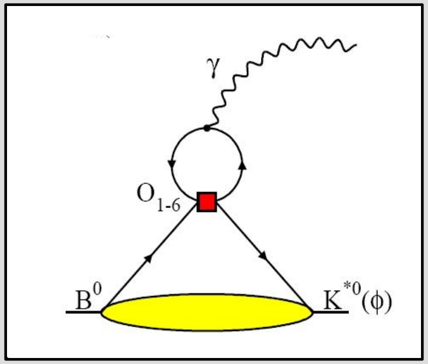
- **At LO:**

  $C_7^{eff} = C_7 + \ldots$

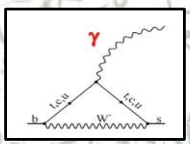
$$\mathcal{Q}_7 = -\frac{e^2}{8\pi^2}\bar{\mathrm{m}}_{\mathrm{b}}(\mu)\bar{\mathrm{q}}\sigma^{\mu\nu}(1+\gamma_5)\mathrm{b}\ \mathrm{F}_{\mu\nu}$$



+

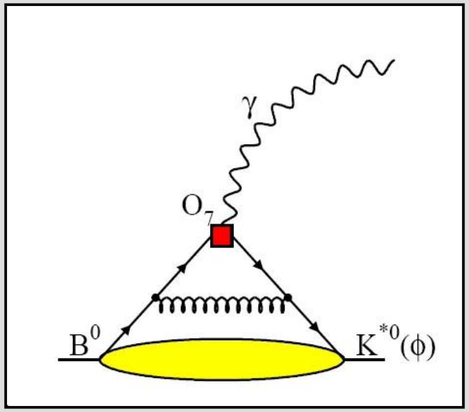


+ ...

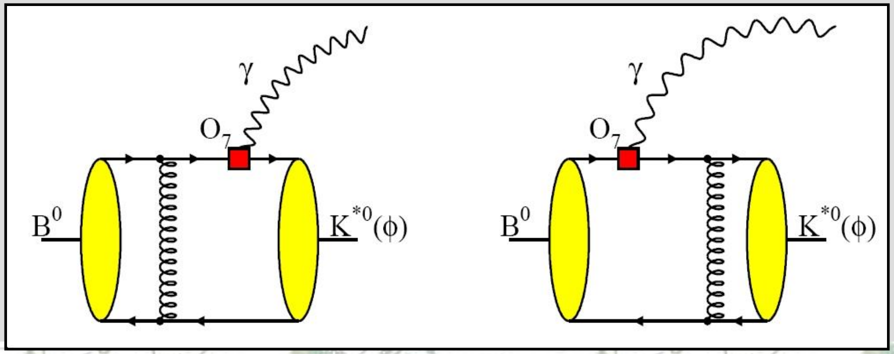


… at next order

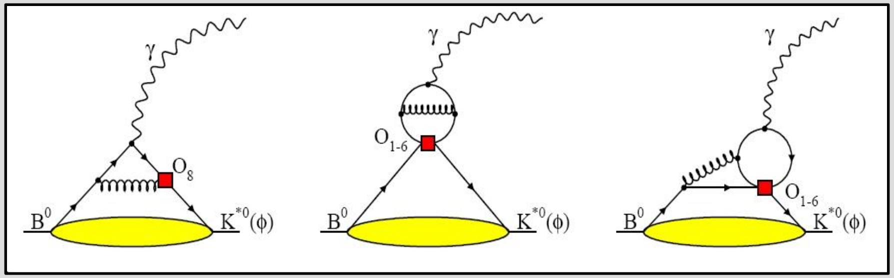
- + factorizable vertex graph



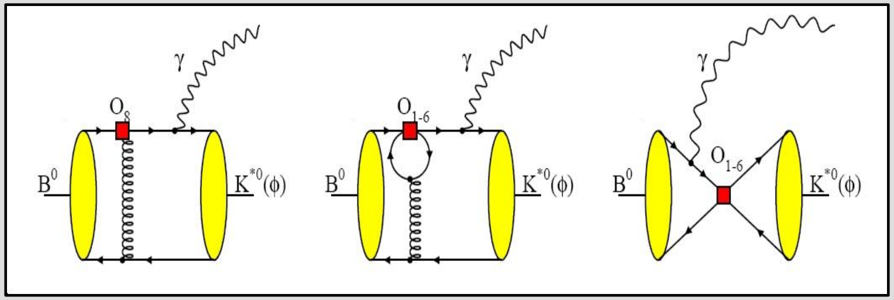
- + non-spectator



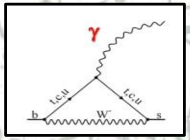
- Non-factorizable vertex:



- Non-spectator +…



… + annihilation



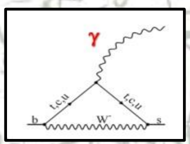
Notes:

- 1-amplitude dominance
- Strong phase appears only in NLO
- Direct *CP*-asymmetries are small
  - (<1%) for $b\to s\gamma$ & $\mathcal{O}$(10%) for $b\to d\gamma$
- *Isotopic asymmetries* due for non-spectator&annihilation $\sim (C_3+C_5/N_C)$ and suppressed by $1/m_b$ and CKM-factors

$\mathcal{O}$(5-12%)

$$\mathbb{A}^{\mathbb{I}}_{B\to K^*\gamma} = \frac{\Gamma_{B^0_d\to K^{*0}\gamma} - \Gamma_{B^-\to K^{*-}\gamma}}{\Gamma_{B^0_d\to K^{*0}\gamma} + \Gamma_{B^-\to K^{*-}\gamma}}$$

- Q7 produces ***left-polarized*** photons
  - $A_R/A_L \sim m_s/m_b$
  - Mixing CP-asymmetries are vanished
    - $B\to f^{CP}\gamma$ is not *CP* eigenstate!



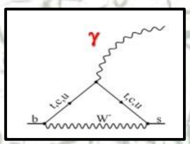
"Mixing asymmetries are vanished, but…"

- $B \to f^{CP}\gamma$ is not *CP* eigenstate! $\gamma_R/\gamma_L \approx m_s/m_b$
- Take it into account:

$$\Gamma(\mathrm{B}_q(\bar{\mathrm{B}}_q) \to f^{CP}\gamma) \propto e^{-\Gamma_q t}\left(\cosh\frac{\Delta\Gamma_q t}{2} - \mathcal{A}^{\Delta}\sinh\frac{\Delta\Gamma_q t}{2} \pm \pm\mathcal{C}\cos\Delta m_q t \mp \mathcal{S}\sin\Delta m_q t\right)$$

- ***SM:***
  - *C* = 0 direct *CP*-violation
  - *S* = sin2ψ sinϕ
  - *A*$^{\Delta}$ = sin2ψ cosϕ

$$\tan\psi \equiv \left|\frac{A(\bar{\mathrm{B}}\to f^{CP}\gamma_R)}{A(\bar{\mathrm{B}}\to f^{CP}\gamma_L)}\right|$$



B^0 vs B_s: $\Delta\Gamma = 0$ vs $\Delta\Gamma_s/\Gamma_s \sim O(10\%)$

- B^0 : $\Delta\Gamma \approx 0$
- B_s: $\Delta\Gamma_s/\Gamma_s \sim O(10\%)$

$C = 0$

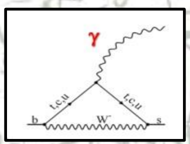
$S = \sin 2\psi \ \sin\phi$

$A^{\Delta} = \sin 2\psi \cos\phi$

- No sensitivity to A^{Δ}
- $\phi = 2\beta - \phi^{peng} \approx 2\beta$
- $\sin 2\psi = S / \sin 2\beta$

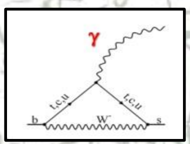
- Sensitive to A^{Δ}
- $\phi = 2\beta_s - \phi^{peng} \approx 0$
  - $S = 0$, double smallness
- $\sin 2\psi = A^{\Delta}$

F.Muheim, Y.Xie & R.Zwicky, **Phys.Lett.B664:174-179,2008**



Photon polarization in SM

- In SM, the admixture of "right"-photon is "*very small*" $\sim m_s/m_b$
- *However the gluon emission* could affect the pattern:
  - $\approx$10%
    - B. Grinstein, Y. Grossman, Z. Ligeti and D. Pirjol, Phys. Rev. D **71**,011504 (2005)
    - B. Grinstein and D. Pirjol, Phys. Rev. D **73, 014013 (2006)**
  - Hard gluon emission, **pQCD** $\leq$ 3-4%
    - M. Matsumori and A.I. Sanda, Phys. Rev. D **73, 114022 (2006)**
  - Non-pertubative, slow gluon emission, c-loop + O_2, annihilation, etc... lightcone sum rules $\sim\mathcal{O}(1\%)$
    - P. Ball and R. Zwicky, Phys. Lett. B **642, 478 (2006)**



Photon polarization outside SM

- Sensitive to the spin structure & couplings of new particles
- Left-Right supersymmetry
  - minimal uSUSI
  - Enhancement: m_q/m_b

$$-1 \le \lambda_\gamma \le 1$$

L. Everett, G.L. Kane, S. Rigolin, L.-T. Wang and T.T. Wang, *JHEP* **0201, 022 (2002)**

- Anomalos top-coupling:

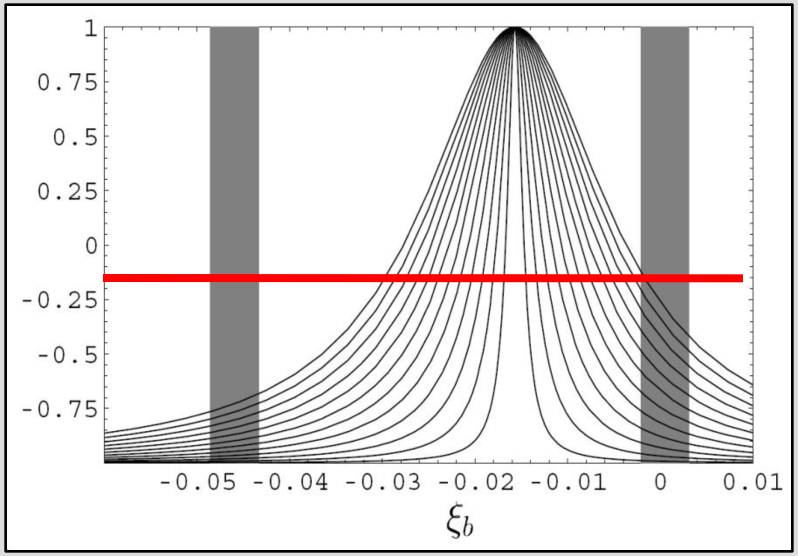
$$-1 \le \lambda_\gamma \le -0.12$$

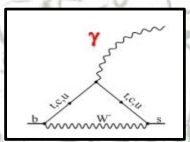
J.-P. Lee, *Phys. Rev. D* **69, 014017 (2004)**.

$$\lambda_\gamma = \frac{|\mathcal{A}_R|^2 - |\mathcal{A}_L|^2}{|\mathcal{A}_R|^2 + |\mathcal{A}_L|^2}$$

λ_γ (SM) = −1

$\lambda_\gamma = \cos 2\psi$



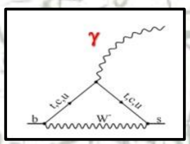


How to measure $\sin 2\psi/\lambda_\gamma$?

- Time-dependent CP-asymmetry for B^0/B_s mesons
- Angular correlations (Dalitz-analysis)

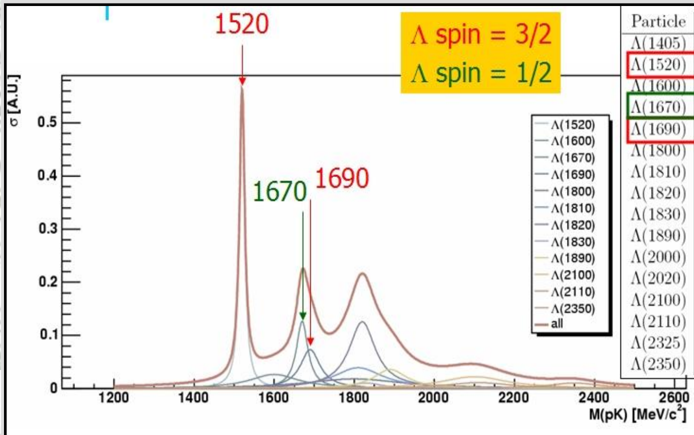
$$\frac{d\Gamma(B \to \Phi\gamma)}{d\Omega} \propto \left(|\mathcal{A}_R|^2 + |\mathcal{A}_L|^2\right) + \lambda_\gamma \left(|\mathcal{A}_R|^2 - |\mathcal{A}_L|^2\right),$$

  - $B \to K\pi\pi\gamma$: many amplitudes, difficult analysis
    - M. Gronau, Y. Grossman, D. Pirjol and A. Ryd, Phys. Rev. Lett. **88, 051802 (2002)**
    - M. Gronau and D. Pirjol, Phys. Rev. D **66, 054008 (2002)**
  - $B^\pm \to \phi K^\pm \gamma$
    - V.D. Orlovsky and V.I. Shevchenko, *Phys. Rev. D 77, 093003 (2008)*
- Polarized b-baryon decays
  - **Mannel, Recksiegel, JPG: NPP 24, 979 (1998)**
  - **Hiller, Kagan, PRD 65, 074038 (2002)**
- Study for converted photons and $B \to V l^+ l^-$ in the limit of $m(l^+ l^-) \to 0$
  - **Melikov, Nikitin, Simula, PLB 442, 381 (1998)**
  - **Grossman, Pirjol, JHEP06, 029 (2000)**



$\Lambda_b \to \Lambda^0\gamma$ $\Lambda_b \to \Lambda(X)\gamma$

- **Baryons are polarized**
  - Polarization can be measured via $\Lambda_b \to J/\psi\Lambda^0$
- exploit the angular correlations between initial and final state
- one can apply to higher resonances $\Lambda(X) \to pK$
  - spin 5/2 is useless (lack of observables)
  - spin ½ need to be separated from 3/2
    - The measurement both photon and proton distributions are required



Particle	$L_{I\cdot 2J}$	Γ [MeV]	NK
$\Lambda(1405)$	S_{01}	50	-
$\Lambda(1520)$	D_{03}	15.6	45%
$\Lambda(1600)$	P_{01}	≈ 150	15–30%
$\Lambda(1670)$	S_{01}	≈ 35	20–30%
$\Lambda(1690)$	D_{03}	≈ 60	20–30%
$\Lambda(1800)$	S_{01}	≈ 300	25–40%
$\Lambda(1810)$	P_{01}	≈ 150	20–50%
$\Lambda(1820)$	F_{05}	≈ 80	55–65%
$\Lambda(1830)$	D_{05}	≈ 95	3–10%
$\Lambda(1890)$	P_{03}	≈ 100	20–35%
$\Lambda(2000)$	???	???	???
$\Lambda(2020)$	F_{07}	???	???
$\Lambda(2100)$	G_{07}	≈ 200	25–35%
$\Lambda(2110)$	F_{05}	≈ 200	5–25%
$\Lambda(2325)$	D_{03}	≈ 170	???
$\Lambda(2350)$	H_{09}	≈ 150	$\sim$ 12%

- $\Lambda_b \to \Lambda^0\,\gamma$

$$\frac{d\Gamma}{d\cos\theta_\gamma} \propto 1 - \alpha_\gamma P_B \cos\theta_\gamma$$

$$\frac{d\Gamma}{d\cos\theta_p} \propto 1 - \alpha_\gamma \alpha_p \cos\theta_p$$

Hiller, Kagan, PRD 65, 074038 (2002)

- $\Lambda_b \to \Lambda(½)\,\gamma$

  $\cos\theta_\gamma$ the same

  $\cos\theta_p$ flat

- $\Lambda_b \to \Lambda(3/2)\,\gamma$

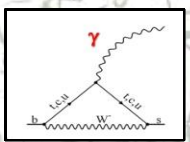
$$\alpha_{\gamma,3/2} = \frac{1-\eta}{1+\eta}\,\alpha_\gamma$$

$$\frac{d\Gamma}{d\cos\theta_\gamma} \propto 1 - \alpha_{\gamma,3/2} P_B \cos\theta_\gamma$$

$$\alpha_{p,3/2} = \frac{\eta - 1}{\eta + \frac{1}{3}}$$

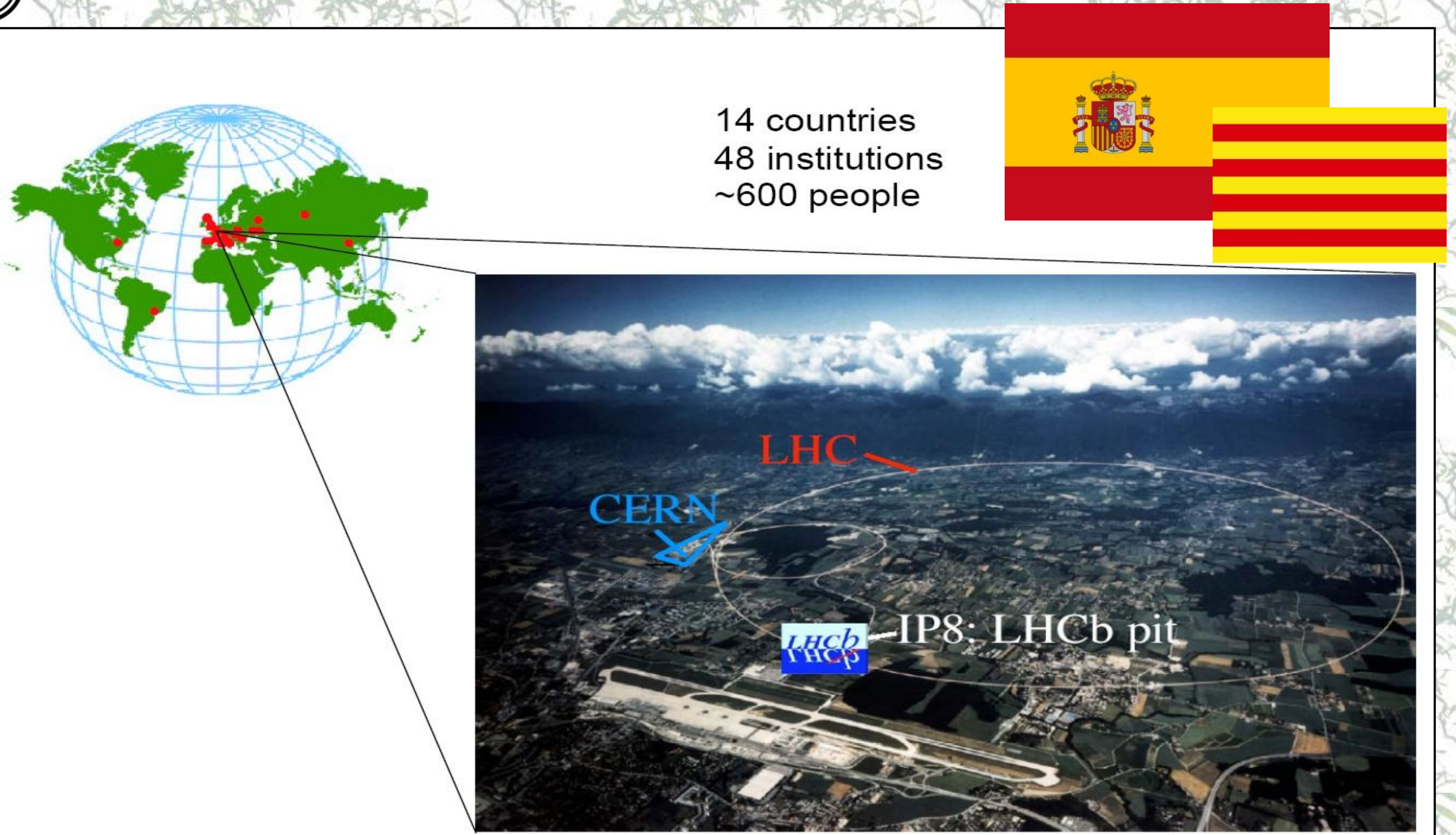
$$\frac{d\Gamma}{d\cos\theta_p} \propto 1 - \alpha_{p,3/2} \cos^2\theta_p$$

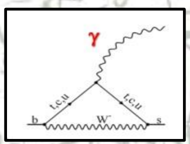
F. Legger and T. Schietinger, *Phys.Lett.B* ***645, 204 (2007)***



LHCb Experiment

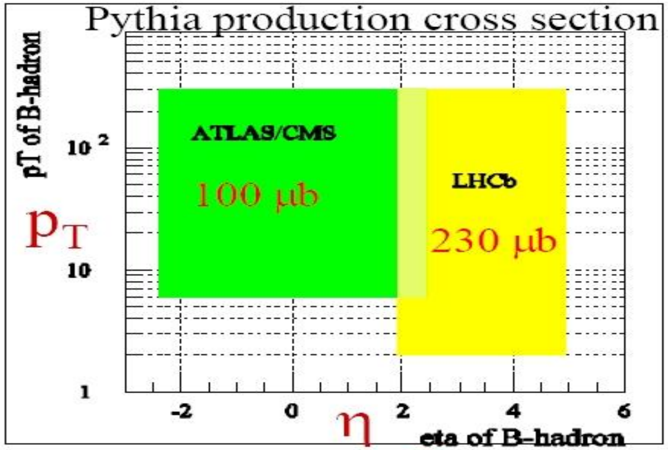
14 countries
48 institutions
~600 people

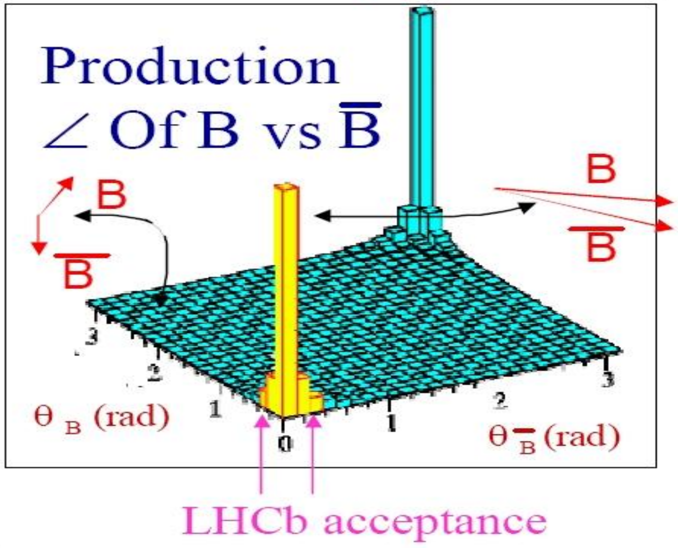


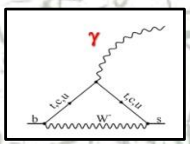


b-production pp@$\sqrt{s}$=14TeV

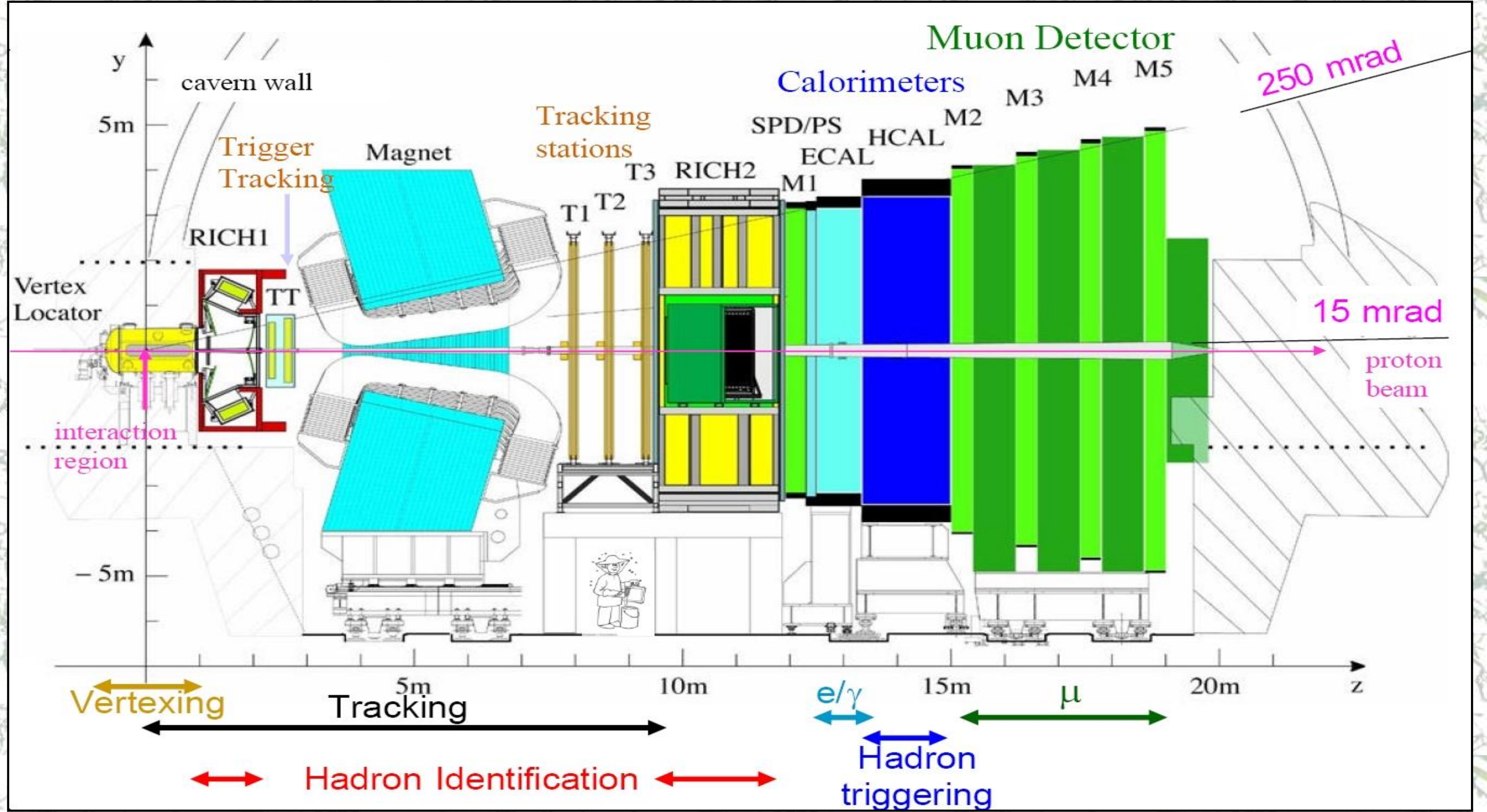
- In the forward region σ_b is large
  - $O(10^{12})$ B-hadrons per 10^7s at $L=2*10^{32}$
  - Limited solid angle → Limited cost
- Both B-hadrons in events are likely to be in acceptance
  - b-flavor tagging!
- B-hadrons are moving with large momentum $\beta\gamma=O(20)$, l_B~1cm
  - Minimize the multiply scattering
  - Background rejection via detached vertex
  - Improved decay time resolution

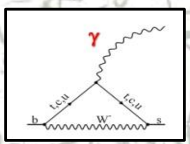






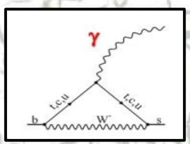
LHCb Detector (sketch)





LHCb Detector in Cavern

The (sub)detectors are being commissioned ***now***. Data taking with cosmic events and the first LHC beam tests. Webcam at http://cern.ch/lhcb/web-cam.htm



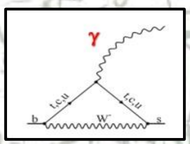
Analysis & Background suppression

- Beauty particles:
  - $m_b \sim 5\ \mathrm{GeV}/c^2$
  - $\beta\gamma c\tau \sim O(1\mathrm{cm})$
- Particles from B-decays:
  - Large p_T
  - Large impact parameters
  - *Exploited in a smart way by L0/HLT triggers!*
- Background:
  - $b\bar{b}$-production with at least one B within 400mrad cone

- We do have L0 trigger for energetic photons!
- Analyses are based on full detailed detector simulation with the realistic reconstruction chain

Common features:

- B-decay products do not point to reconstructed primary vertices
- Exclusively reconstructed B-candidate does point to primary vertex
- B-candidate is associated with primary vertex with minimal impact parameter (significance)



Selection of $B_d \to K^{*0}\gamma$ and $B_s \to \phi\gamma$

Important factors

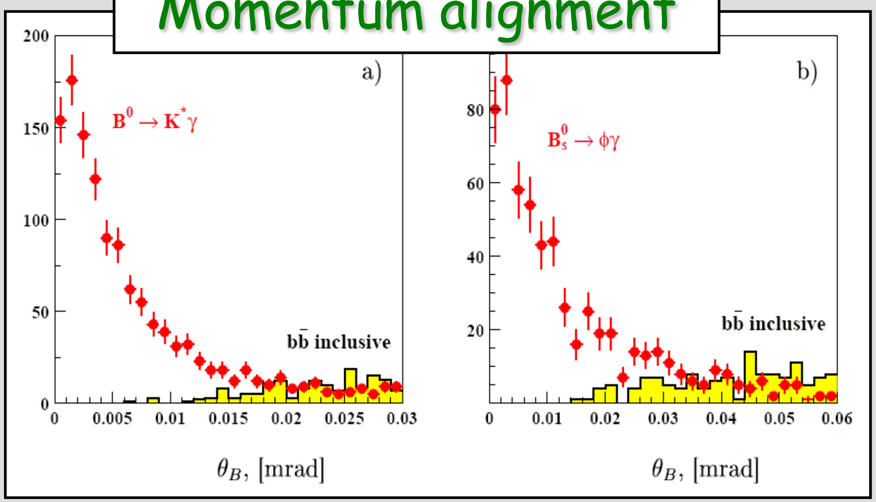
- Good hadron PID :
  - $K/\pi/p$ separation
- Good quality of 2-prong vertex fit

Correlated feeddown from energetic $\pi^0 \to$ "γ"

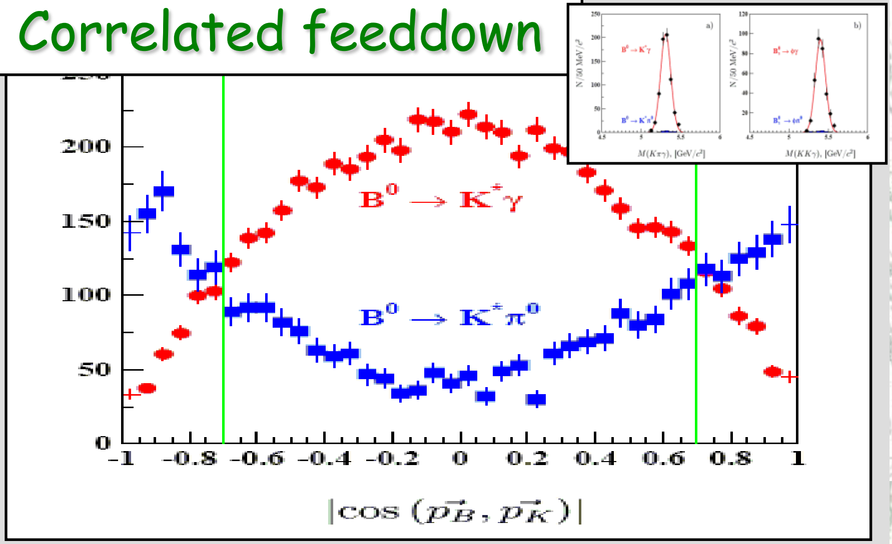
- $K^{*0}\pi^0 \to K^{*0}$ "γ"
- $\phi\pi^0 \to \phi$ "γ"

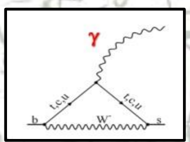
Different vector polarisation

Momentum alignment



Correlated feeddown



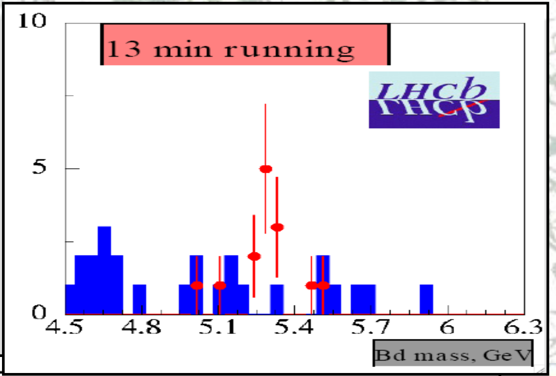


Yields per $2fb^{-1}$

- Selection of other channels

$\Lambda_b \to \Lambda^0\gamma$, $\Lambda_b \to (\Lambda^0(1670) \to pK^-)\gamma$,

$B^\pm \to (\phi \to K^+K^-)K^\pm\gamma, \ldots$ ~ the same

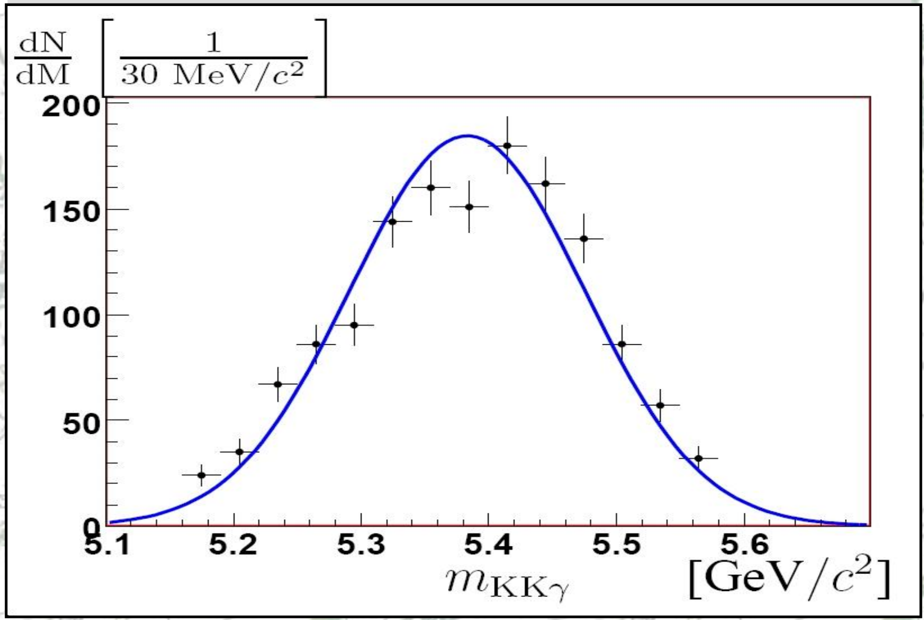


Decay Mode	$\#/2fb^{-1}$		$\mathcal{B}_{b\bar{b}}/\mathcal{S}$
$B^0 \to K^{*0}\gamma$	$7 \cdot 10^4$		0.6-0.7
$B^0_s \to \phi\gamma$	$1.1 \cdot 10^4$	$\mathcal{O}$(1 $B_s \to \phi\gamma$)/hour	$< 0.6 - 0.9$
$\Lambda_b \to \Lambda^0\gamma$	750		< 42
$\Lambda_b \to \Lambda^0(1670)\gamma$	$2.5 \cdot 10^3$	~ $\Lambda^0(1690)$, ~ ½$\Lambda^0(1520)$	< 18
$B^+ \to \phi K^+\gamma$	$\sim 7 \cdot 10^3$		$< 2 - 4$

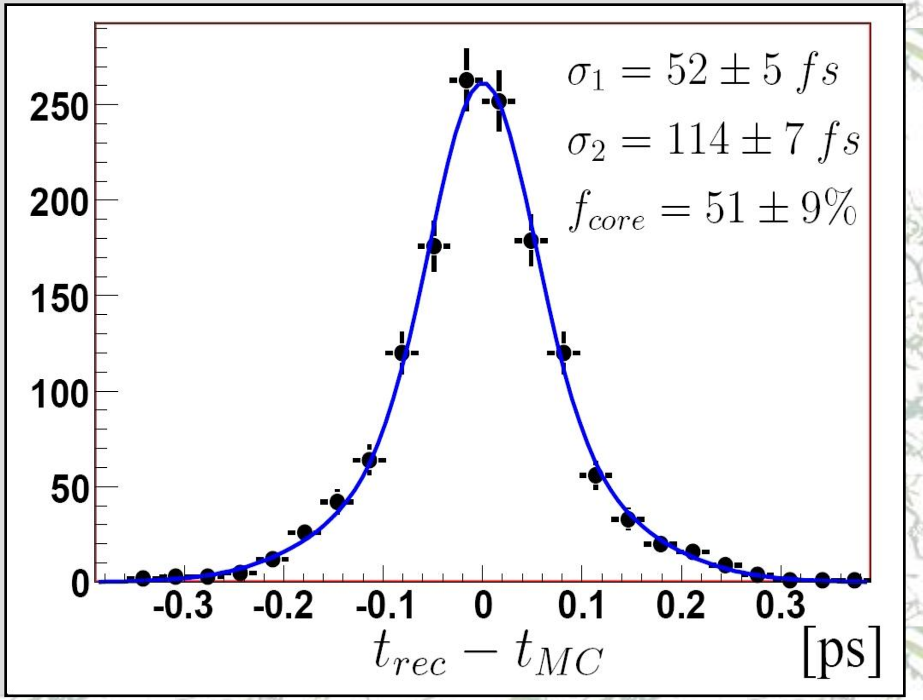
- L. Shchutska, A. Golutvin and I. Belyaev, *CERN-LHCb-2007-030*
- F. Legger, *CERN-LHCb-2006-012*

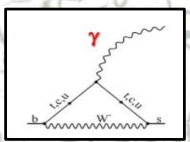
What do we "know" about signal?

- Mass resolution
  - ~90 MeV/c^2
  - Totally dominated by Ecal energy resolution



- Proper Life-time resolution
  - σ~78fs



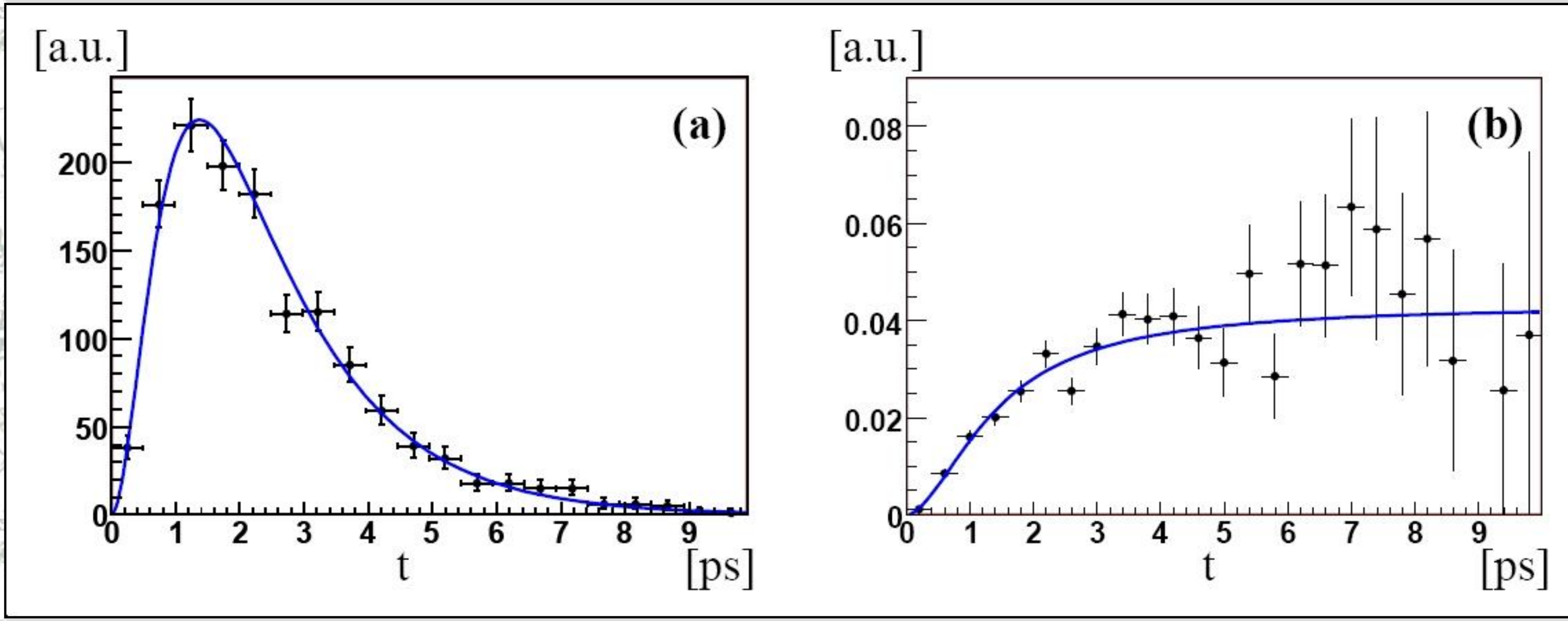


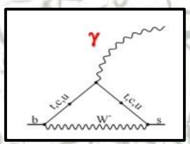
(Signal) proper time acceptance

a = 0.74±0.09 ps^{-1}

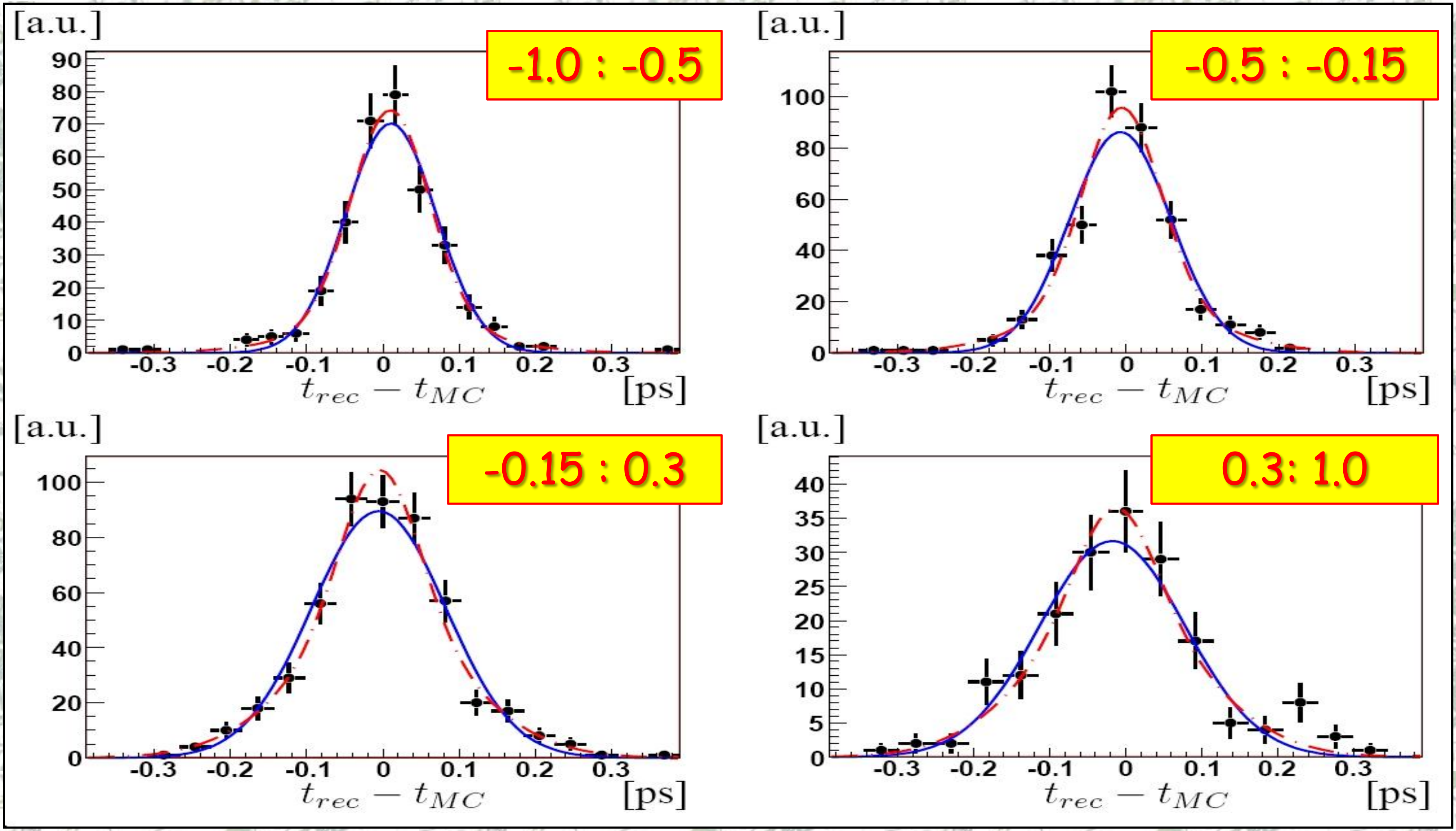
c = 1.86±0.15

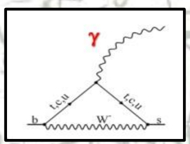
$$\varepsilon_s(t) \propto \frac{(at)^c}{1+(at)^c}$$





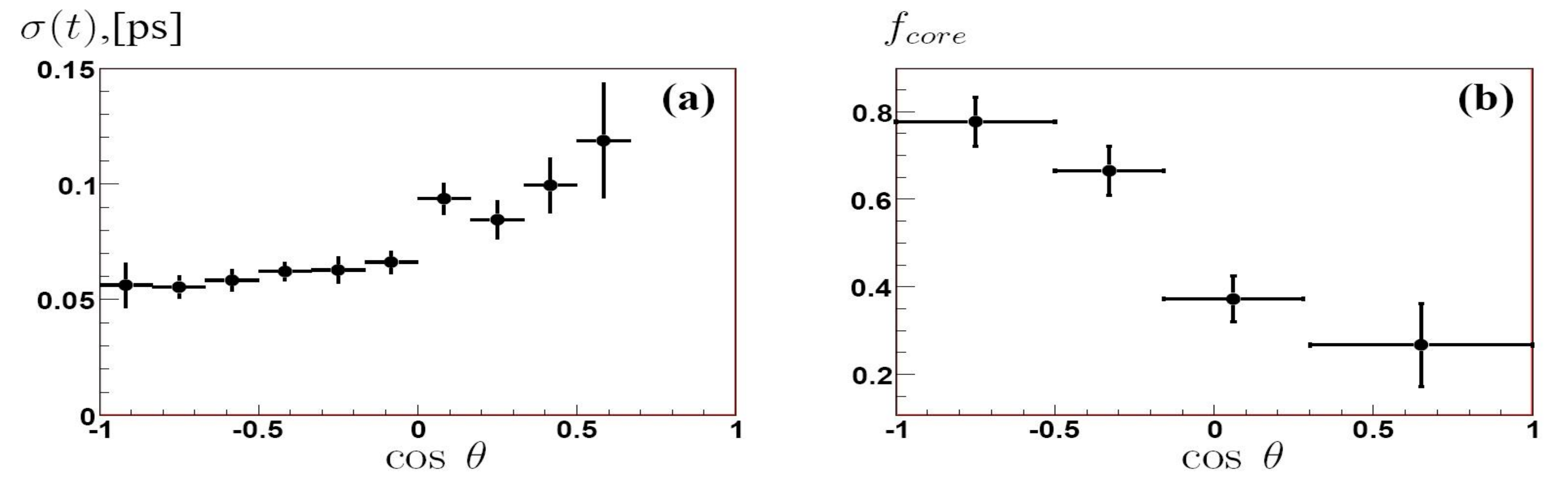
Signal proper time resolution as function of cosΘ

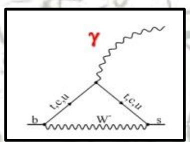




Signal proper time resolution as function of cosΘ

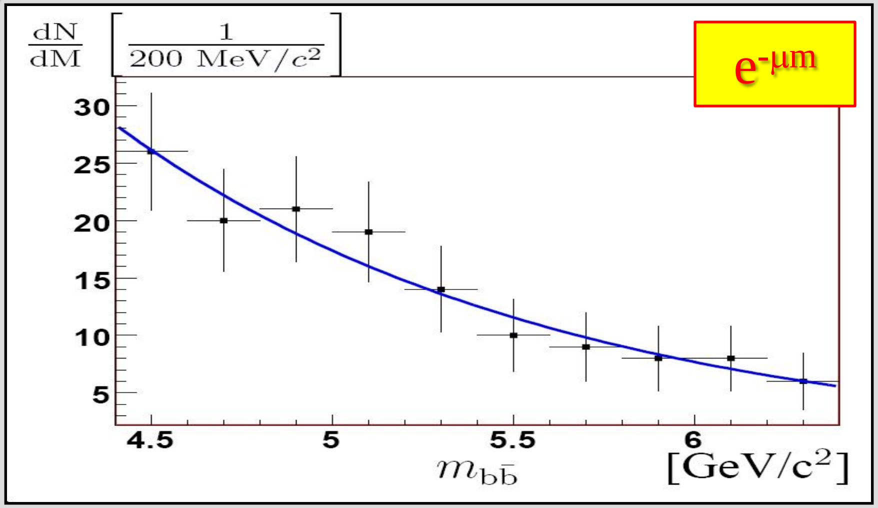
$\cos\,\theta$	$\text{mean}_{1G},\ fs$	$\sigma,\ fs$	$\text{mean}_{2G},\ fs$	f_{core}
[-1,-0.5)	10 ± 3	59 ± 3	10 ± 3	0.78 ± 0.06
[-0.5,-0.15)	-8 ± 4	66 ± 4	-6 ± 4	0.66 ± 0.06
[-0.15,0.3)	-5 ± 4	88 ± 4	-4 ± 4	0.37 ± 0.05
[0.3,1]	-18 ± 8	96 ± 7	-13 ± 8	0.27 ± 0.09



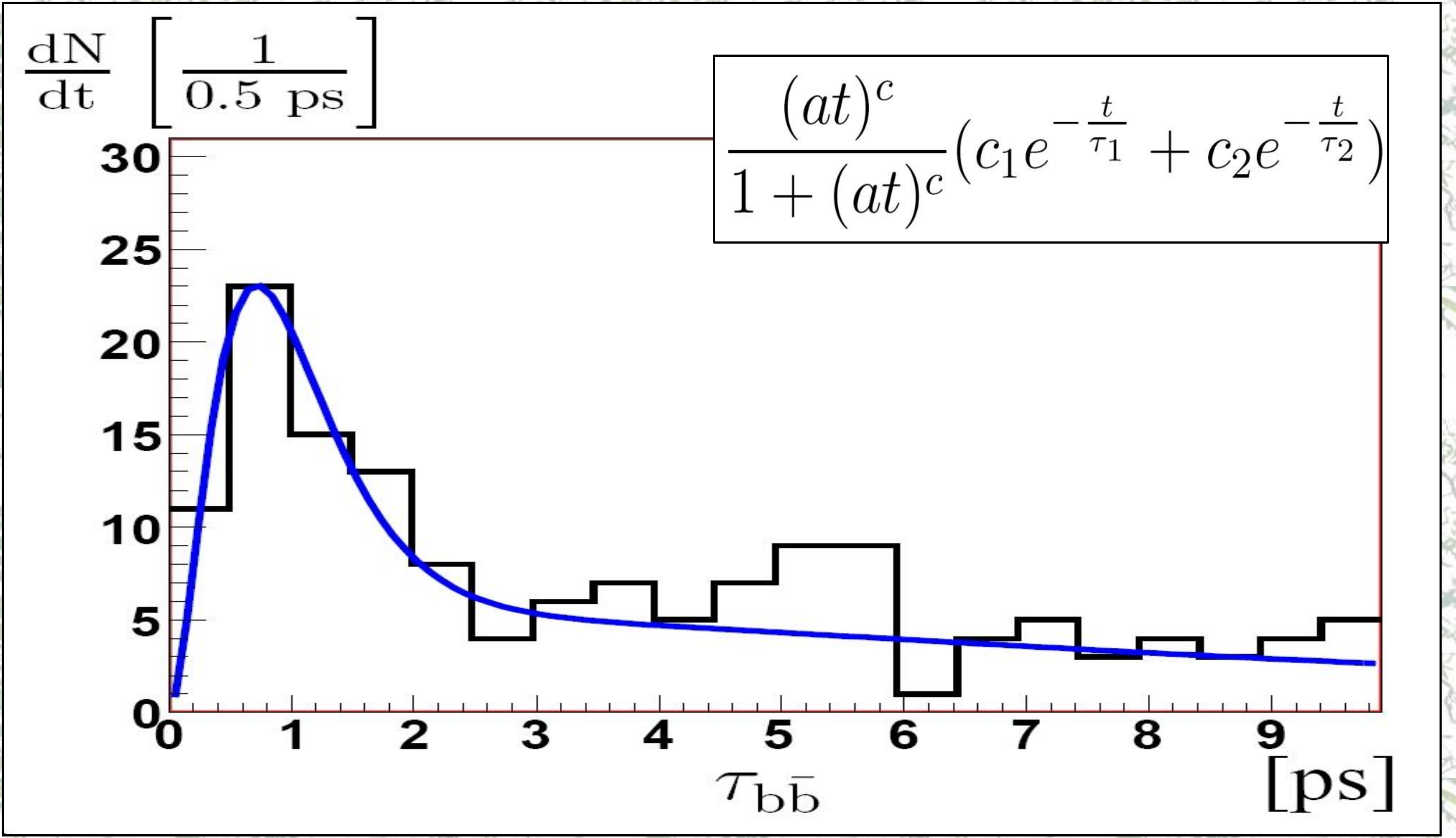


What we "know" about background?

- Limited set of Monte Carlo statistics ~(1-5)10^7 potentially dangerous "forward" bb-events
  - 15-20 minutes of LHC
- Many estimates are (MC) statistically limited and rely on some assumptions.
  - "loose cuts …"

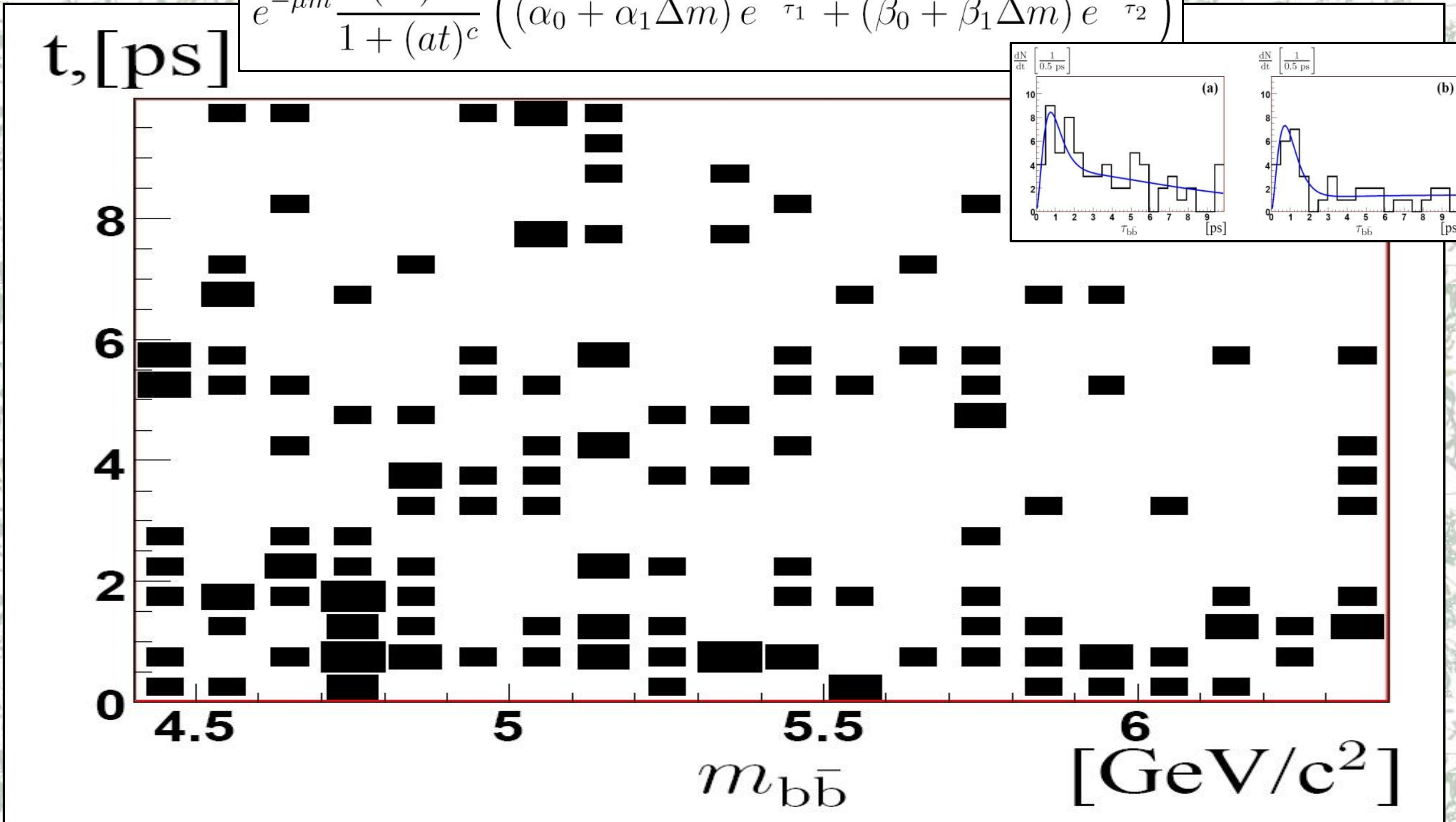


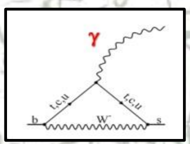
Background “proper time” distribution



B: "proper-time" vs mass

$$e^{-\mu m}\frac{(at)^c}{1+(at)^c}\left(\left(\alpha_0+\alpha_1\Delta m\right)e^{-\frac{t}{\tau_1}}+\left(\beta_0+\beta_1\Delta m\right)e^{-\frac{t}{\tau_2}}\right)$$



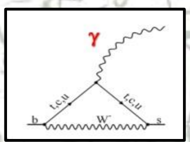


Likelihood

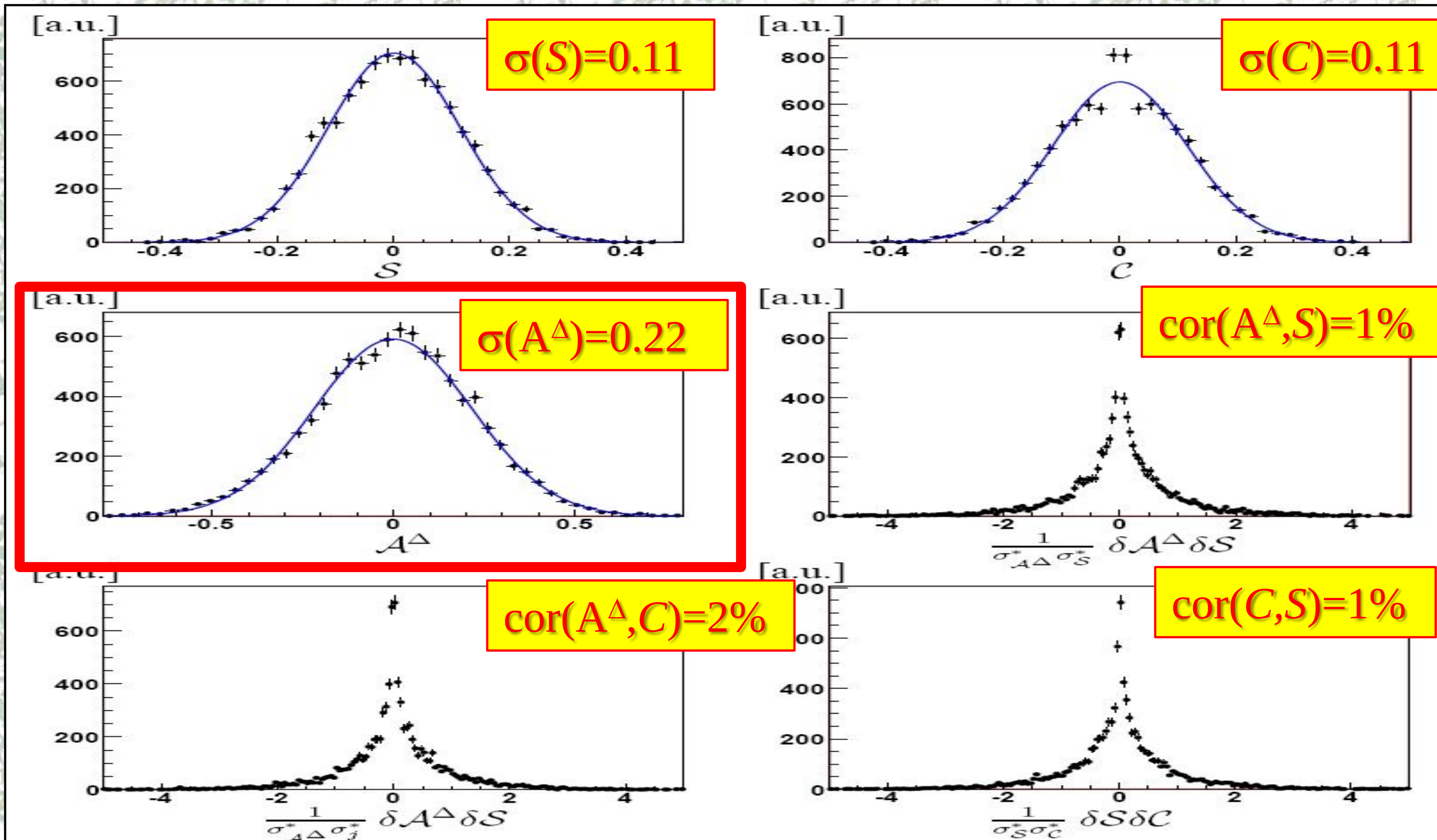
$$P_\kappa(t,m) = f_s \frac{\{e^{-\Gamma\tau}[I_+(\tau)+\kappa(1-2\omega)I_-(\tau)]\}\otimes G(t-\tau)\varepsilon(t)g_s(m)}{\int\{e^{-\Gamma\tau}[I_+(\tau)+\kappa(1-2\omega)I_-(\tau)]\}\otimes G(t'-\tau)\varepsilon(t')\mathrm{d}t'} + \\ + (1-f_s)\varepsilon_b(m,t),$$

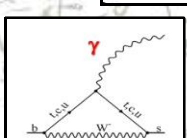
$$\begin{aligned} I_+(\tau) &= \cosh\frac{\Delta\Gamma\tau}{2} - \mathcal{A}^\Delta \sinh\frac{\Delta\Gamma\tau}{2} \\ I_-(\tau) &= \mathcal{C}\cos\Delta m_s\tau - \mathcal{S}\sin\Delta m_s\tau \end{aligned}$$

$$\mathcal{L}_0 = \prod_{i=1}^{N_{\mathrm{B_s}}} P_{-1}(m_i,t_i,\sigma_{ti}) \prod_{i=1}^{N_{\mathrm{\bar{B}_s}}} P_1(m_i,t_i,\sigma_{ti}) \prod_{i=1}^{N_{untagged}} P_0(m_i,t_i,\sigma_{ti}),$$



Result: 10^4 toys

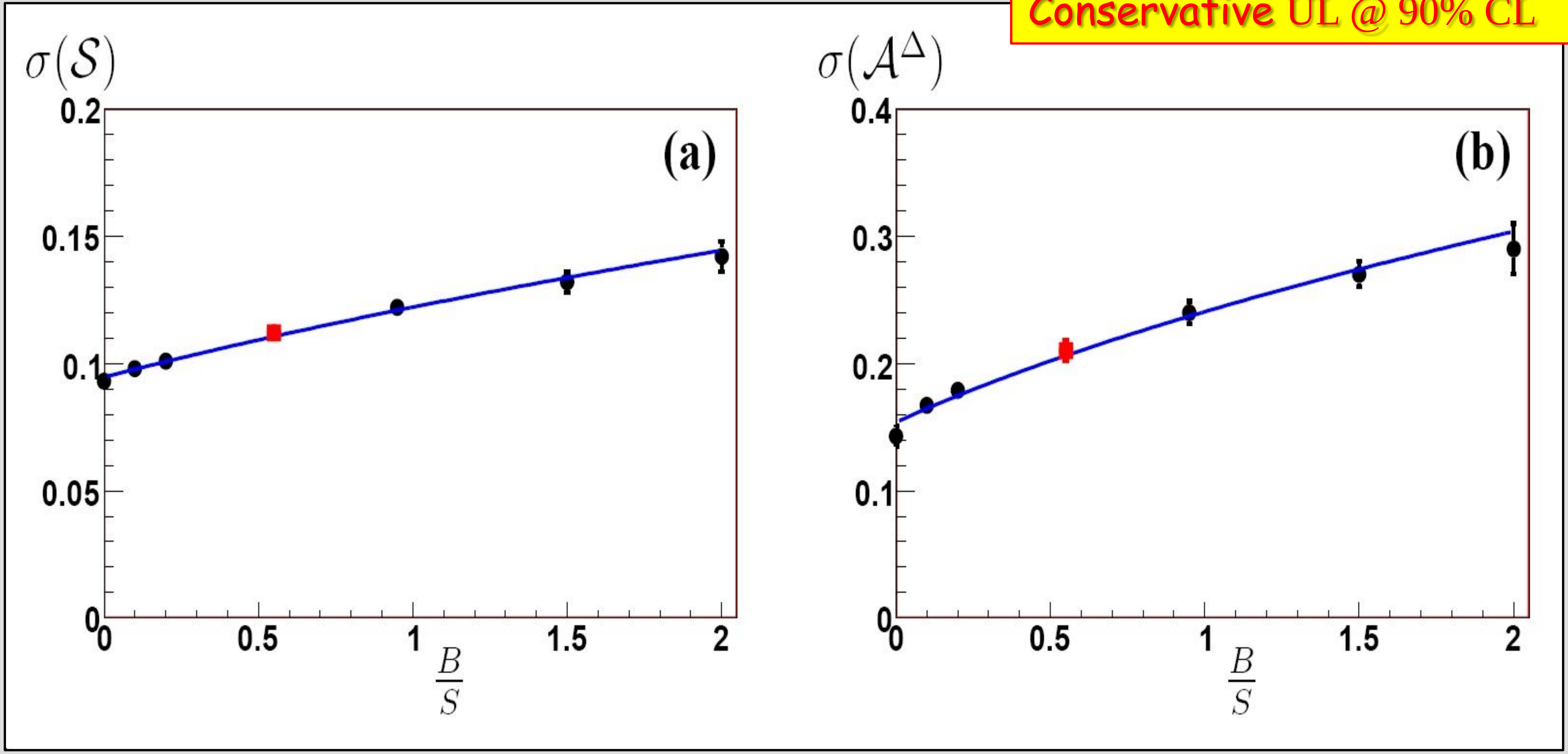


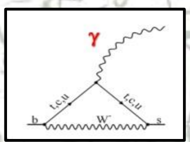


Stability tests: *B/S*

- There is some dependency on *B/S* level:

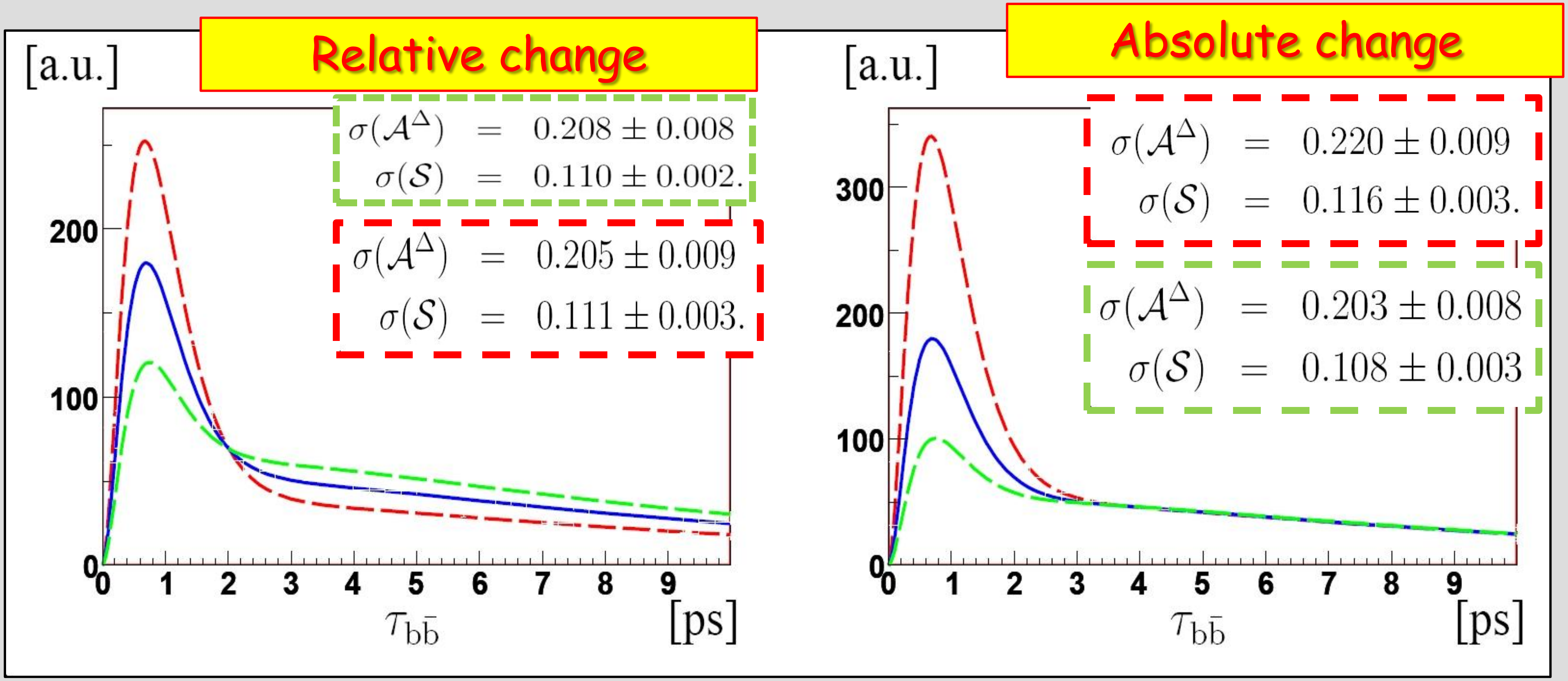
Conservative UL @ 90% CL

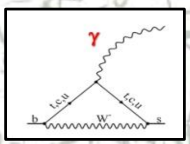




The shape of background

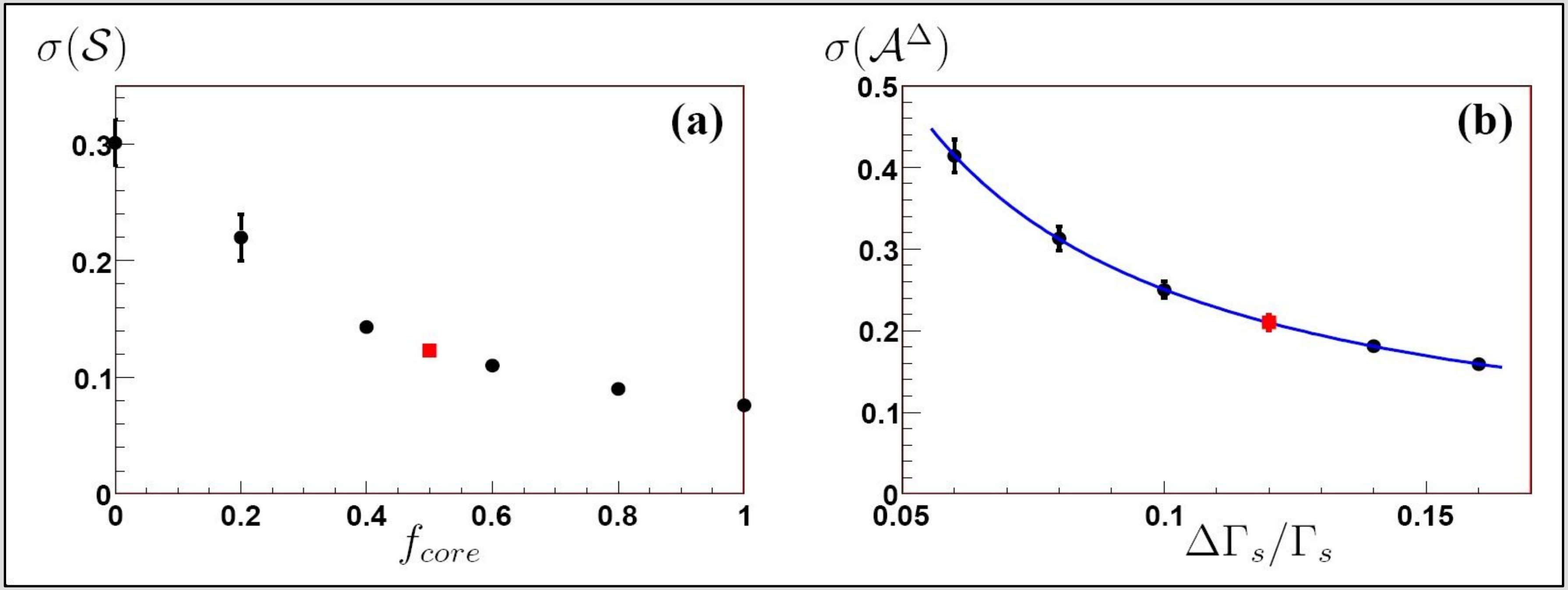
- Vary the "short/long"-lived components





Resolution and $\Delta\Gamma_s/\Gamma_s$

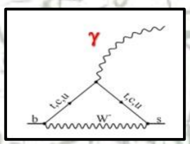
- Vary the proper time resolution
  - Use simple model with two Gaussians and vary the proportion



$B_s \to \phi\gamma$

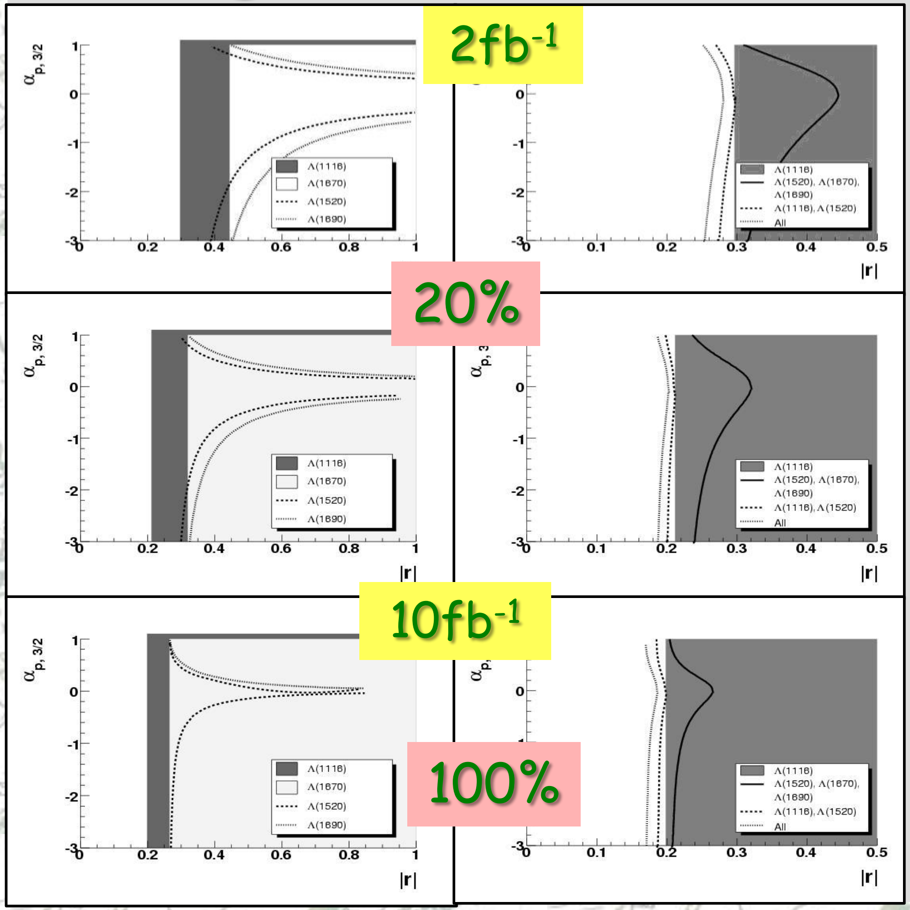
- LHCb has good potential for measurement of photon polarization in $B_s \to \phi\gamma$ decay
- For 2 fb^{-1}: $\sigma(A^{\Delta})=0.22$, $\sigma(S)=\sigma(C)=0.11$
  - for 500pb^{-1} ($\int Ldt$ for "the first year"): $\sigma(A^{\Delta})\sim 0.4$
- The result has *moderate* dependency on *B/S*
- *The determination of proper time acceptance function from data in under the study now*

L.Shchutska, Y.Xie, A.Golutvin, V.Egorychev, V.Shevchenko, I.Belyaev LHCb-2007-147



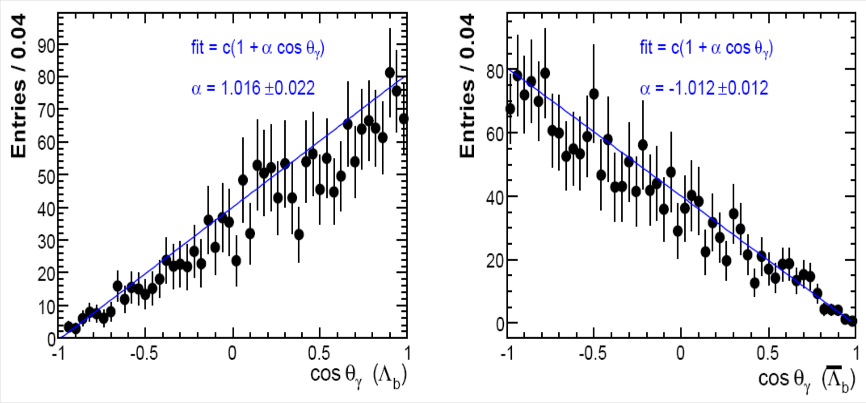
3σ measurement of $\tan\psi$ for $\Lambda_b \to \Lambda^0\gamma$ $\Lambda_b \to \Lambda(X)\gamma$

Single Combined

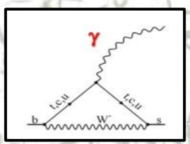


$|A_R/A_L| = \tan\psi \equiv |r|$

- Can be probed at 3σ for 5years
  - >20% with $\Lambda_b \to \Lambda^0\gamma$
  - >25% with $\Lambda_b \to \Lambda^*\gamma$



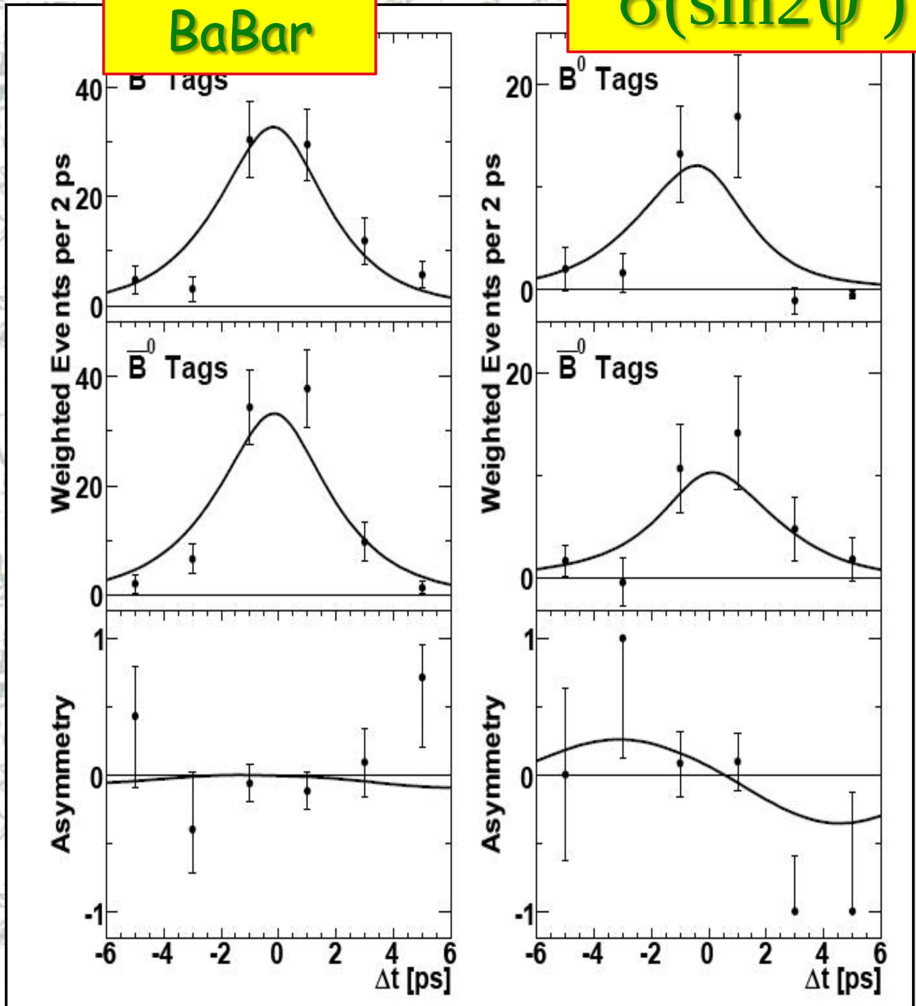
F.Legger & T.Schitienger, LPHE 2006-003,LHCb 2006-013



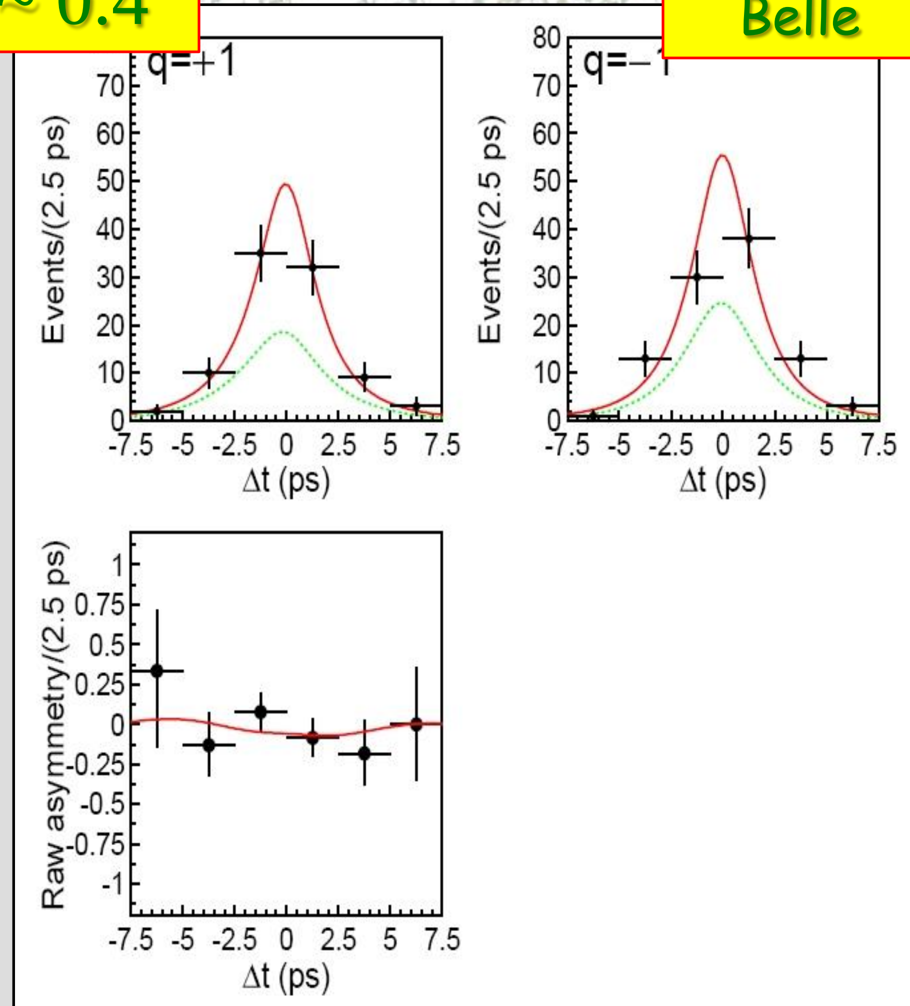
$\sin 2\psi$ now for B-factories

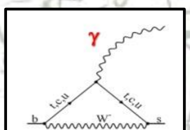
$\sigma(\sin 2\psi) \sim 0.4$

BaBar



Belle





Direct *CP*-asymmetry for $B^0 \to K^{*0}\gamma$

- Is expected to be small
- Statistical error of practically negligible
- Systematic error is an issue ☹
- But: use the normalization channel $B^0 \to K^{*0} J/\psi$

$$\mathcal{R} = \frac{\mathcal{N}_{B^0 \to K^{*0}\gamma}}{\mathcal{N}_{B^0 \to K^{*0} J/\psi}}$$
$$\bar{\mathcal{R}} = \frac{\mathcal{N}_{\bar{B}^0 \to \bar{K}^{*0}\gamma}}{\mathcal{N}_{\bar{B}^0 \to \bar{K}^{*0} J/\psi}}$$

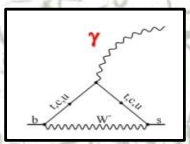
$$\mathcal{A}_{\mathcal{R}} = \frac{\bar{\mathcal{R}} - \mathcal{R}}{\bar{\mathcal{R}} + \mathcal{R}}.$$

$$\mathcal{A}_{\mathcal{R}} = \frac{\mathcal{A}^{\rm dir}_{K^{*0}\gamma} - \mathcal{A}^{\rm dir}_{K^{*0}J/\psi}}{2 - \frac{1}{2}\mathcal{A}^{\rm dir}_{K^{*0}\gamma}\mathcal{A}^{\rm dir}_{K^{*0}J/\psi}}.$$

$$\frac{\int \varepsilon(\Phi)\left(p^s(\Phi) - p^c(\Phi)\right) d\Phi}{\int \varepsilon(\Phi)\left(p^s(\Phi) + p^c(\Phi)\right) d\Phi}$$

$$\mathcal{A}^{\rm dir}_{K^{*0}\gamma} \equiv \frac{\mathcal{B}_{\bar{B}^0 \to \bar{K}^{*0}\gamma} - \mathcal{B}_{B^0 \to K^{*0}\gamma}}{\mathcal{B}_{\bar{B}^0 \to \bar{K}^{*0}\gamma} + \mathcal{B}_{B^0 \to K^{*0}\gamma}} = \frac{2\mathcal{A}_{\mathcal{R}} + \mathcal{A}^{\rm dir}_{K^{*0}J/\psi}}{1 + \frac{1}{2}\mathcal{A}_{\mathcal{R}}\mathcal{A}^{\rm dir}_{K^{*0}J/\psi}}.$$

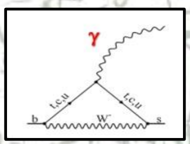
O(1%) is reachable



$Br(B_s\to \phi\gamma)/Br(B^0\to K^{*0}\gamma)$

- Good prediction from theory
  - A.Ali, B.D. Pecjak and C.Greub, Eur.Phys.J. C55:577-595,2008
  - + test the formfactors
- The absolute measurements impossible?
- But *the double ratio* is easy to measure and almost free from the experimental uncertanties

$$\mathcal{R}_{\mathcal{D}}^{B_s^0\to\phi\gamma} = \frac{\mathcal{B}_{B_s^0\to\phi\gamma}/\mathcal{B}_{B_s{}^0\to\phi J/\psi}}{\mathcal{B}_{B^0\to K^{*0}\gamma}/\mathcal{B}_{B^0\to K^{*0}J/\psi}} = \frac{\mathcal{B}_{B_s^0\to\phi\gamma}/\mathcal{B}_{B^0\to K^{*0}\gamma}}{\mathcal{B}_{B_s{}^0\to\phi J/\psi}/\mathcal{B}_{B^0\to K^{*0}J/\psi}},$$



Summary

- **LHCb** experiment is well suited for detailed study of exclusive radiative decays of beauty hadrons
  - Experimental challenge
- Study for photon polarization in $B_s \to \phi\gamma$, $\Lambda_b \to \Lambda\gamma$ and $B^{\pm} \to \phi K^{\pm}\gamma$ are of the primary interest
  - Combined sensitivity?
- Many other interesting measurements, like direct *CP*-asymmetries are possible

Stay tuned!