$B_s \to \phi\gamma$ analysis

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Outline

- Photon polarization in $B_s \to \phi\gamma$
- Proper time resolution
  - Causes of the τ resolution bias
- Photon calibration
  - The need of a proper photon calibration
  - Photon calibration in upgrade samples
- Reconstruction efficiencies
- Conclusions

Photon polarization in $B_s \to \phi\gamma$

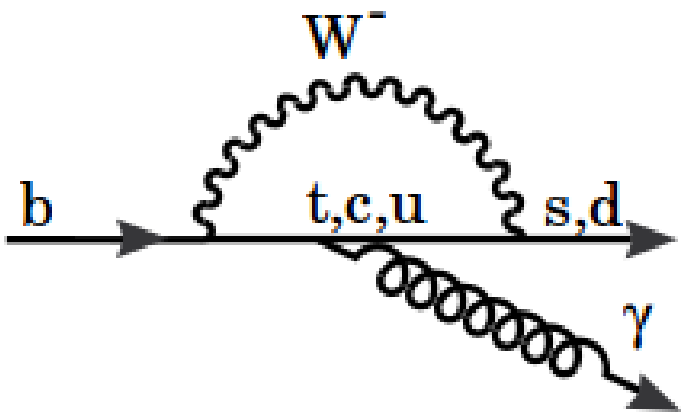
- The information of the **photon polarization in $B_s \to \phi\gamma$** can be extracted from the flavour-untagged proper time distribution:

$$\Gamma_{B_s \to \phi\gamma} \simeq \Gamma_s + \frac{\mathcal{A}^{\Delta} \Delta\Gamma_s}{2},$$

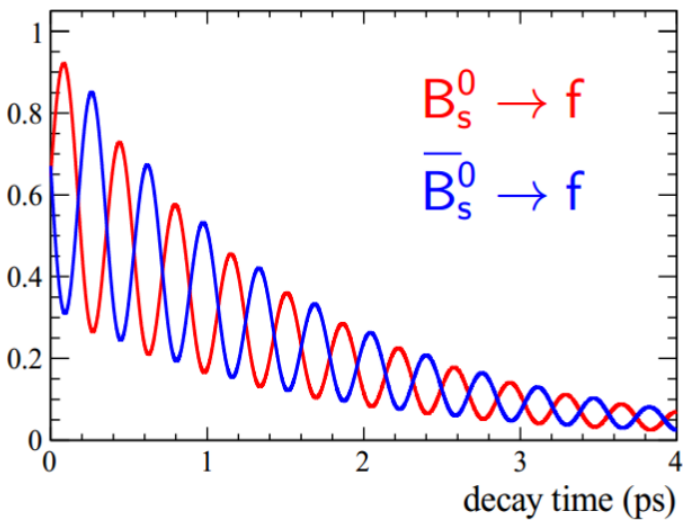
where $\mathcal{A}^{\Delta}$ is related to the photon polarization:

$$\mathcal{A}^{\Delta} = \sin 2\psi \cos\phi, \qquad \tan\psi = \frac{B \to f_{CP}\,\gamma_L}{B \to f_{CP}\,\gamma_R}.$$

- SM prediction: $\mathcal{A}^{\Delta} = \mathbf{0.045}$. Some models predict a larger $\mathcal{A}^{\Delta}$ value $\to$ new physics.



$b \to (s,d)\gamma$ penguin diagram

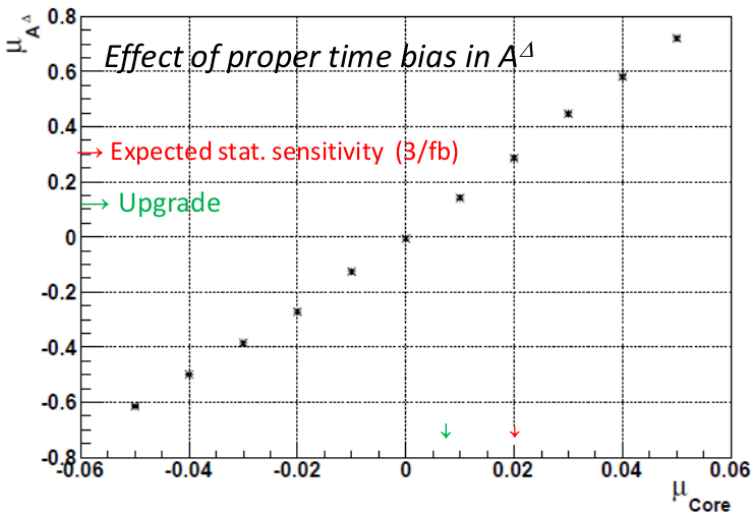


Proper time, B-$\bar{B}$ oscillations

Proper time resolution

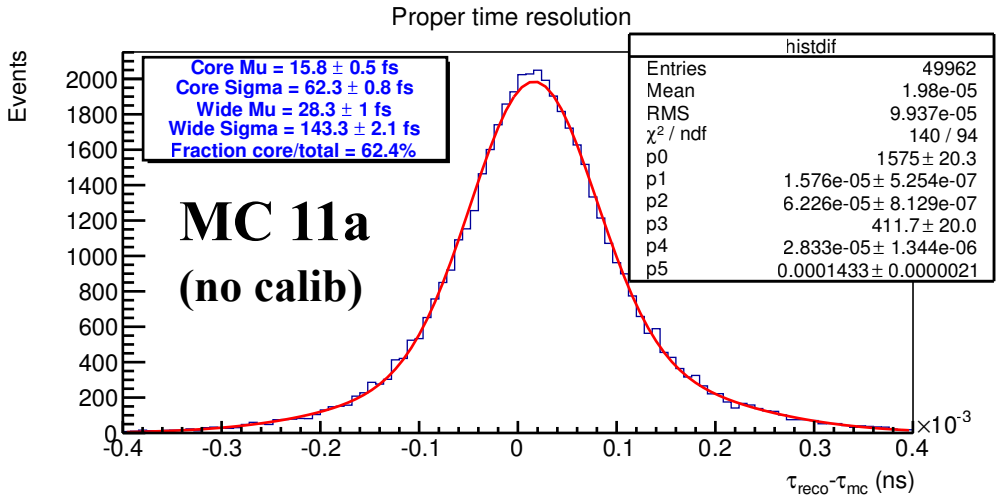
Proper time resolution is defined as $\tau_{reco} - \tau_{true}$.

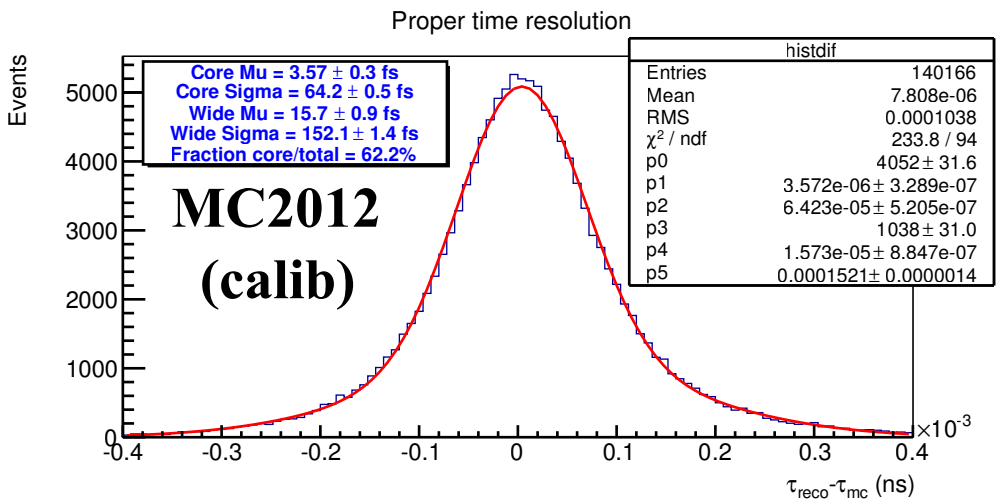
- τ resolution is parametrized as a double Gaussian. The narrower Gaussian (Core) has around 60% of the events, and a bias μ_{core}.
- MC11a not calibrated
- MC2012 calibrated ad hoc from $B \to K^* \gamma$, Mostafa (Clermont).
- μ_{core} is reduced from **15.8** to **3.57** fs (after stripping 20). σ remains the same.



F. Soomro, CERN-THESIS-2011-035

Stripping 20 is applied:

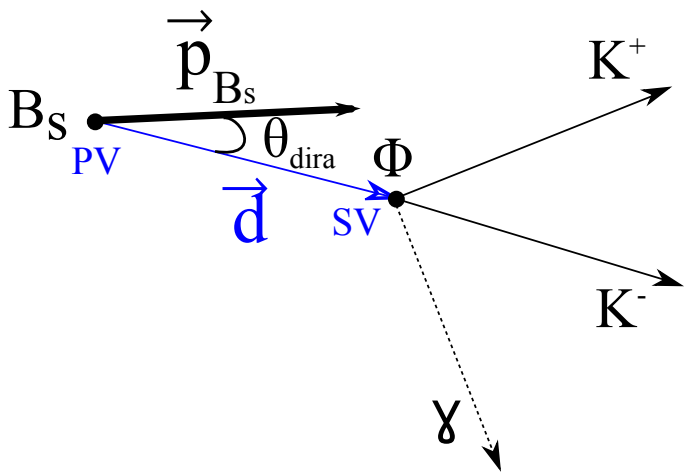




Causes of the τ resolution bias

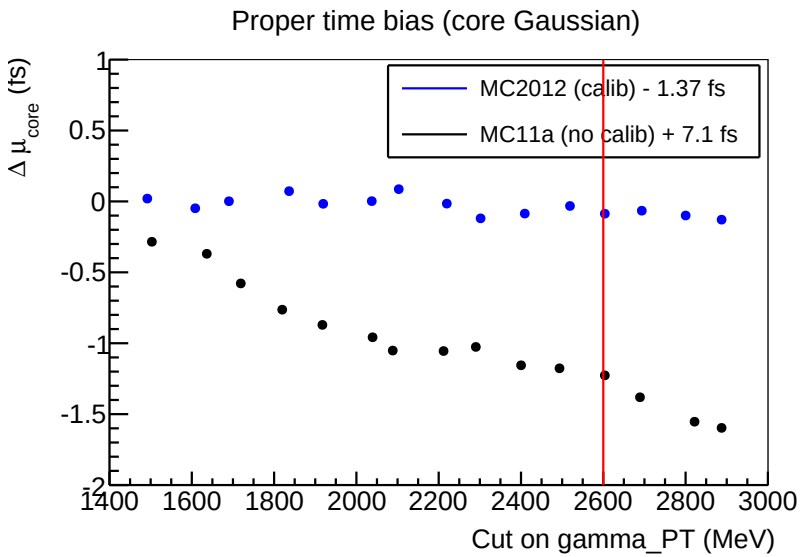
Variables biasing the τ resolution in $B_s \to \phi\gamma$ MC11a (not calibrated):

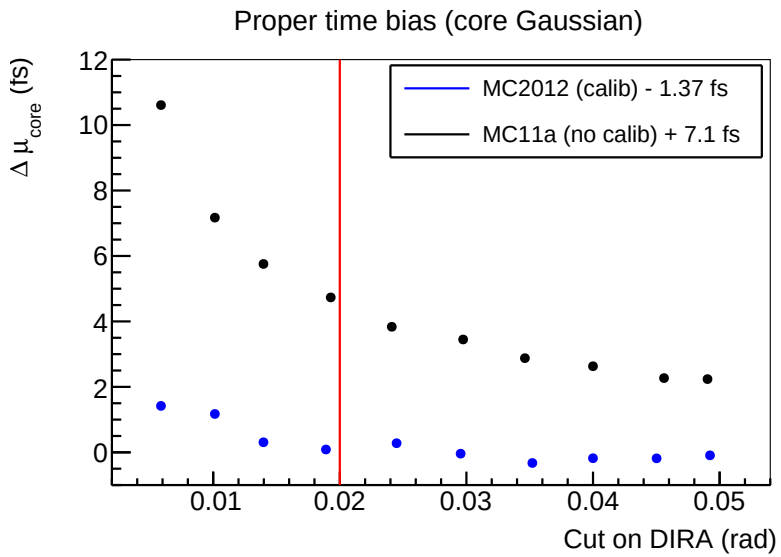
- gamma_PT: transverse momentum of the photon.
- gamma_CL: γ/e separation. **SPD is used.**
- B_s FDχ^2: χ^2 of the flight distance, defined as the distance between the decay and production vertices.
- B_s DIRA: angle between the flight distance and the B_s momentum.

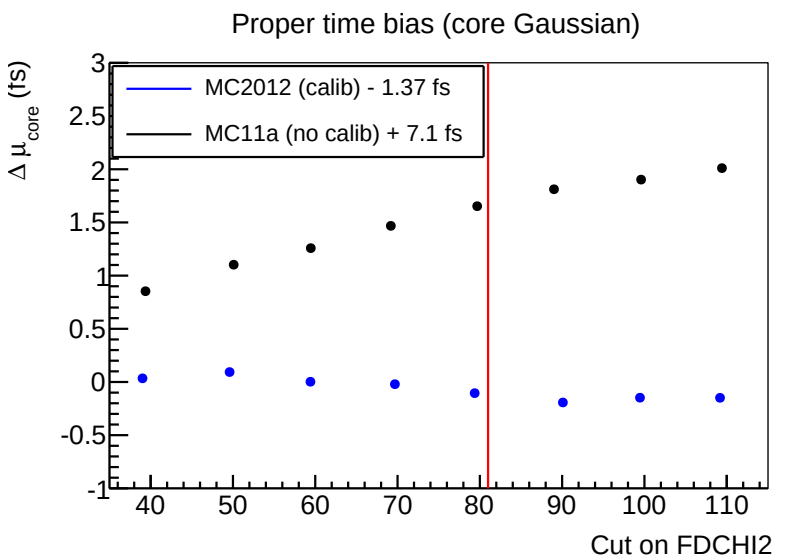


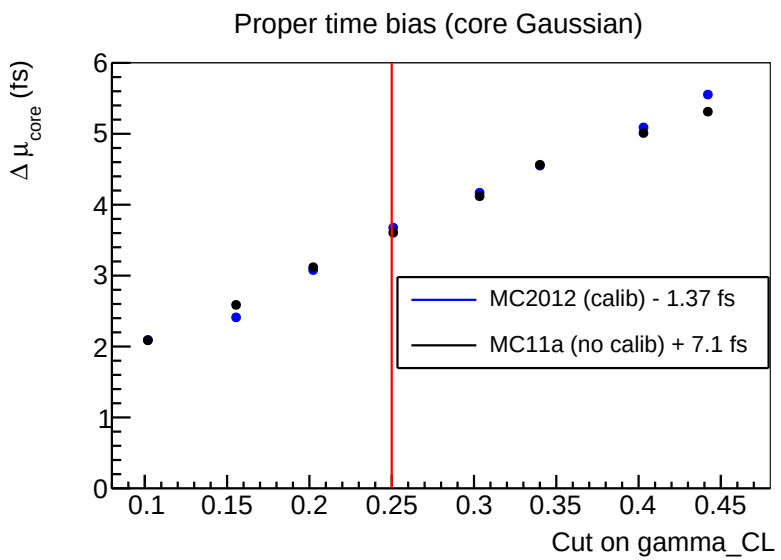
$$\cos(\theta_{\text{dira}}) = \frac{\mathbf{p}_{B_s} \cdot \mathbf{d}}{|\mathbf{p}_{B_s}||\mathbf{d}|}$$

Causes of the τ resolution bias



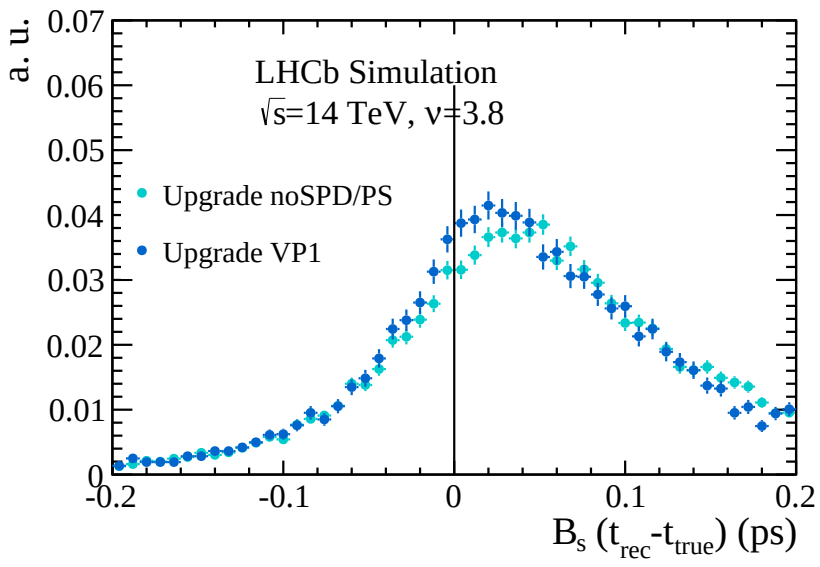






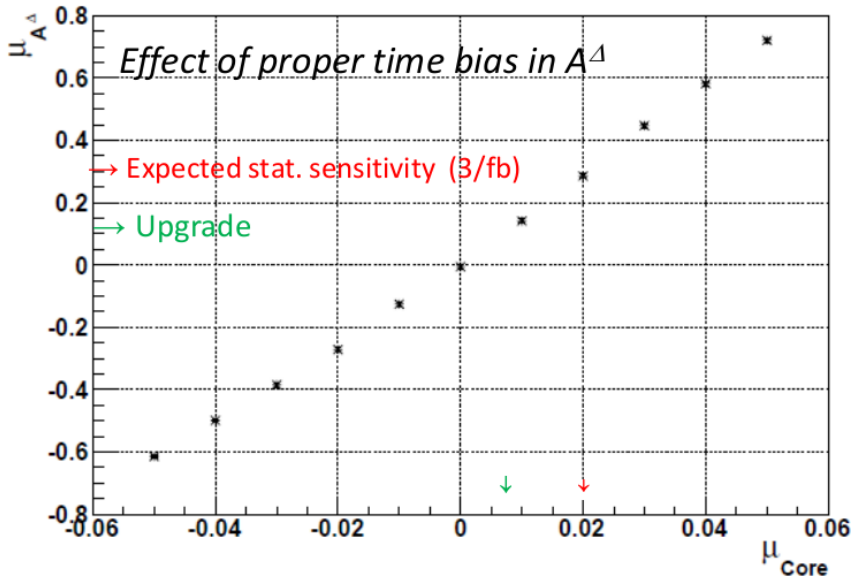
The need of a photon calibration

Upgrade MC samples:



$\sim$ 30-50 fs bias.

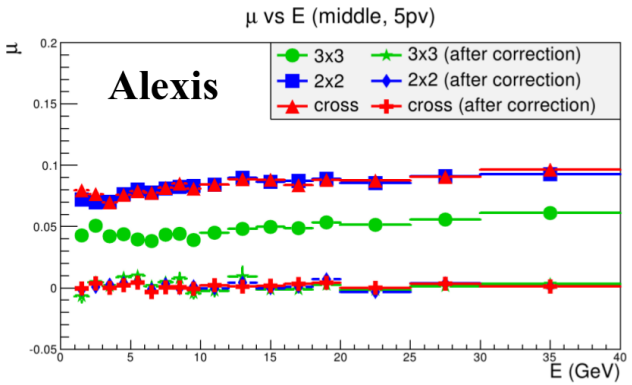
Photon calibration has to be applied!



Bias has to be less than **5 fs**.

New config.: AppCong v3r180, Pythia8, **NoSPD/PRS**, UT UUT, VP UVP
VP1 config.: AppCong v3r178, Pythia8, +SPD/PRS, UT, VP

Applying photon calibration



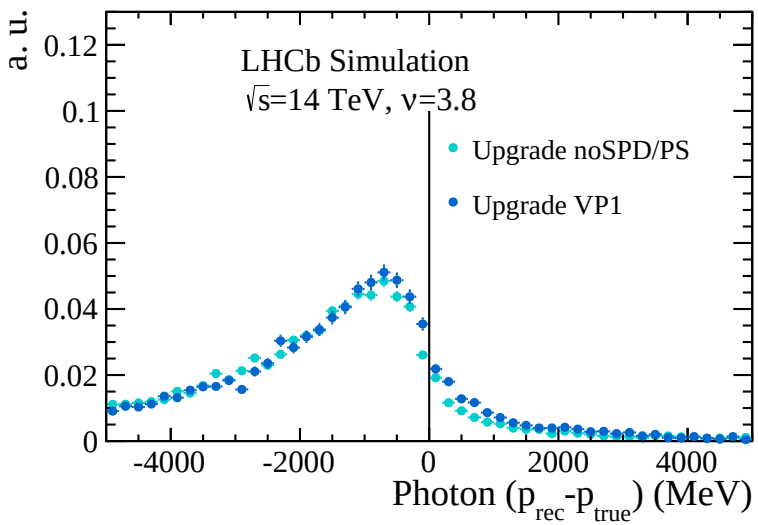
Photon calibration for the upgrade done by A. Vallier (LAL-Orsay):

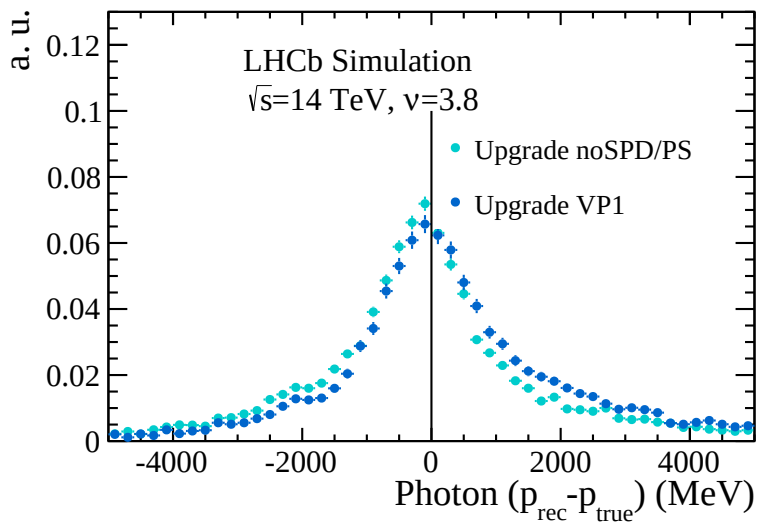
$$E_{cor} = (1 + \beta)\, E_{rec}\,.$$

β factor in energy bins, and for each region of the calorimeter (averaging over nPV).

We have applied the energy calibration in the $B_s \to \phi\gamma$ upgrade samples.

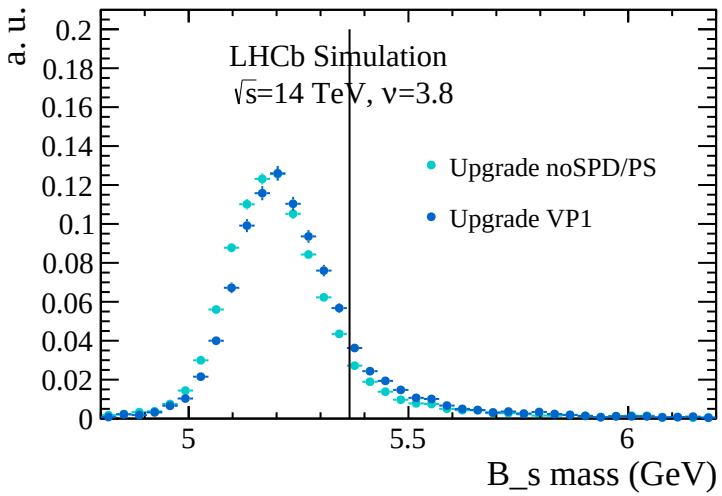
- Photon momentum resolution:

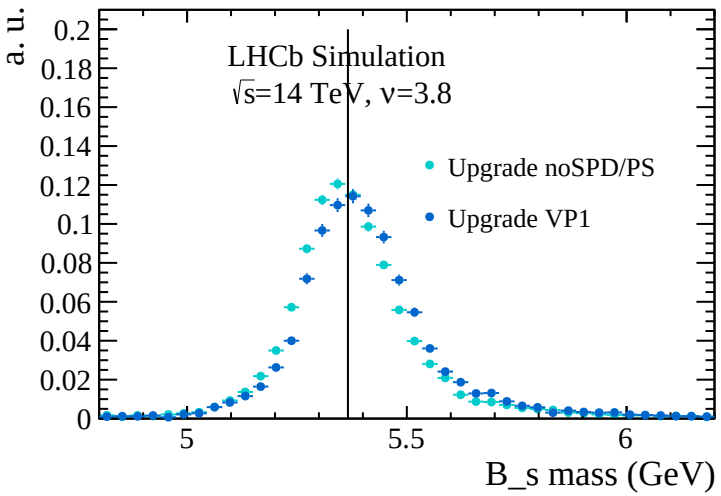




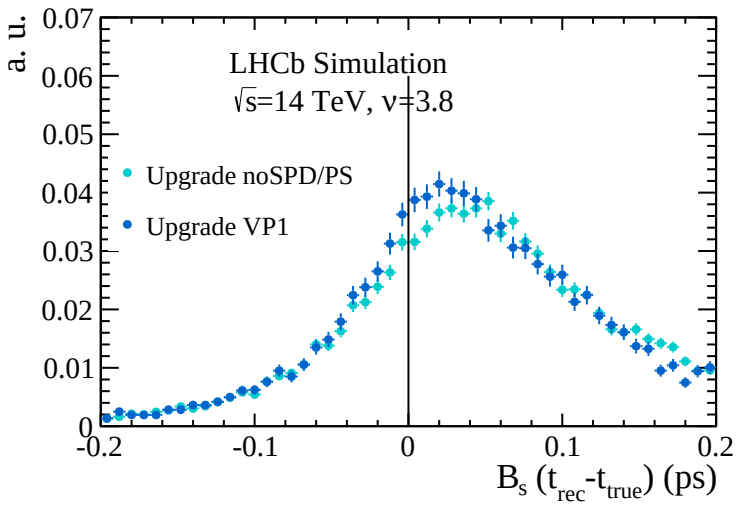
Applying photon calibration

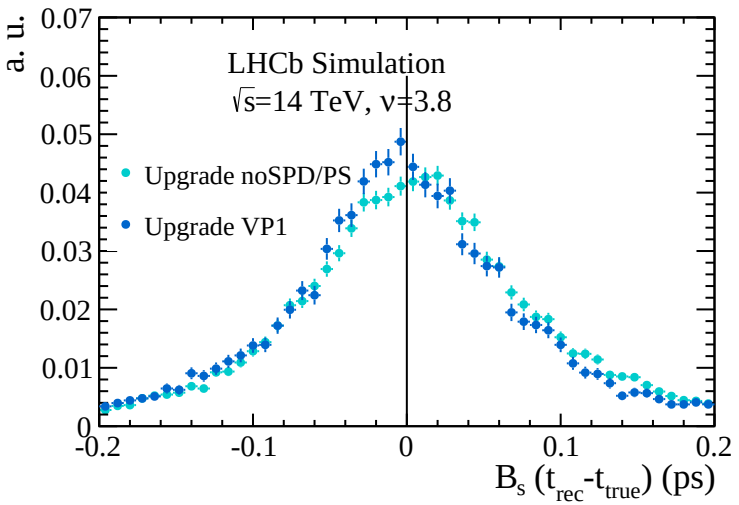
- B_s mass (the reported ~ -130 MeV shift is now corrected):





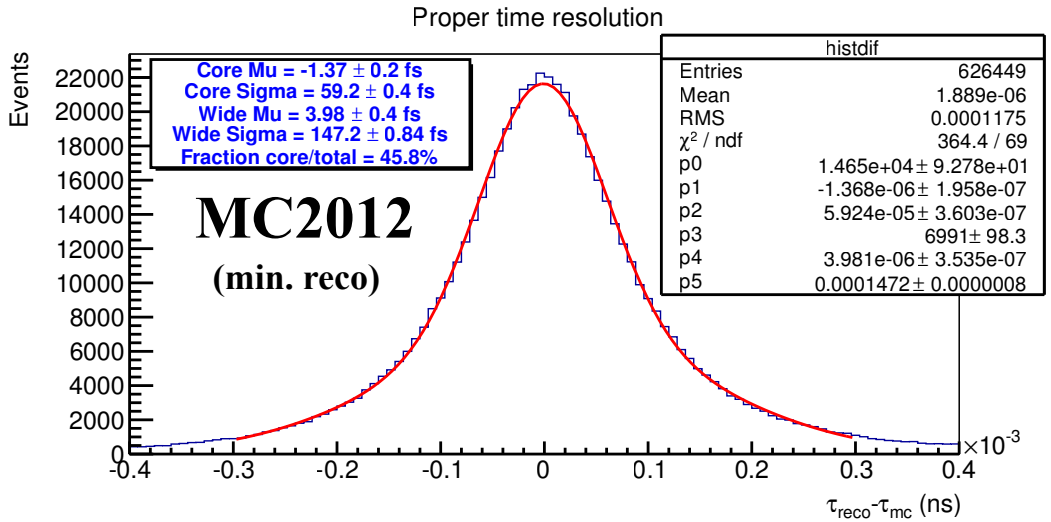
- Proper time resolution:

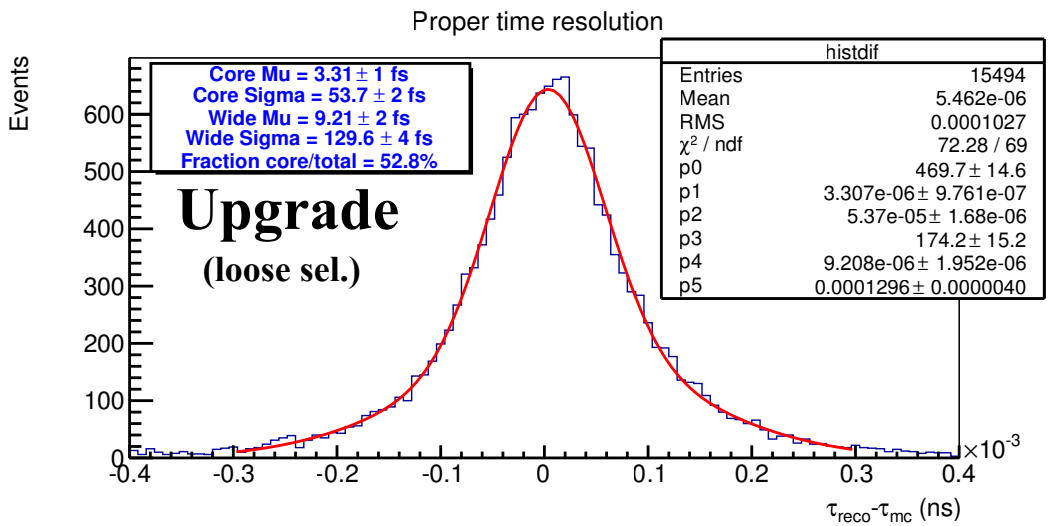




Applying photon calibration

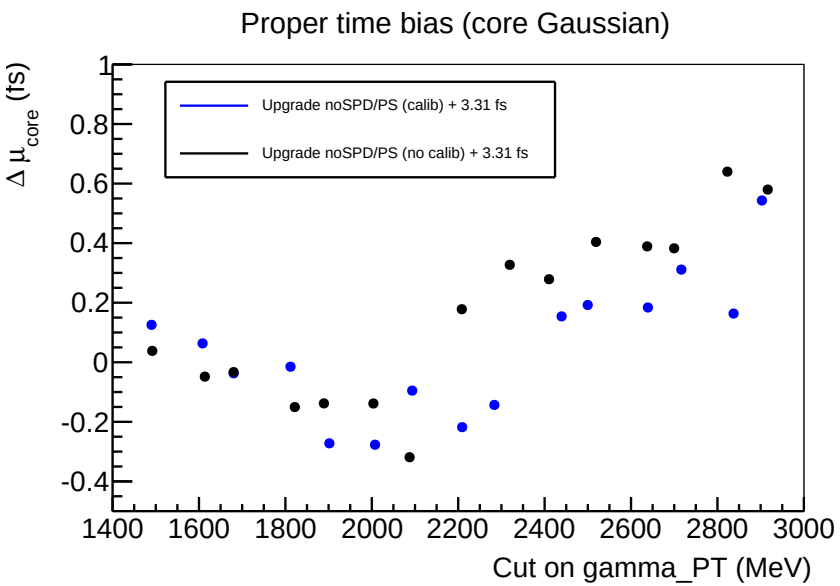
- τ resolution width is improved by $\sim$ **10%** (in both core and wide Gaussians).

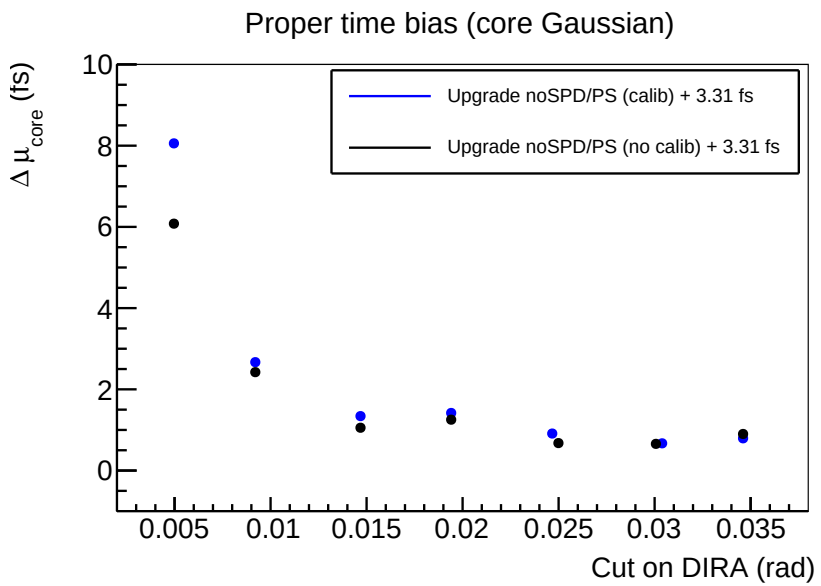




Applying photon calibration

- However, calibration variables are still producing a bias.





Efficiencies

- $B_s \to \phi\gamma$ selection efficiencies $\epsilon_{B_s\to\phi\gamma} = N_{sel}/N_{gen}$:

New config.: AppCong v3r180, Pythia8, **NoSPD/PRS**, UT UUT, VP UVP
VP1 config.: AppCong v3r178, Pythia8, +SPD/PRS, UT, VP

ν	New config., 25 ns	New config.	VP1 config.
3.8	$3.04 \pm 0.05\%$	$3.51 \pm 0.06\%$	$2.04 \pm 0.04\%$
7.6	$1.98 \pm 0.04\%$	$3.06 \pm 0.05\%$	$1.69 \pm 0.04\%$
11.4	$0.51 \pm 0.04\%$	$2.81 \pm 0.05\%$	-

MC11 ($\nu = 2$): $\epsilon = 1.27 \pm 0.01\%$

Selection:

Kaons:

- $DLL_{K\pi} > 0$
- $DLL_{Kp} > 0$
- $p_T(K^{\pm}) > 500$
- IP$\chi^2 > 10$
- Trackχ^2/ndof < 5

ϕ:

- $\Delta M[\phi(1020)] < 15$ MeV
- Vertex$\chi^2 < 15$

Photons:

- $p_T(\gamma) > 2600$ MeV
- $\gamma_{CL} > 0.25$ (only if SPD/PS)

B_s:

- $\Delta M[B_s] < 1$ GeV
- IP$\chi^2 < 15$
- $p_T(B_s) > 2$ GeV
- $\theta_{DIRA} < 20$ mrad

Efficiencies

Config.	Selection	Efficiency $\phi \to K^+K^-$	Efficiency $B_s \to \phi\gamma$
VP1	Standard	$20.66 \pm 0.13\%$	$2.52 \pm 0.05\%$
New	Standard	$19.15 \pm 0.12\%$	$\mathbf{3.43} \pm 0.06\%$
VP1	Loose	$30.79 \pm 0.15\%$	$9.77 \pm 0.10\%$
New	Loose	$31.81 \pm 0.14\%$	$\mathbf{14.38} \pm 0.11\%$

Photon reconstruction efficiency increased by $\sim$ **40%** in the noSPD/PS configuration.

- Standard selection: same as previous slide, without γ_{CL}.

Loose selection:

Kaons:

- $DLL_{K\pi} > -10$
- $p_T(K^{\pm}) > 500$
- IP$\chi^2 > 10$
- Trackχ^2/ndof < 5

ϕ:

- $\Delta M[\phi(1020)] < 15$ MeV
- Vertex$\chi^2 < 15$

Photons:

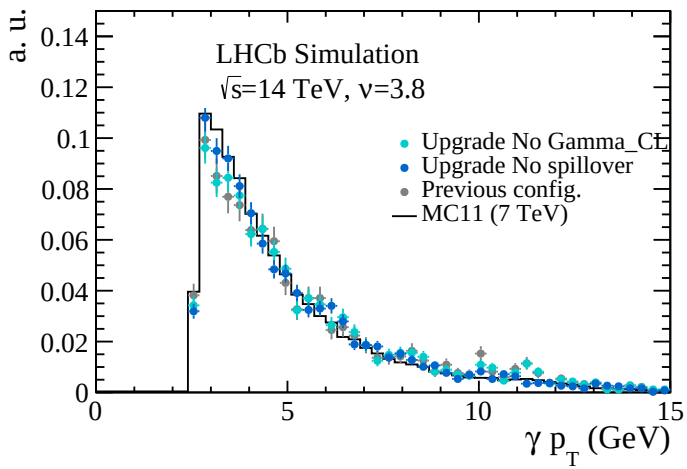
- -

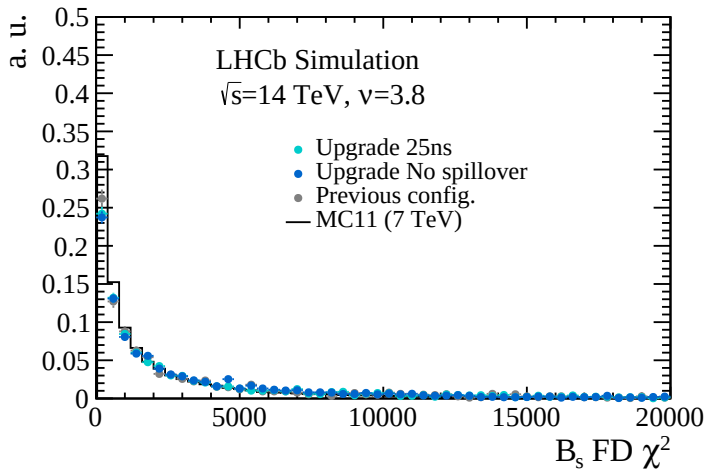
B_s:

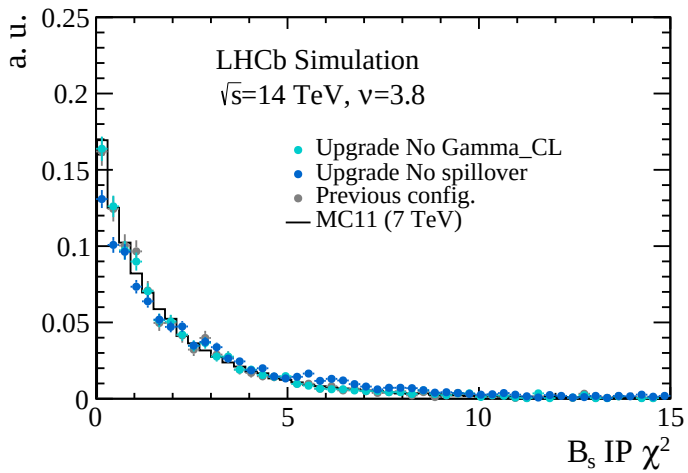
- $\Delta M[B_s] < 1$ GeV
- IP$\chi^2 < 15$
- $p_T(B_s) > 0.5$ GeV

Efficiencies

- Variables distributions are very similar for the VP1 and New configurations.
- Photon reconstruction efficiency increases $\sim 40\%$.
  - Still background rejection (e and π^0) has to be studied.







Conclusions

- Photon calibration has been applied in the $B_s \to \phi\gamma$ upgrade samples.
  - B_s mass shift and τ resolution corrected.
  - τ resolution width improves by $\sim 10\%$.
  - Variable cuts still biasing the τ resolution (to understand).
- $B_s \to \phi\gamma$ efficiency:
  - Photon reconstruction efficiency increases $\sim 40\%$ without SPD/PS.
  - $B_s \to \phi\gamma$ efficiency largerly affected by pile-up and nPV.
  - Background rejection (e and π^0) still has to be studied.
- After the first year of upgrade data taking, we expect a sensitivity on the photon polarization parameter $\sigma_{\mathcal{A}^\Delta} \sim 0.1$. The τ resolution bias has to be much less than 5 fs.
  - The upgrade calorimeter is crucial for this task.