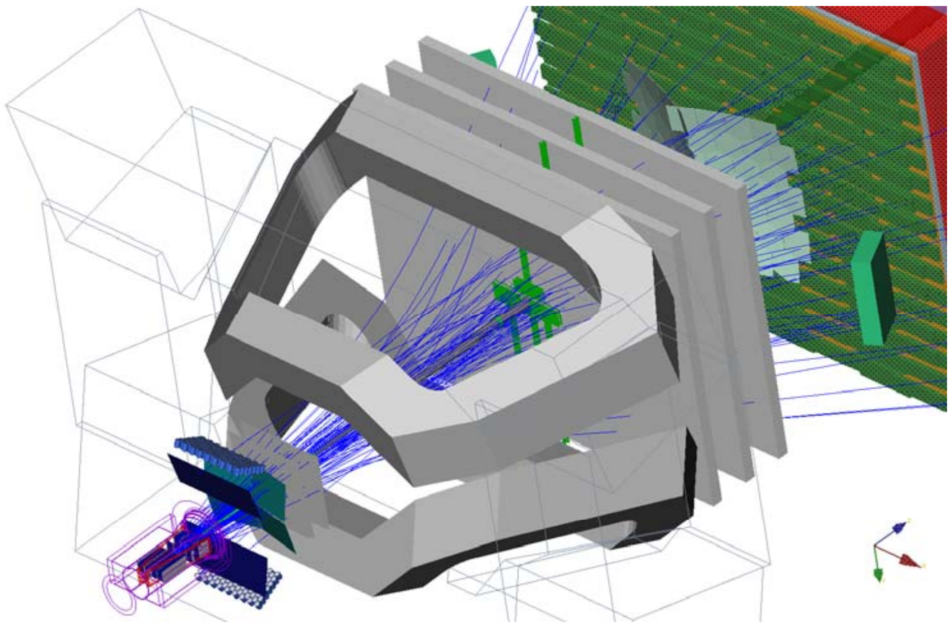
CERN Theory Institute: Flavour as a window to New Physics at the LHC: May 5 –June 13, 2008

LHCb Physics Programme

Marcel Merk
For the LHCb Collaboration
May 26, 2008

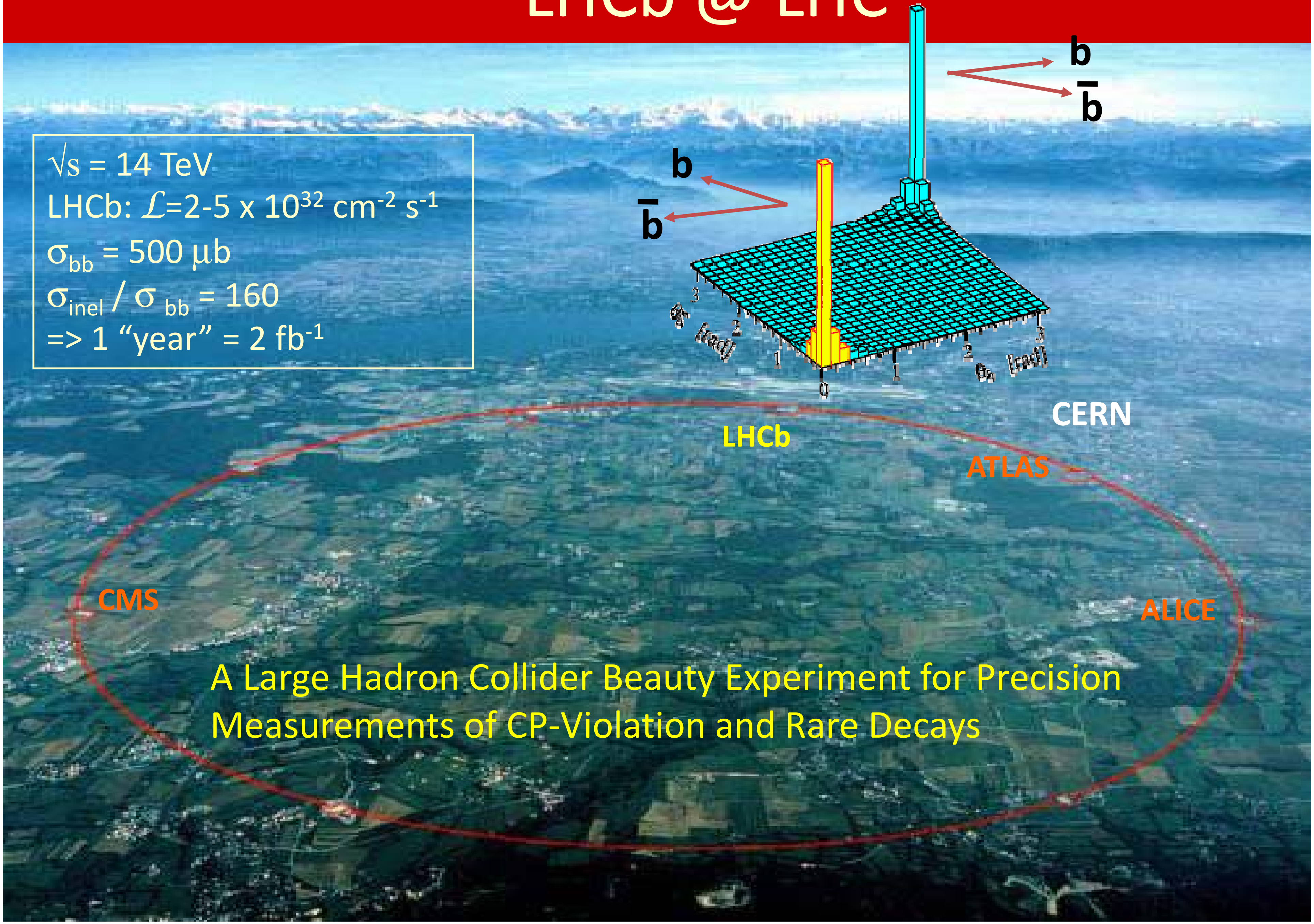


Contents:

- The LHCb Experiment
- Physics Programme:
    - CP Violation
    - Rare Decays

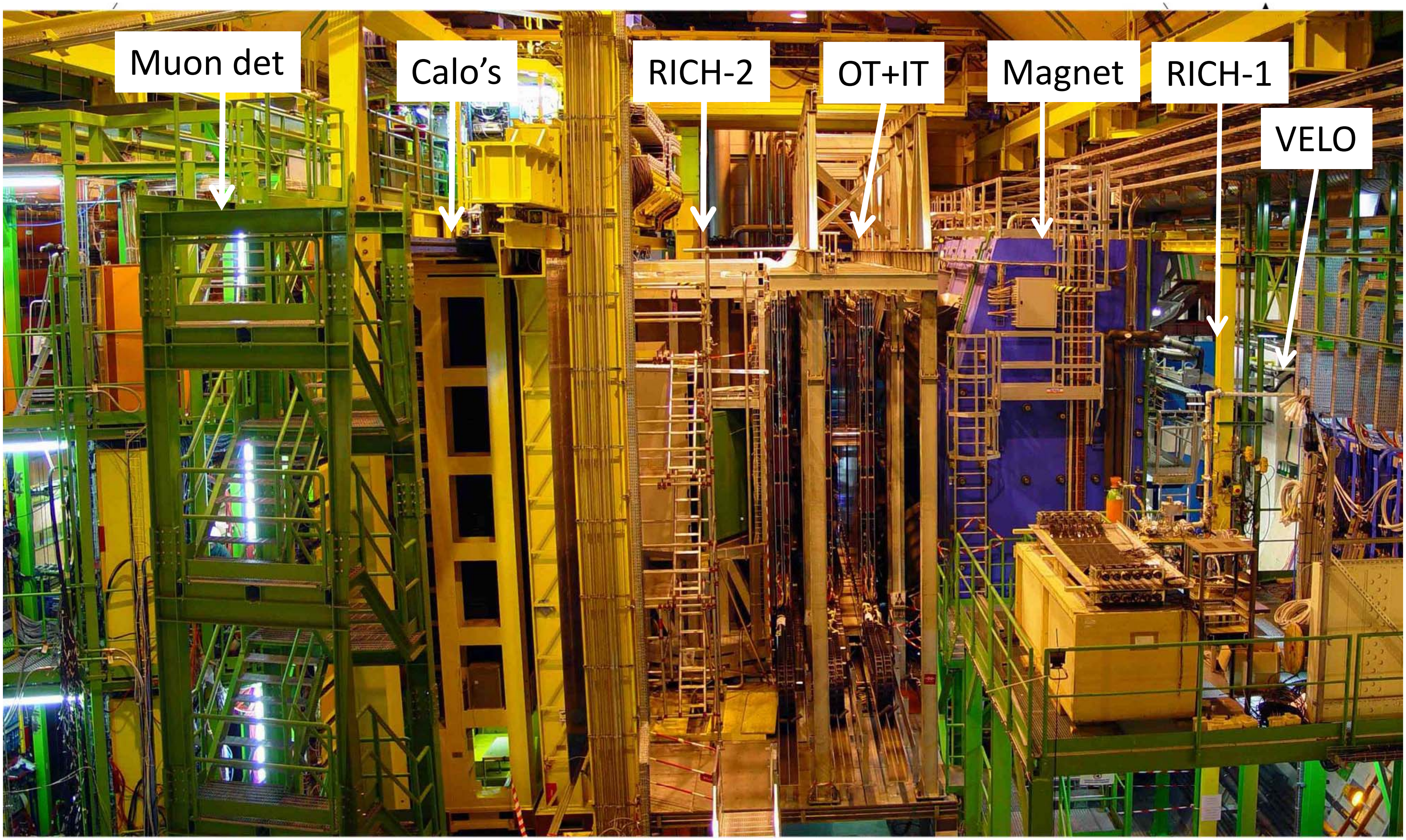
LHCb @ LHC

$\sqrt{s}$ = 14 TeV
LHCb: $\mathcal{L}$=2-5 x 10^{32} cm^{-2} s^{-1}
σ_{bb} = 500 μb
σ_{inel} / σ_{bb} = 160
=> 1 “year” = 2 fb^{-1}



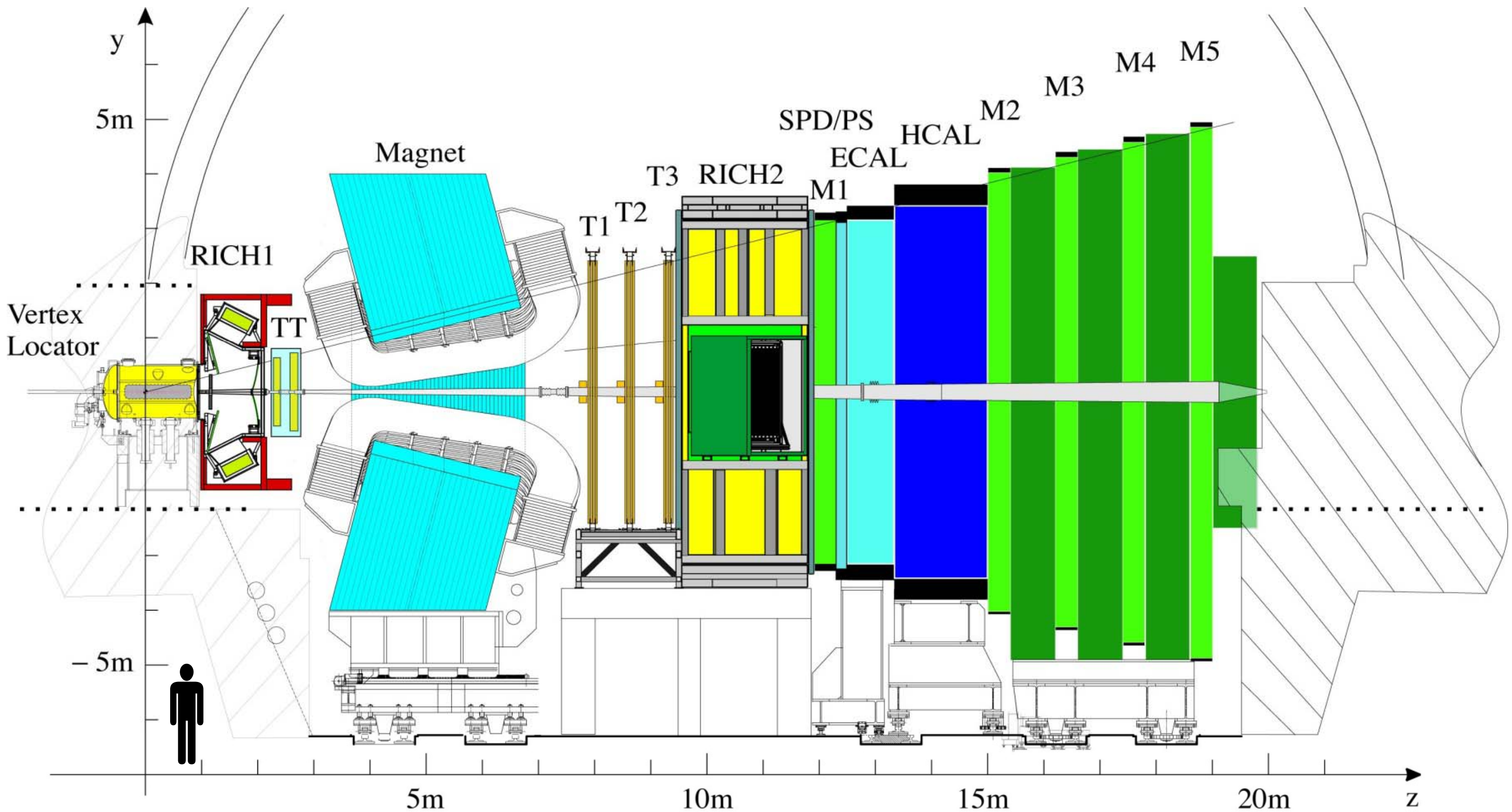
A Large Hadron Collider Beauty Experiment for Precision Measurements of CP-Violation and Rare Decays

The LHCb Detector

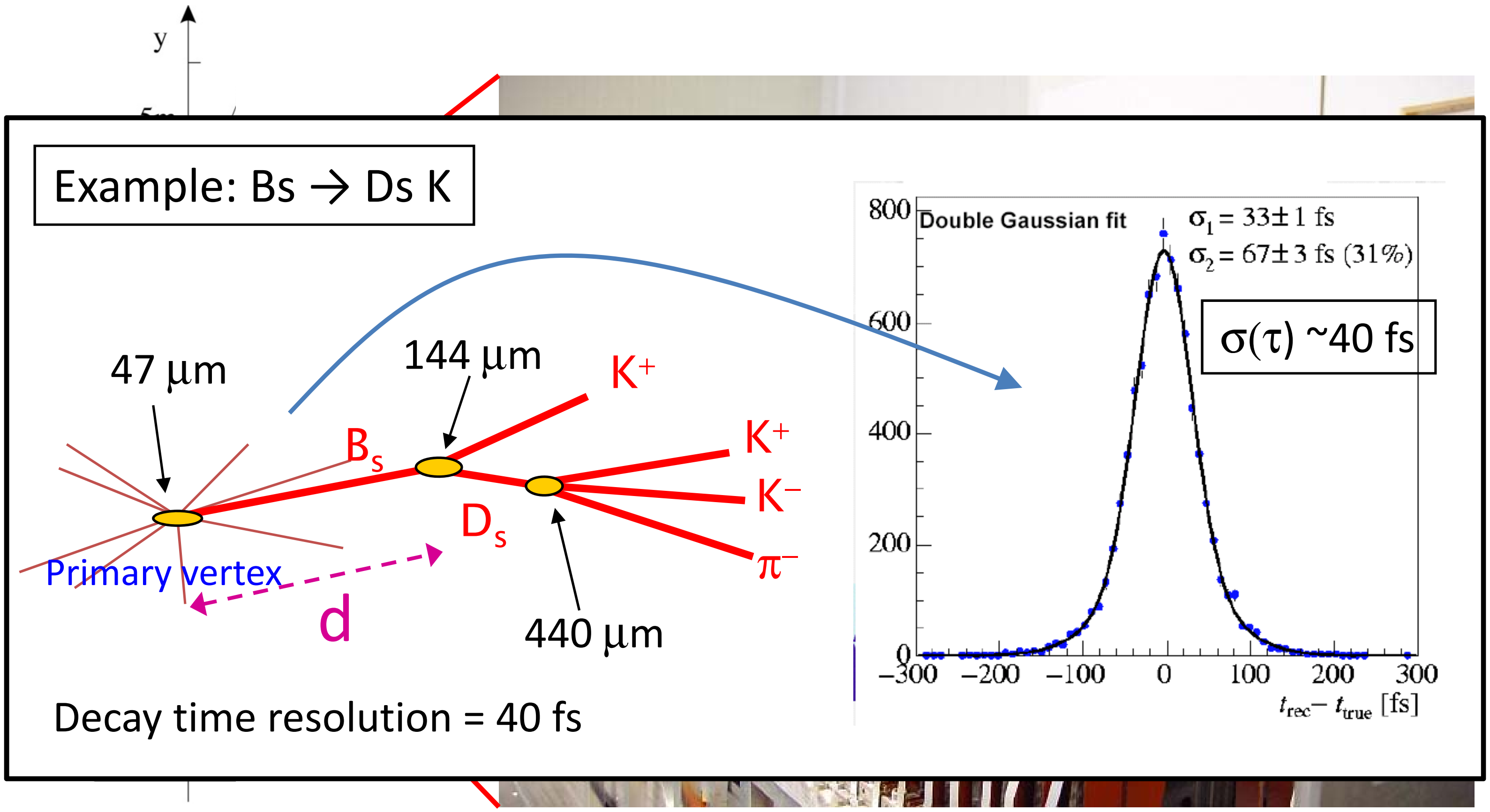


Installation of major structures is complete

A walk through the LHCb spectrometer…



B-Vertex Measurement



Vertex Locator (Velo)

Silicon strip detector with

~ 5 μm hit resolution

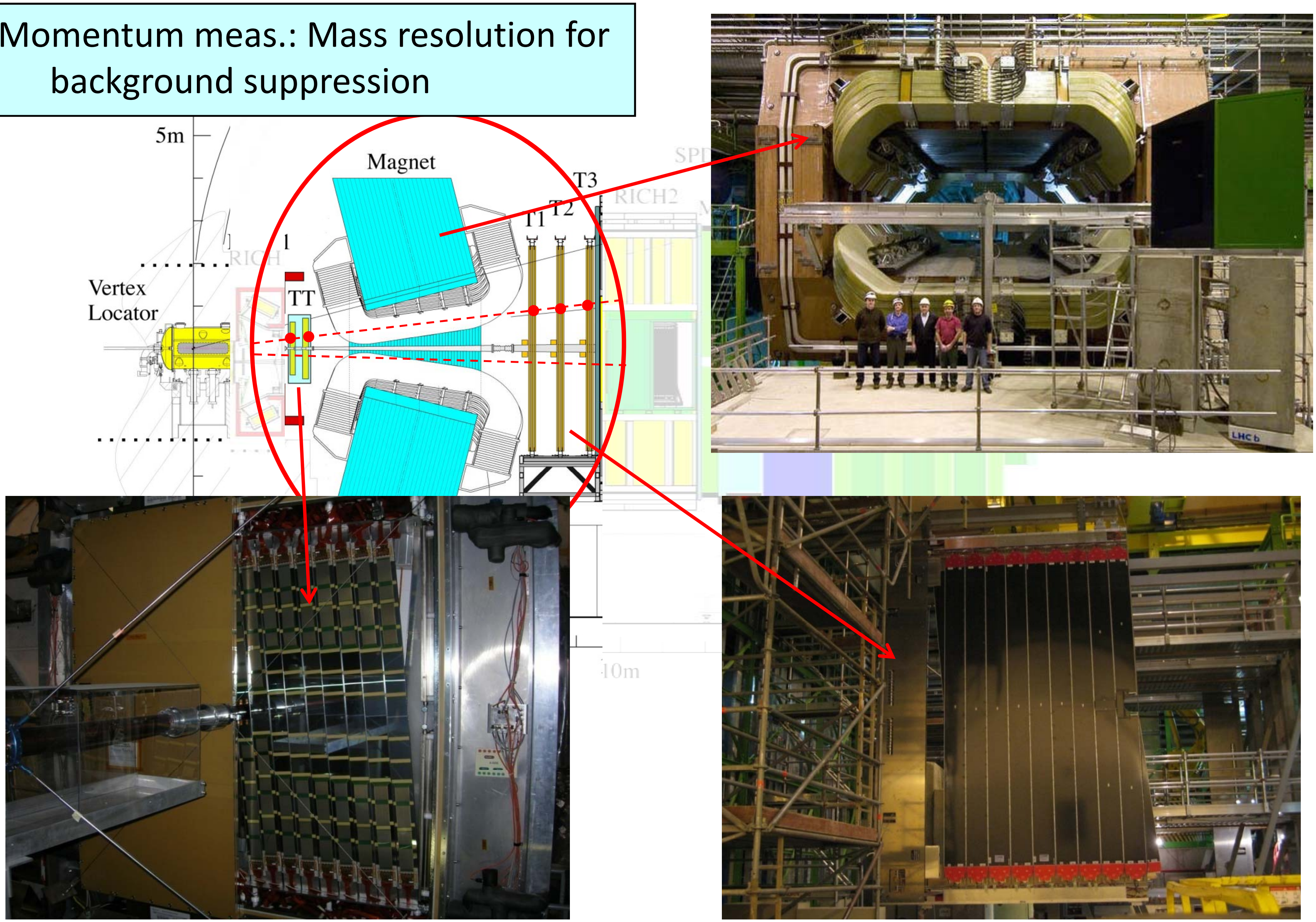
→ 30 μm IP resolution

Vertexing:

- Impact parameter trigger
- Decay distance (time) measurement

Momentum and Mass measurement

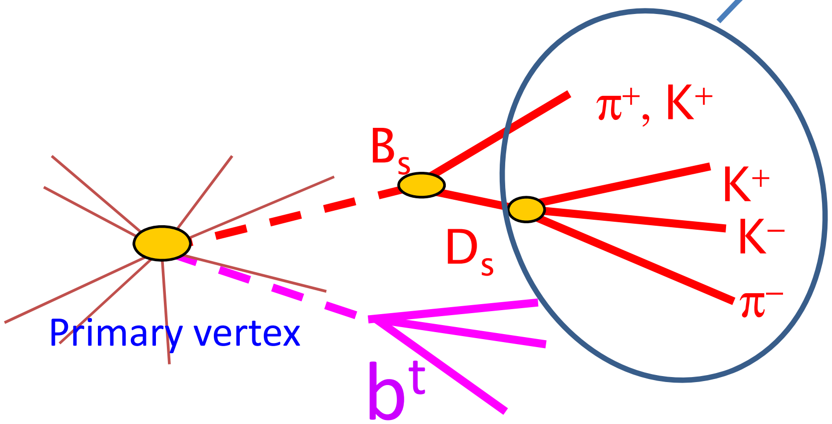
Momentum meas.: Mass resolution for background suppression

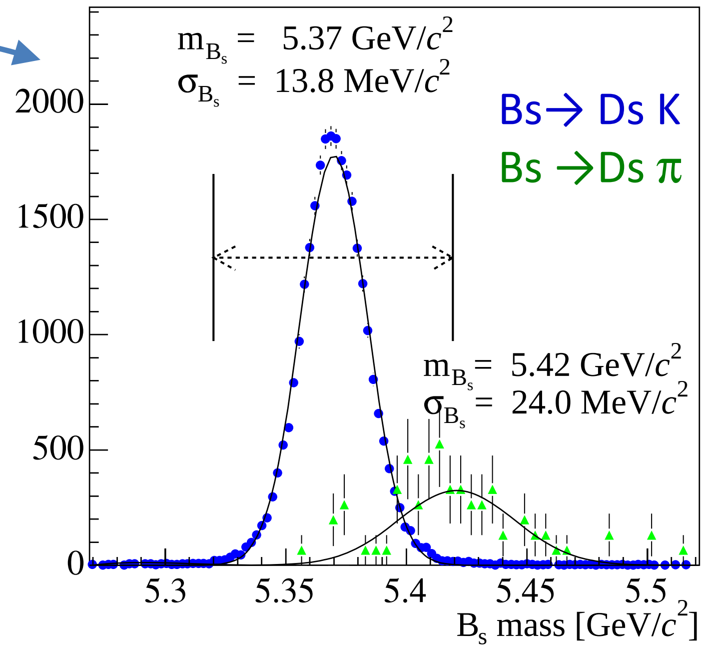


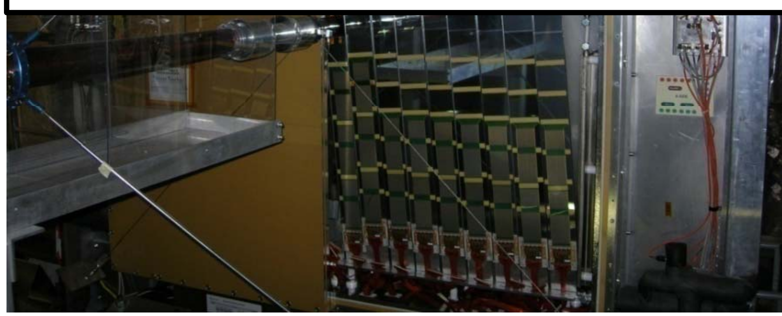
Momentum and Mass measurement

Momentum meas.: Mass resolution for background suppression

Mass resolution
σ ~14 MeV

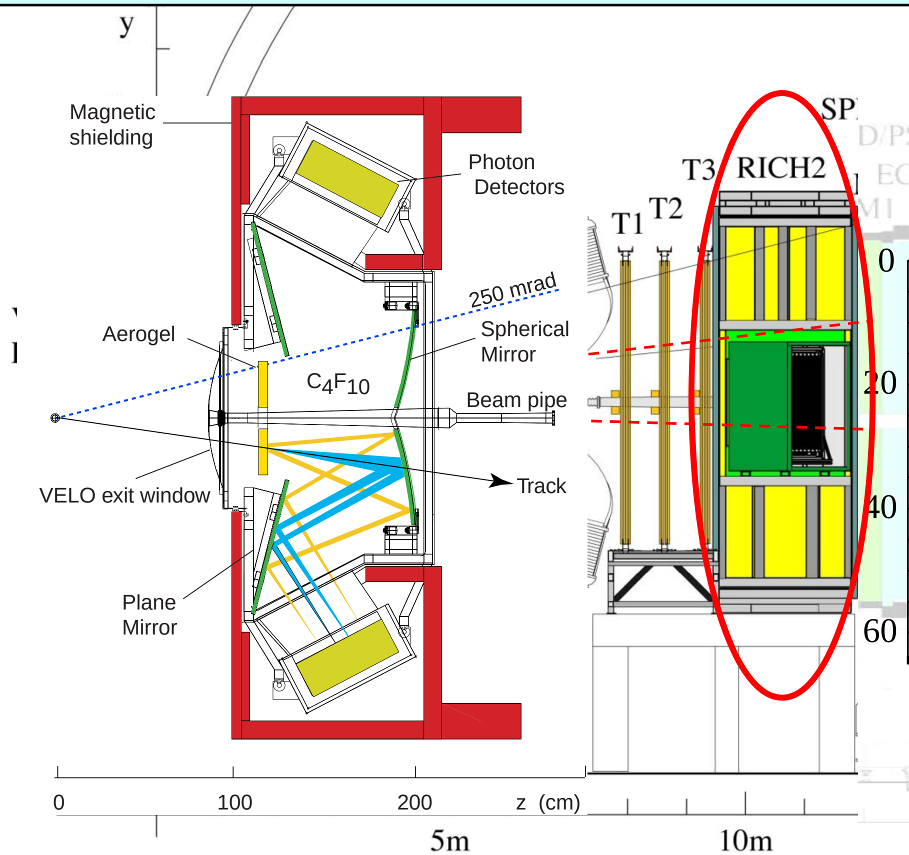






Particle Identification

RICH: K/π identification using Cherenkov light emission angle



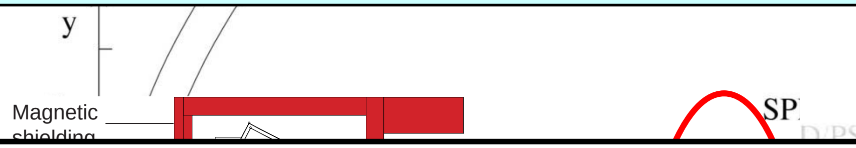
RICH1: 5 cm aerogel n=1.03

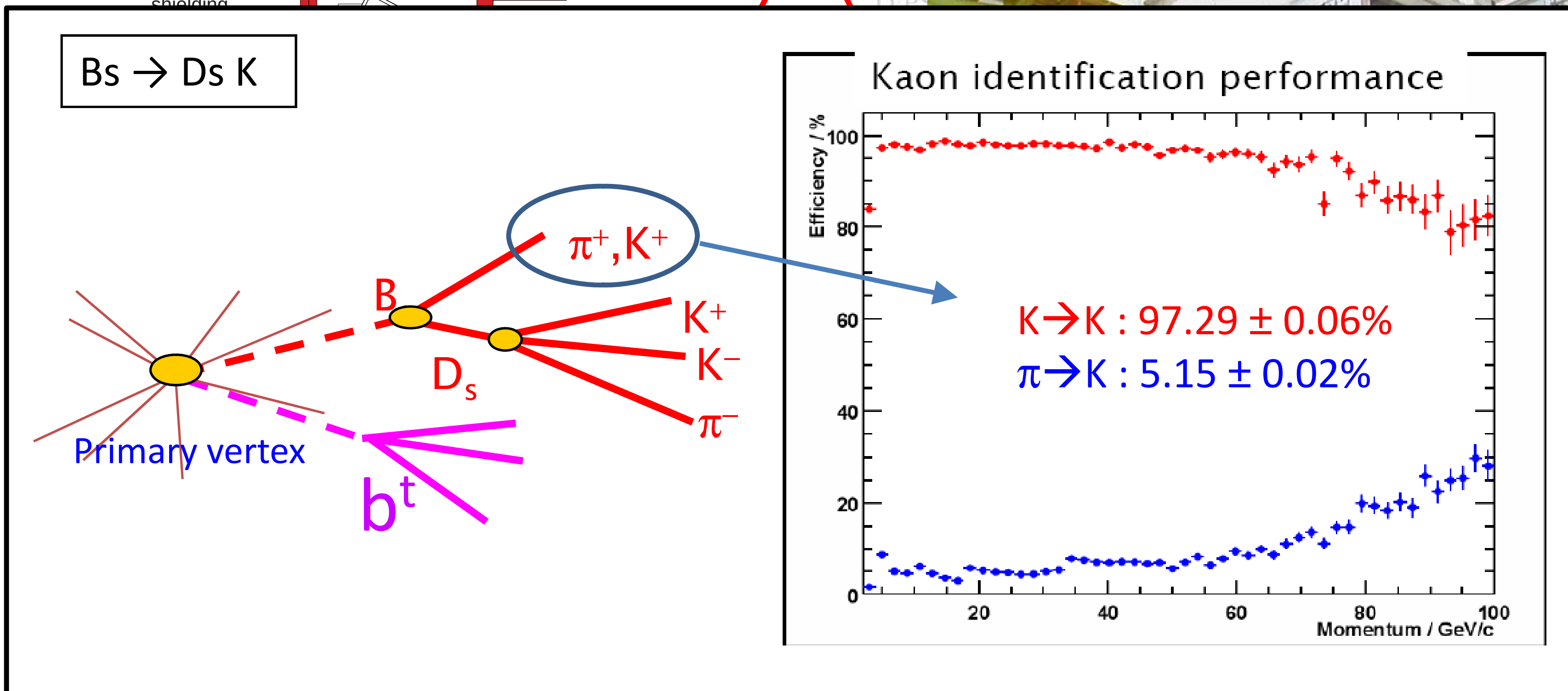
$4\ m^3\ C_4F_{10}$ n=1.0014

RICH2: 100 m3 CF4 n=1.0005

Particle Identification

RICH: K/π identification; eg. distinguish $D_s\pi$ and D_sK events.



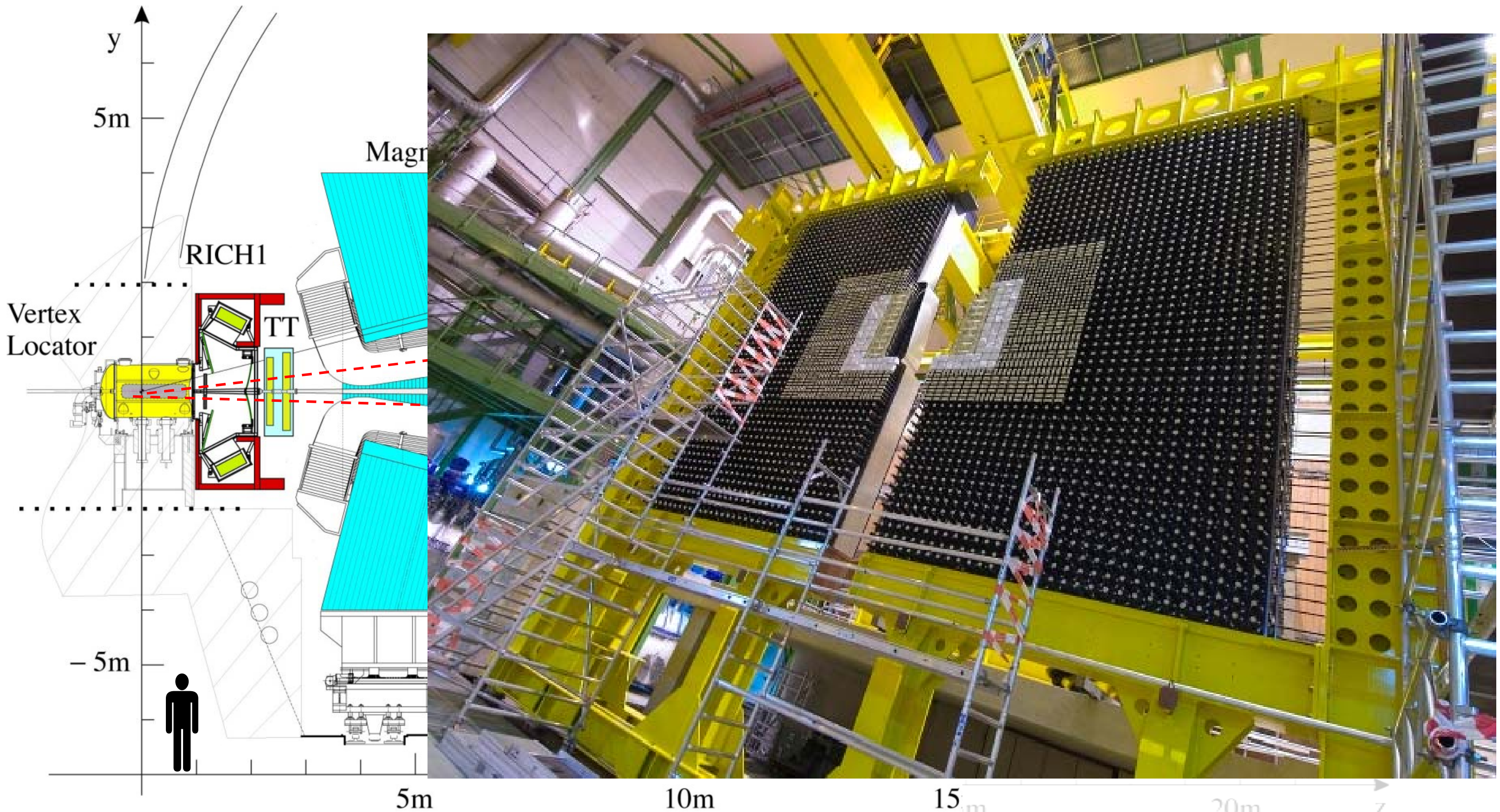


RICH1: 5 cm aerogel n=1.03

$4\ m^3\ C_4F_{10}$ n=1.0014

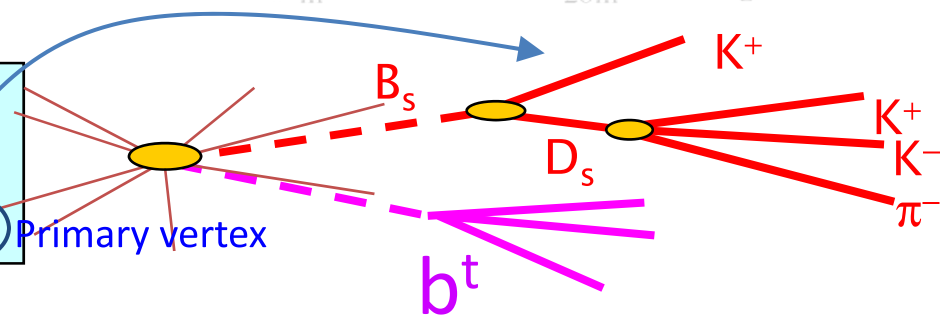
RICH2: 100 m3 CF4 n=1.0005

LHCb calorimeters

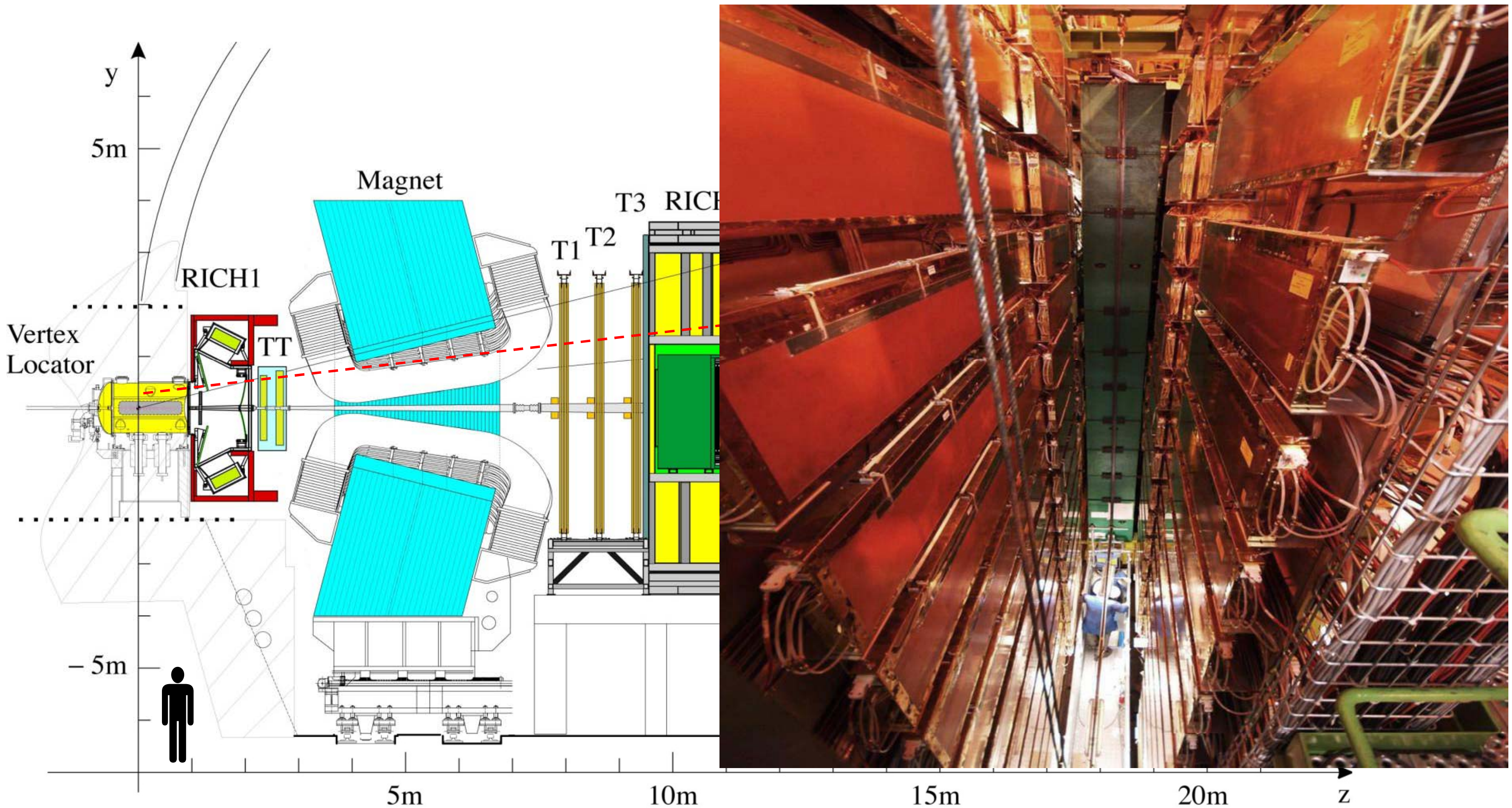


Calorimeter system :

- Identify electrons, hadrons, neutrals
- Level 0 trigger: high E_T electron and hadron

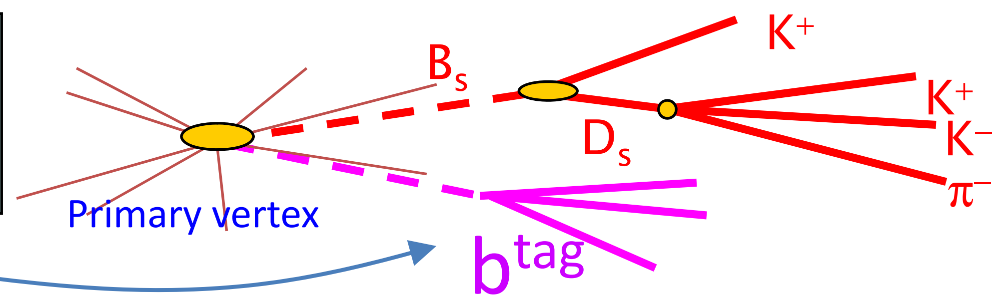


LHCb muon detection



Muon system:

- Level 0 trigger: High Pt muons
- Flavour tagging: $\varepsilon D^2 = \varepsilon\,(1\text{-}2w)^2 \approx 6\%$



LHCb trigger

Detector

40 MHz ↓

L0: high p_T (μ, e, γ, h) [hardware, 4 μs]

1 MHz ↓

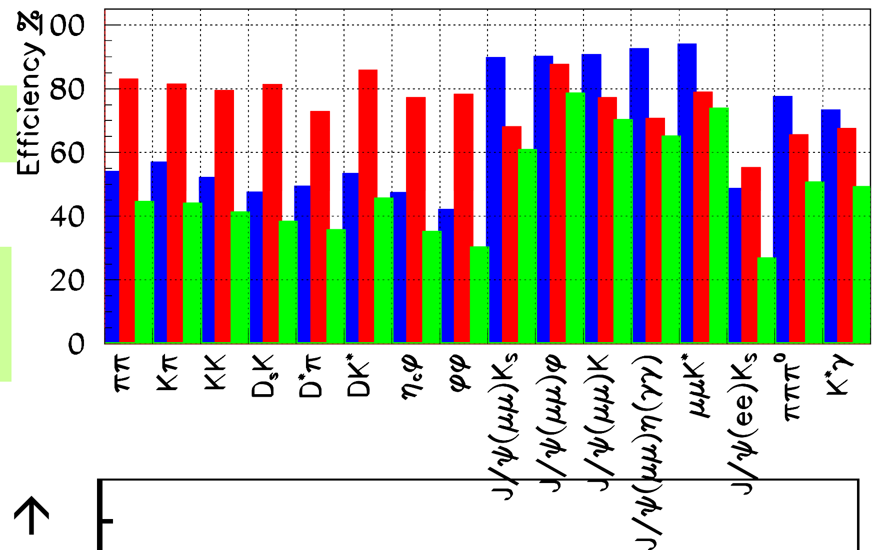
HLT: high IP, high p_T tracks [software]
then full reconstruction of event

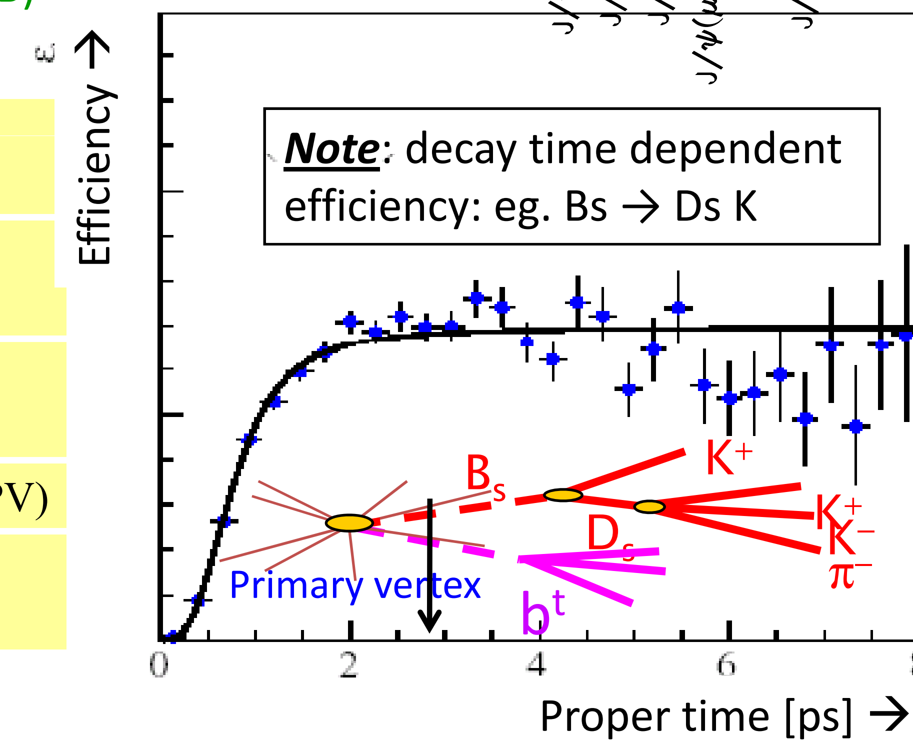
2 kHz ↓

Storage (event size ~ 50 kB)

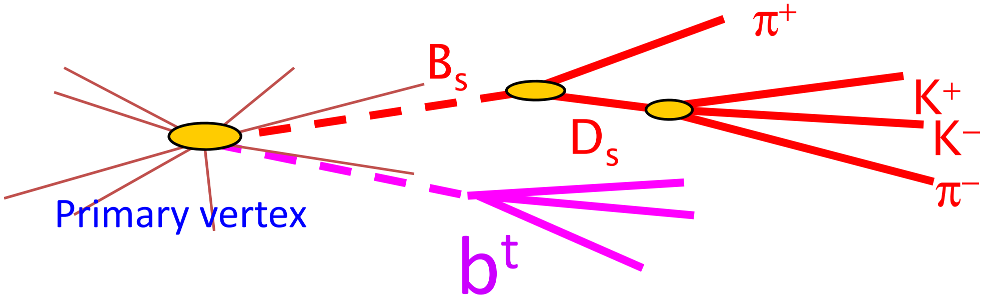
HLT rate	Event type	Physics
200 Hz	Exclusive B candidates	B (core program)
600 Hz	High mass di-muons	J/ψ, b→J/ψX (unbiased)
300 Hz	D* candidates	Charm (mixing & CPV)
900 Hz	Inclusive b (e.g. b→μ)	B (data mining)

L0, **HLT** and **L0×HLT** efficiency

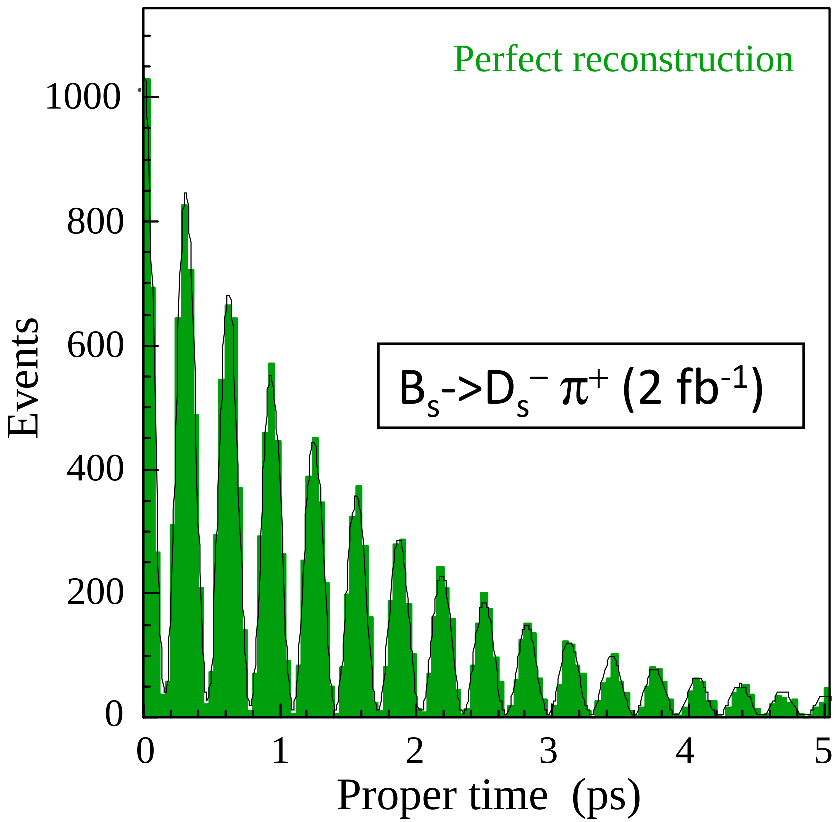




Measuring time dependent decays



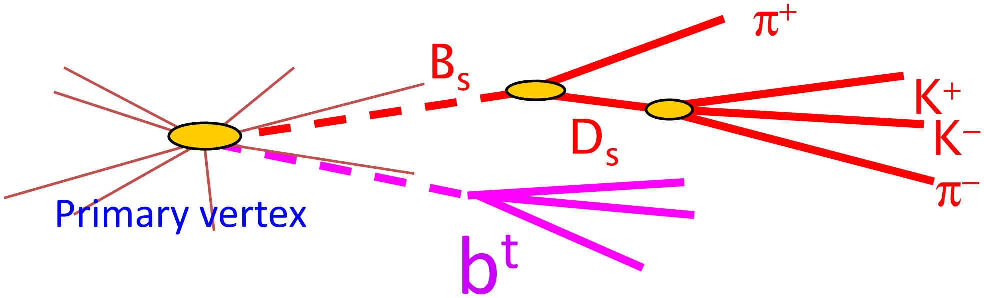
Measurement of Bs oscillations:



Experimental Situation:

- Ideal measurement (no dilutions)

Measuring time dependent decays

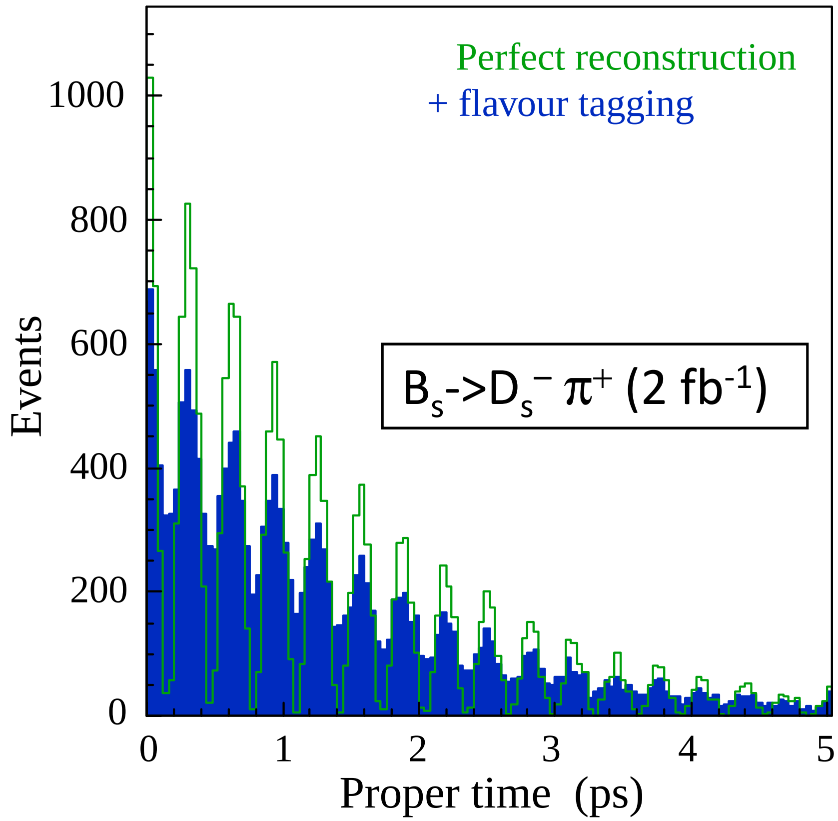


Experimental Situation:

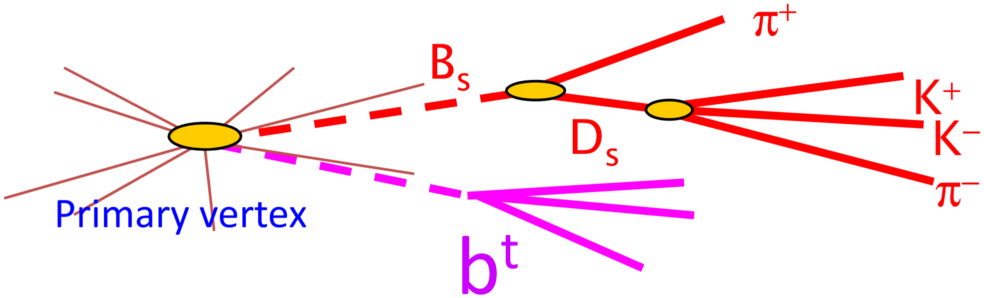
Ideal measurement (no dilutions)

+ Realistic flavour tagging dilution

Measurement of Bs oscillations:



Measuring time dependent decays



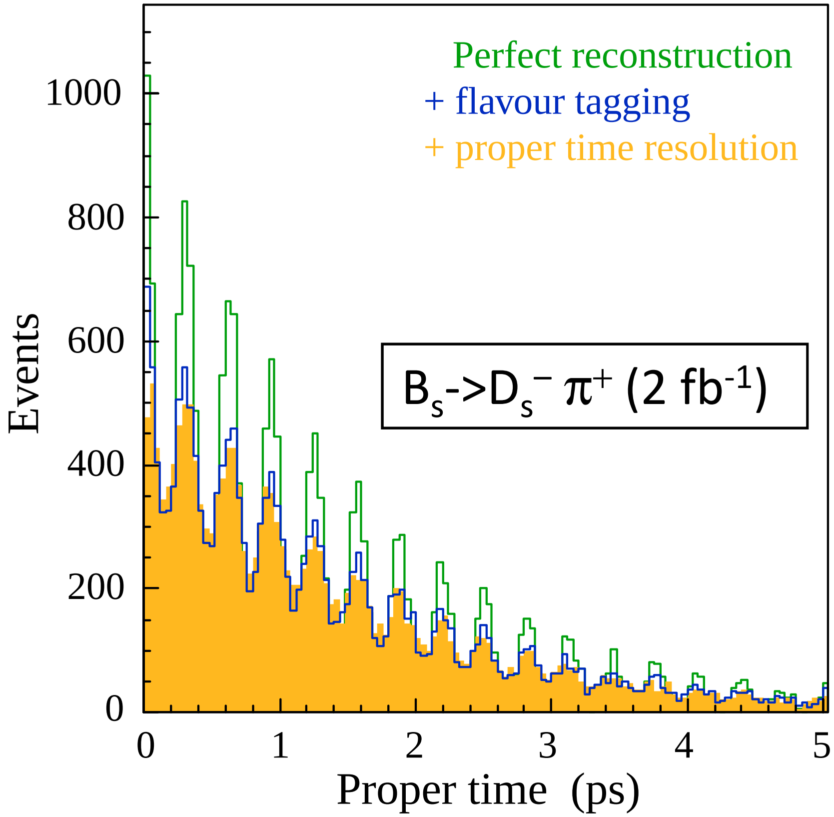
Experimental Situation:

Ideal measurement (no dilutions)

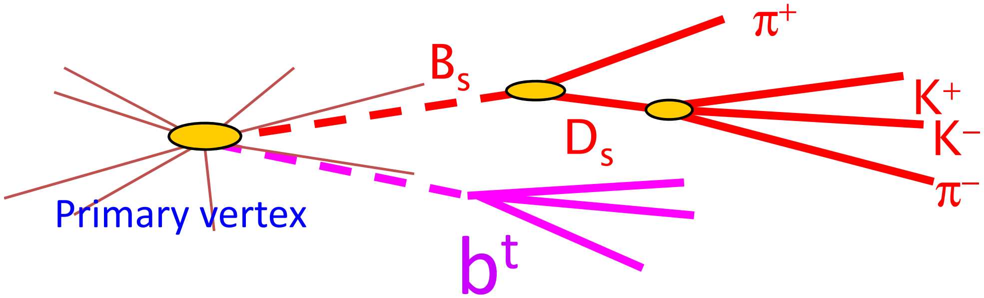
+ Realistic flavour tagging dilution

+ Realistic decay time resolution

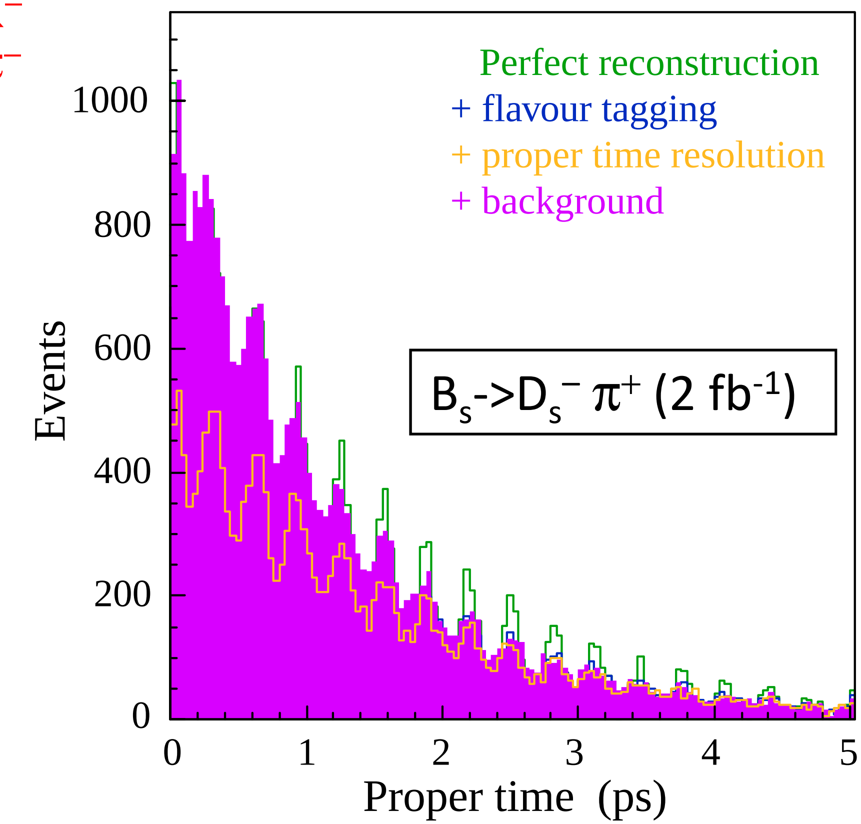
Measurement of Bs oscillations:



Measuring time dependent decays



Measurement of Bs oscillations:



Experimental Situation:

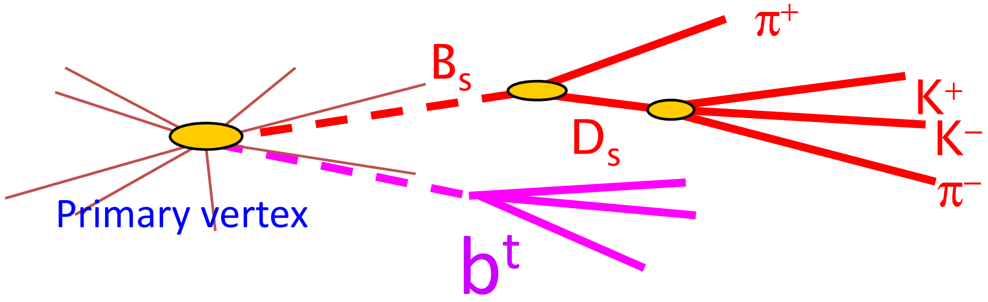
Ideal measurement (no dilutions)

+ Realistic flavour tagging

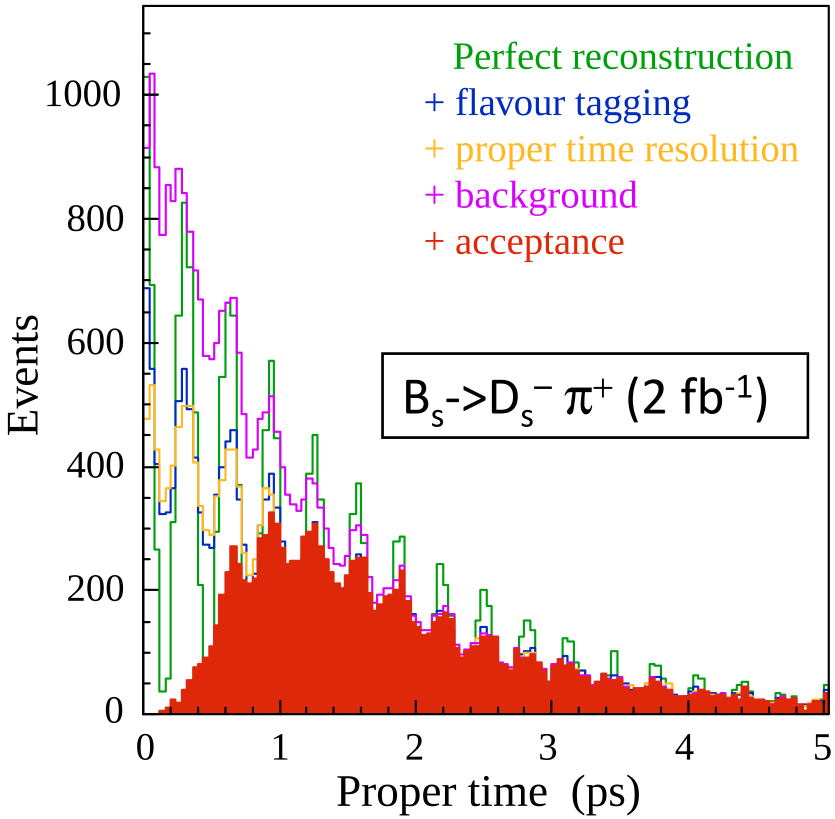
+ Realistic decay time resolution

+ Background events

Measuring time dependent decays



Measurement of Bs oscillations:



Experimental Situation:

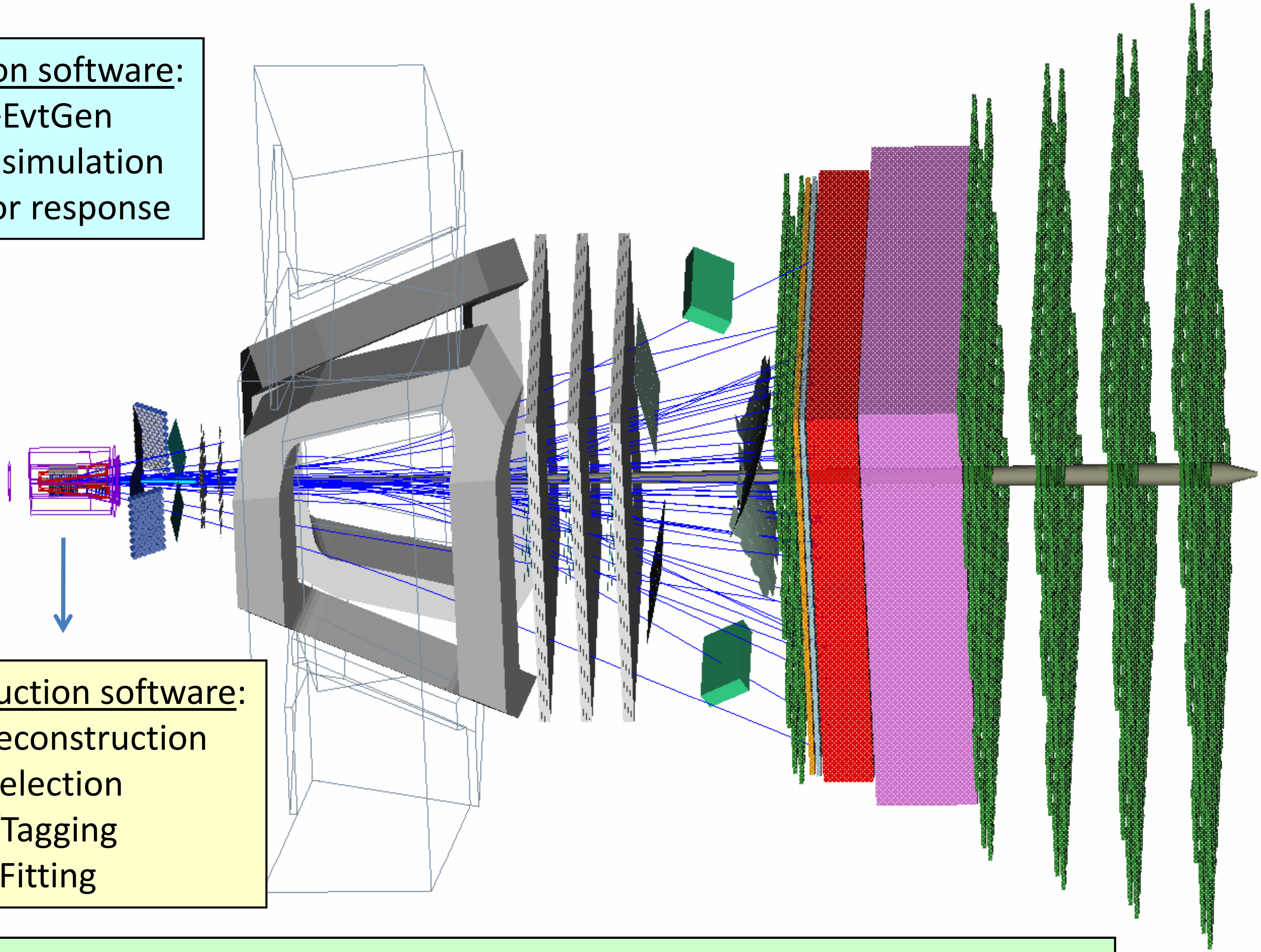
Ideal measurement (no dilutions)
+ Realistic flavour tagging dilution
+ Realistic decay time resolution
+ Background events
+ Trigger and selection acceptance

Two equally important aims for the experiment:

- Limit the dilutions: good resolution, tagging etc.
- Precise knowledge of dilutions

Expected Performance: GEANT MC simulation

Simulation software:
- Pythia+EvtGen
- GEANT simulation
- Detector response



Reconstruction software:
- Event Reconstruction
- Decay Selection
- Trigger/Tagging
- Physics Fitting

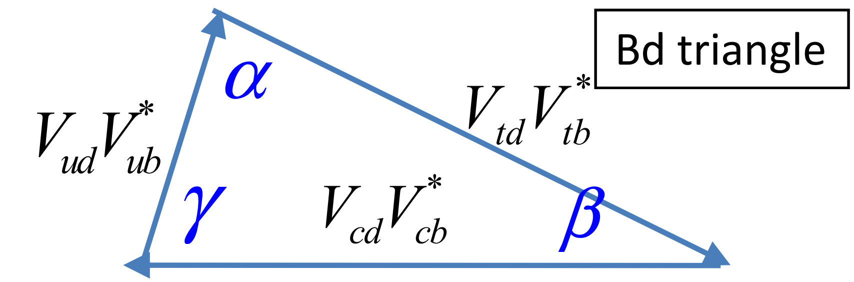
Used to optimise the experiment and to test physics sensitivities

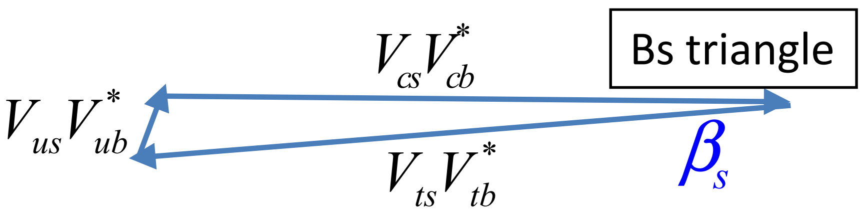
Physics Programme

LHCb is a heavy flavour precision experiment searching for new physics in CP-Violation and Rare Decays

→
- CP Violation
- Rare Decays

CP Violation – LHCb Program

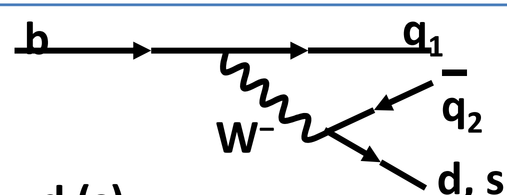


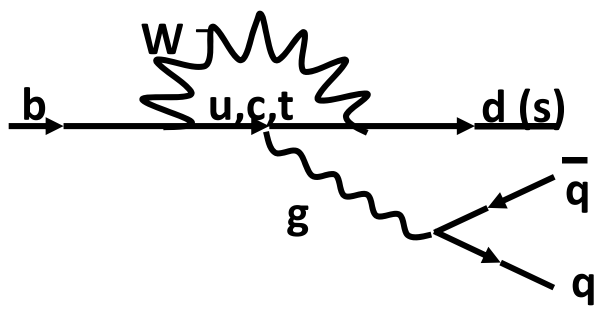


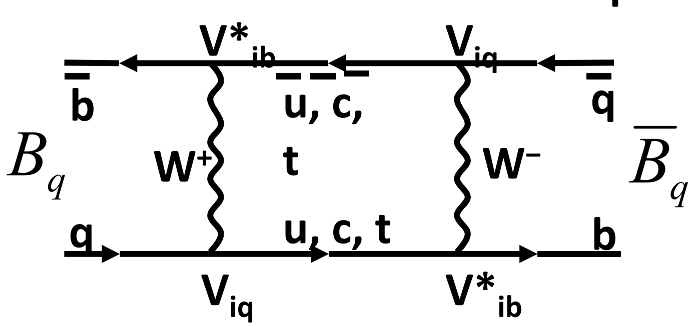
$$V_{CKM} \approx \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3 e^{-i\gamma} \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3 e^{-i\beta_d} & -A\lambda^2 e^{i\beta_s} & 1 \end{pmatrix}$$

$$\alpha = \arg\left(-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right) \quad ; \quad \beta = \arg\left(-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}\right)$$

$$\gamma = \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right) \quad ; \quad \beta_s = \arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right)$$







B_d mixing phase (SM): $\phi_d = 2\beta$

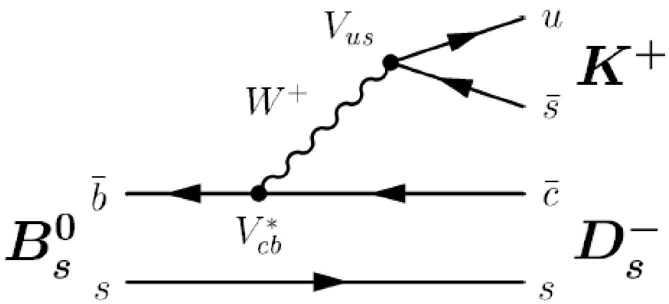
B_s mixing phase (SM): $\phi_s = -2\beta_s$

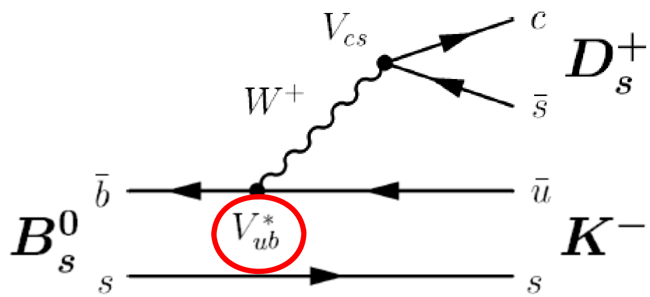
CP Program: Is CKM fully consistent for trees, boxes and penguins?

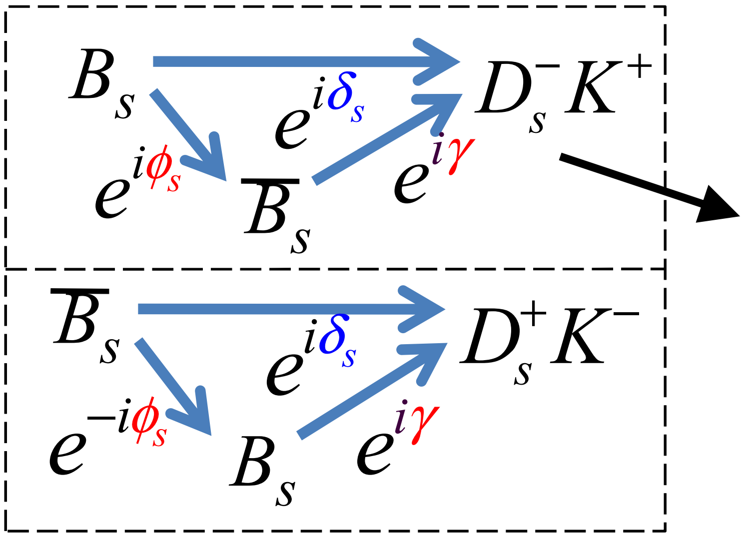
1. γ measurements from trees
2. γ measurement from penguins
3. β_s from the box: “Bs mixing phase”
4. β_s in penguins

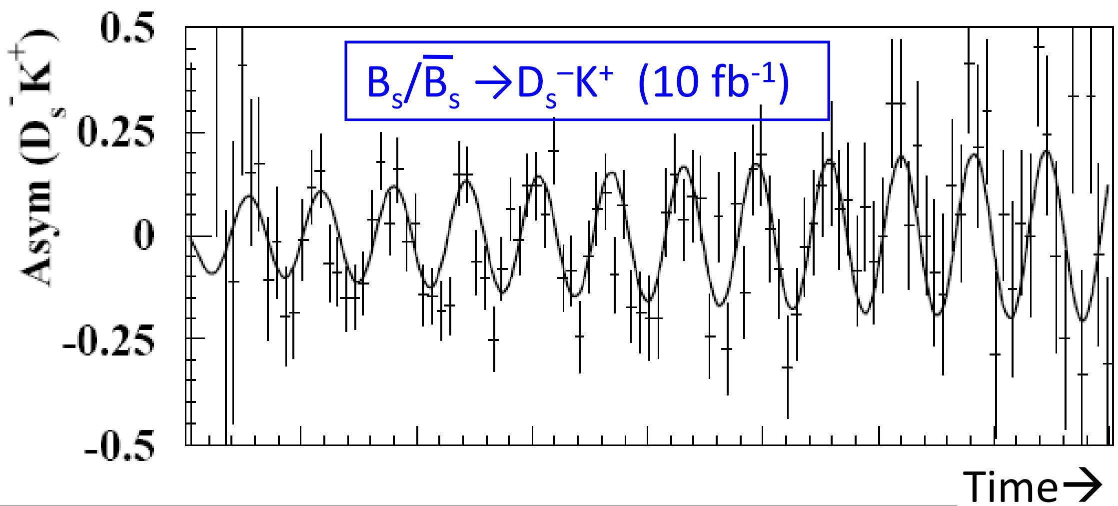
1.a $\gamma+\phi_s$ from trees: $B_s \to D_s K$

- Time dependent CP violation in interference of b→c and b→u decays:





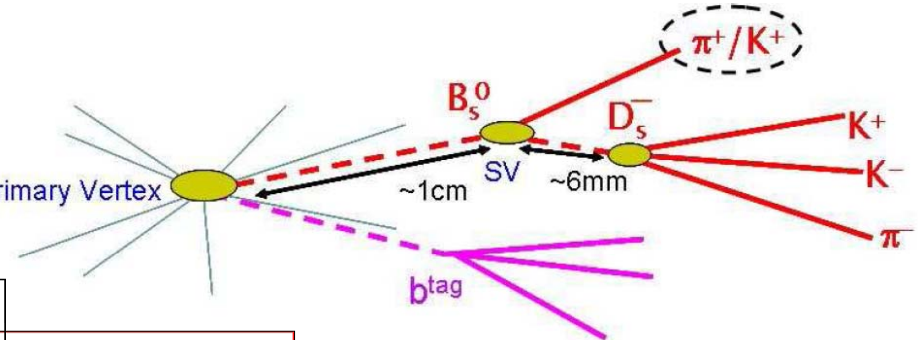


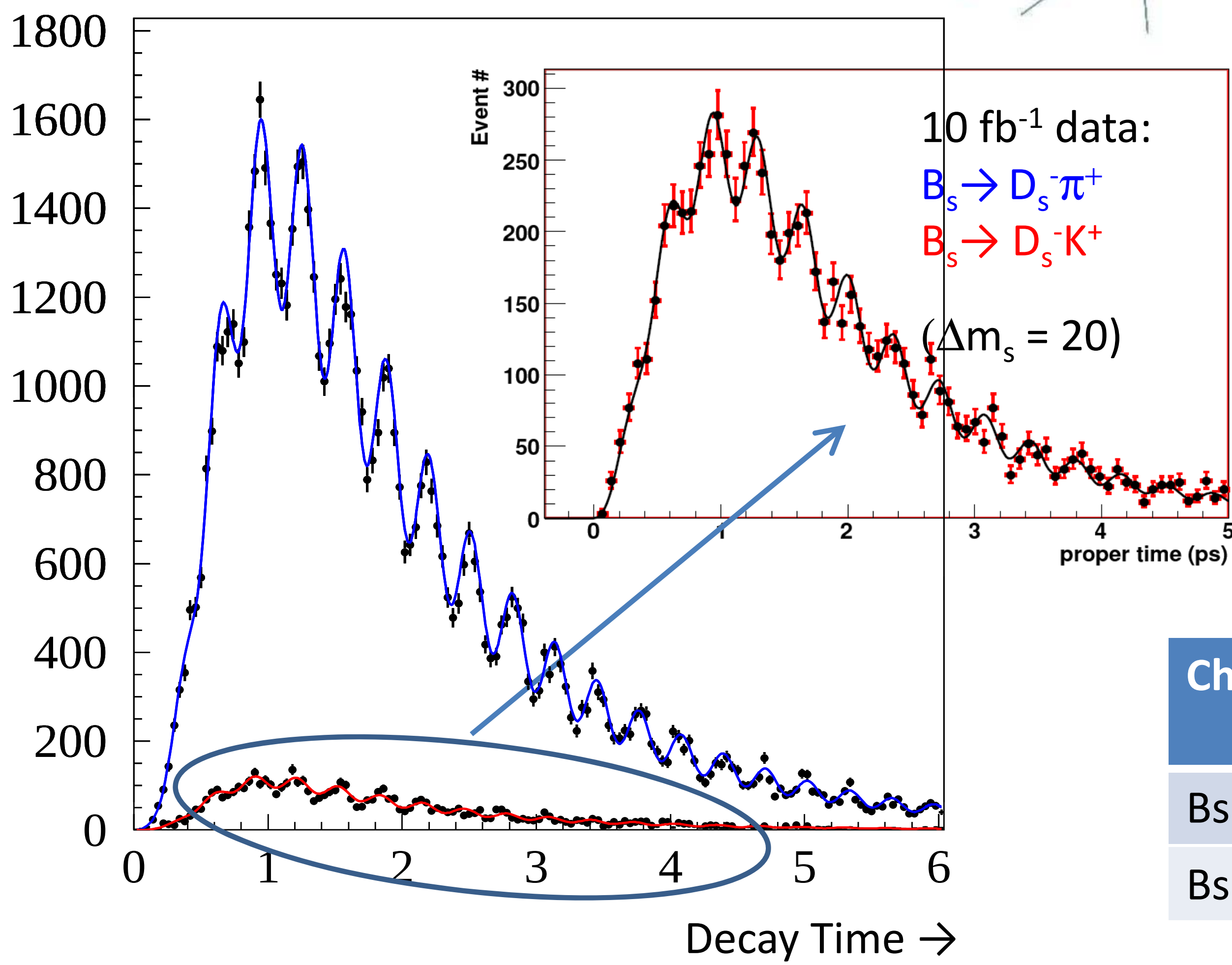


$$A^{B/\overline{B}}_{D_s^{\mp}K^{\pm}} = \frac{\left(1-|\lambda|^2\right)\cos\Delta m t - 2|\lambda|\sin\left(\delta_s \mp \left(\gamma+\phi_s\right)\right)\sin\left(\Delta m t\right)}{\left(1+|\lambda|^2\right)\cosh\frac{\Delta\Gamma t}{2} - 2|\lambda|\cos\left(\delta_s \mp \left(\gamma+\phi_s\right)\right)\sinh\left(\frac{\Delta\Gamma t}{2}\right)}$$

$B_s \rightarrow D_s K$

- Since same topology $B_s \rightarrow D_s K$, $B_s \rightarrow D_s\pi$ combine samples to fit Δm_s, $\Delta\Gamma_s$ and Wtag together with CP phase $\gamma+\phi_s$.





- Use lifetime difference $\Delta\Gamma_s$ to resolve some ambiguities (2 remain).

$$\sigma(\gamma+\phi_s) = 9^o\text{–}12^o$$

Channel	Yield (2 fb-1)	B/S (90% C.L.)
Bs→DsK	6.2 k	[0.08-0.4]
Bs→Dsπ	140 k	[0.08-0.3]

B →Dπ and B_s→D_sK

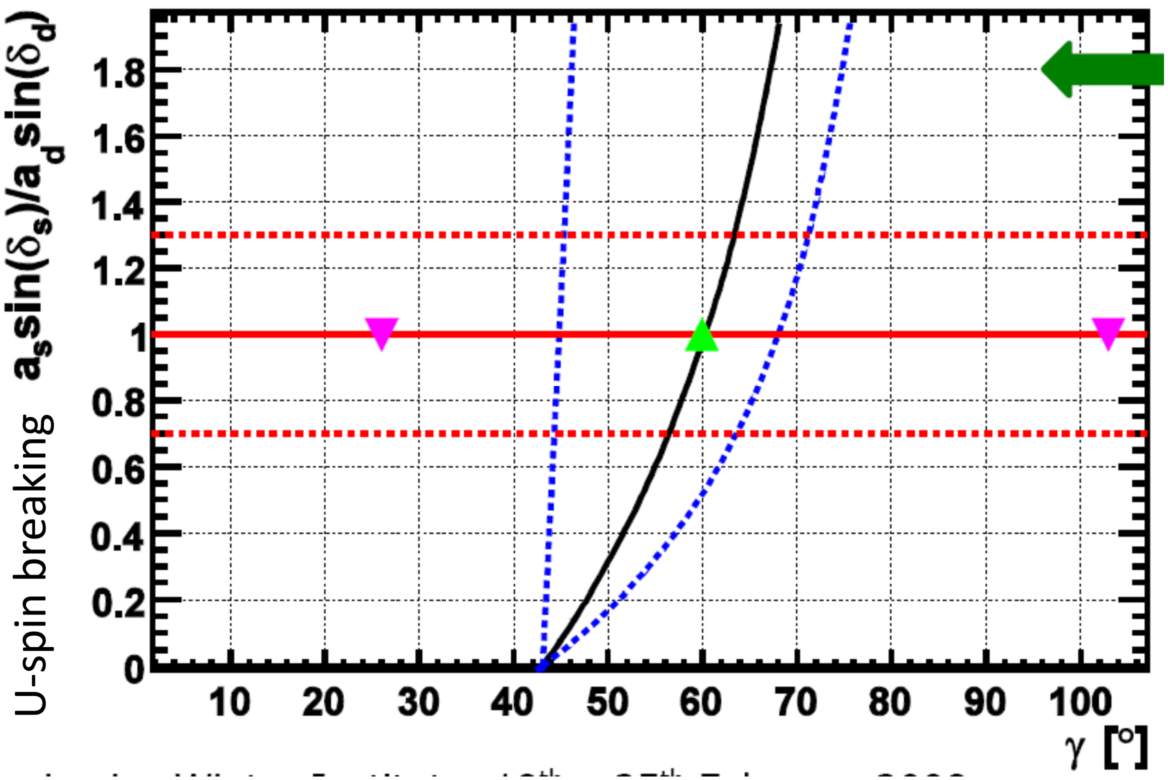
B → D(*)π measures γ in similar way as Bs→DsK

- More statistics, but smaller asymmetry
- No lifetime difference:

  8 –fold ambiguity for γ solutions

LHCb-2005-036

Channel	Yield (2 fb-1)	B/S
Bs→D*(K π) π	206 k	<0.3
B->D π	210 k	0.3



Invoking U-spin symmetry (d↔s) can resolve these ambiguities in a combined analysis of DsK and D(*)pi (Fleisher)

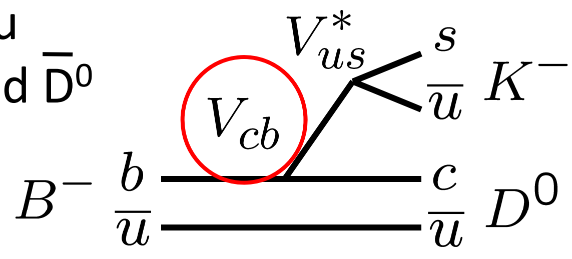
Can make an unambiguous extraction, depending on The value of strong phases:

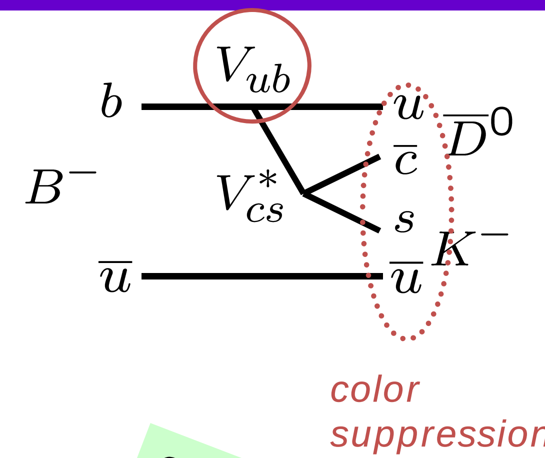
$\sigma(\gamma) < 10^o$ (in 2 fb^{-1})

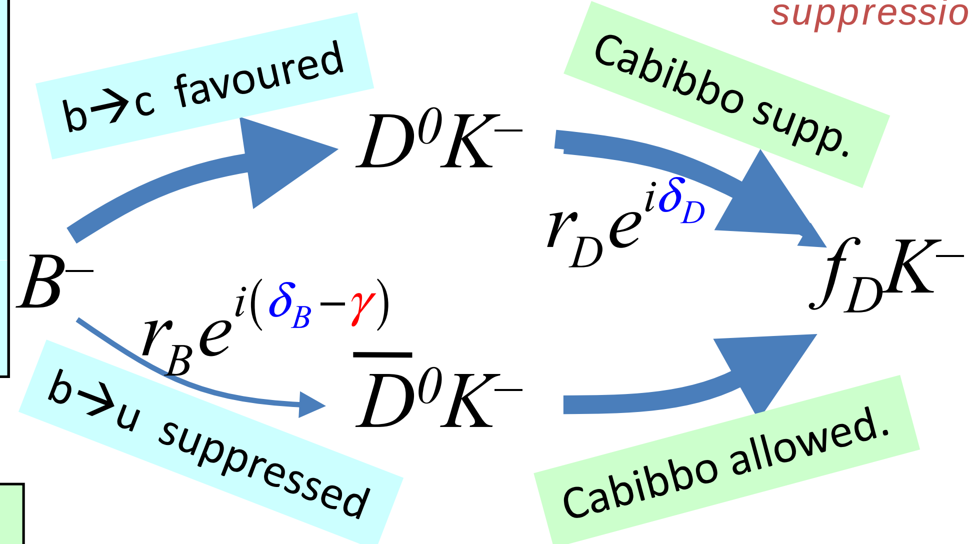
1.b γ from trees: B→DK

- Interfere decays b→c with b→u to final states common to D^0 and $\bar{D}^0$

$$\frac{A(B^- \to \bar{D}^0 K^-)}{A(B^- \to D^0 K^-)} = r_B e^{i\delta_B} e^{-i\gamma}$$







GLW method:

f_D is a CP eigenstate common to D^0 and $\bar{D}^0$: f_D= K^+K^-, $\pi^+\pi^-$,...

Measure: B→D^0K, B → $\bar{D}^0$K, B→ D_1K

- Large event rate; small interference
- Measurement r_B difficult

ADS method:

Use common flavour state f_D=($K^+\pi^-$)

Note: decay D^0→$K^+\pi^-$ is double Cabibbo suppressed

- Lower event rate; large interference

Decay time **in**dependent analysis

$B \to D^{(*)}K^{(*)}$

See talk of Angelo Carbone

GLW: $D \to KK$ (2 rates) ; $\Gamma\left(B^- \to \left(K^+K^-\right)_D K^-\right) \propto 1 + r_B^2 + 2r_B \cos\left(\delta_B - \gamma\right)$

ADS: $D \to K\pi$ (4 rates) ; $\Gamma\left(B^- \to \left(K^+\pi^-\right)_D K^-\right) \propto r_B^2 + \left(r_D^\pi\right)^2 2r_B r_D^\pi \cos\left(\delta_B + \delta_D^\pi - \gamma\right)$

ADS: $D \to K3\pi$ (4 rates) ; $\Gamma\left(B^- \to \left(K^+3\pi^-\right)_D K^-\right) \propto r_B^2 + \left(r_D^{3\pi}\right)^2 2r_B r_D^{3\pi} \cos\left(\delta_B + \delta_D^{3\pi} - \gamma\right)$

Channel	Yield (2 fb^{-1})	B/S
$B \to D(hh)\ K$	7.8 k	1.8
$B \to D(K\pi)\ K$, Favoured	56 k	0.6
$B \to D(K\pi)\ K$, Suppressed	0.71k	2
$B \to D(K3\pi)\ K$, Favoured	62k	0.7
$B \to D(K3\pi)\ K$, Suppressed	0.8k	2

Normalization is arbitrary:
7 observables for 5 unknows:
$\gamma, r_B, \delta_B, \delta_D^{\pi}, \delta_D^{3\pi}$

$\sigma(\gamma)$ = 5° to 13° depending on strong phases.

<u>Also under study:</u>

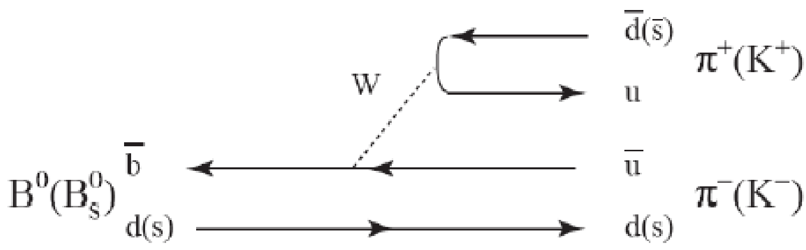
	$\sigma(\gamma)$	
$B^\pm \to DK^\pm$ with $D \to K_s\ \pi\pi$	8^0–12^o	Dalitz analyses
$B^\pm \to DK^\pm$ with $D \to KK\ \pi\pi$	18^o	Dalitz analyses
$B^0 \to DK^{*0}$ with $D \to KK, K\pi, \pi\pi$	6^o – 12^o	
$B^\pm \to D^*K^\pm$ with $D \to KK, K\pi, \pi\pi$	(high background)	

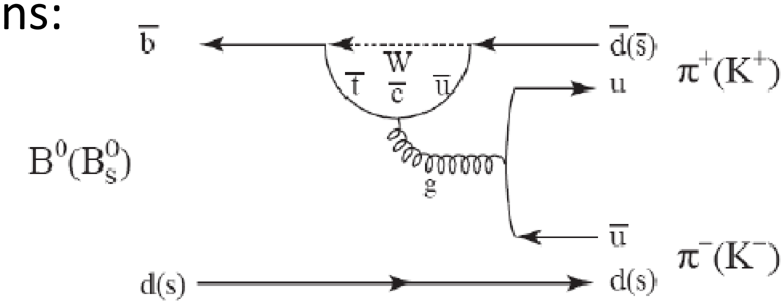
<u>Overall</u>: expect precision of $\sigma(\gamma)$ = 5° with 2 fb^{-1} of data

2. γ from loops: $B_{(s)} \rightarrow hh$

See talk of Angelo Carbone

- Interfere b→ u tree diagram with penguins:





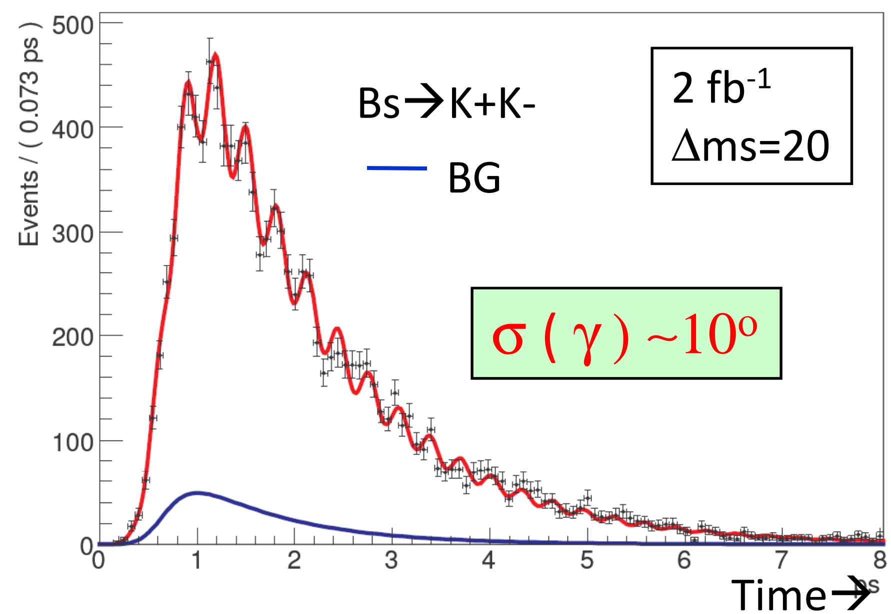
$$A_f^{CP}(t) = \frac{A_f^{dir}\cos\Delta m t + A_f^{mix}\sin\Delta m t}{\cosh\left(\frac{\Delta\Gamma t}{2}\right) - A_f^{\Delta}\sinh\left(\frac{\Delta\Gamma t}{2}\right)}$$

$$A_{mix}^{\pi\pi} = f_1(d,\theta,\sin\phi_d) \quad ; \quad A_{dir}^{\pi\pi} = f_2(d,\theta,\sin\gamma)$$

$$A_{dir}^{KK} = f_3(d',\theta',\sin\gamma) \quad ; \quad A_{mix}^{KK} = f_4(d',\theta',\sin\phi_s)$$

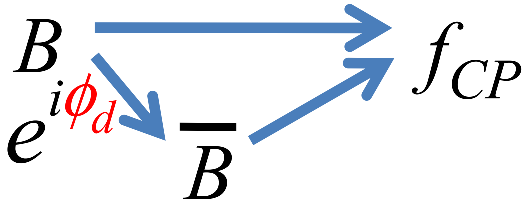
- Strong parameters d (d'), θ (θ') are strength and phase of penguins to tree. Weak U-spin assumption : d=d'+-20% , θ, θ' independent
- Assume mixing phases known

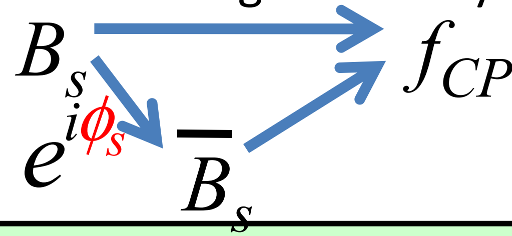
Channel	Yield (2 fb^{-1})	B/S
B→ππ	36k	0.5
B_s→KK	36k	0.15



3. The B_d and B_s Mixing Phase

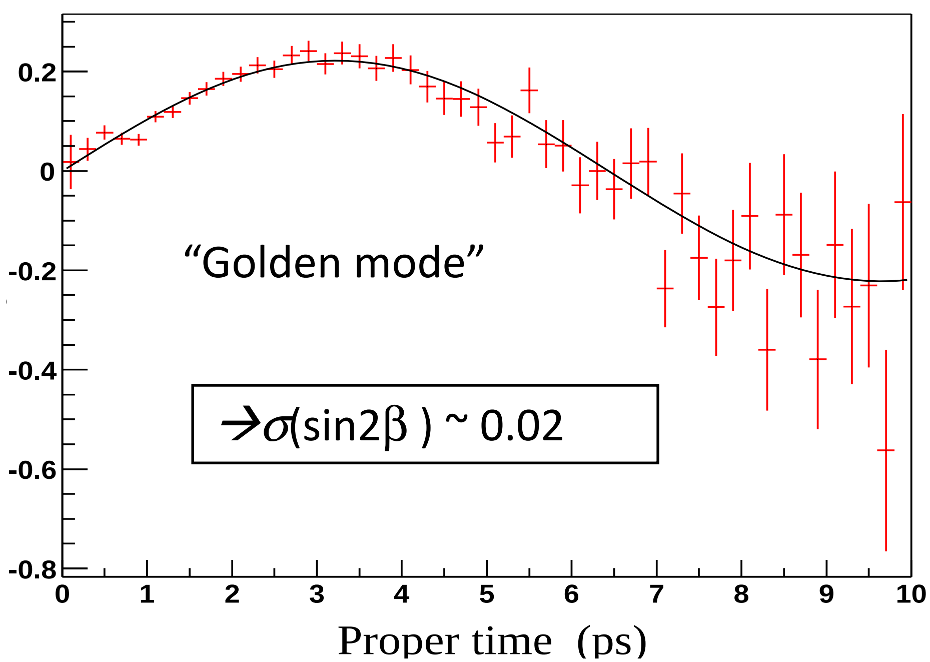
Time dependent CP violation in interference between mixing and decay





$$B^0: \quad A_{CP}(t) = \eta_f \sin\phi_d \sin(\Delta m_d t)$$

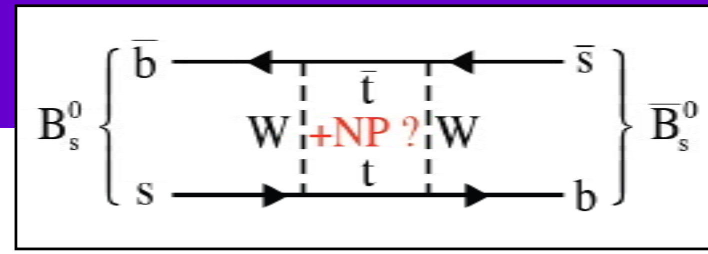
$$B_s: \quad A_{CP}(t) = \frac{\eta_f \sin\phi_s \sin(\Delta m_s t)}{\cosh\frac{\Delta\Gamma_s t}{2} - \eta_f \cos\phi_s \sinh\frac{\Delta\Gamma_s t}{s}}$$



Channel	Yield ($2\ fb^{-1}$)	B/S
Bd→J/ψKs	216 k	0.8

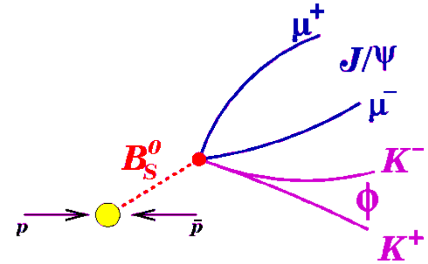
“Yesterday’s sensation is today’s calibration and tomorrow’s background” – Val Telegdi

B_s mixing phase

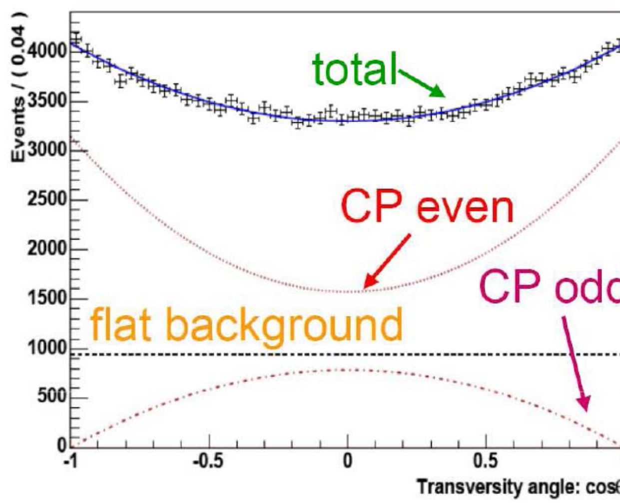


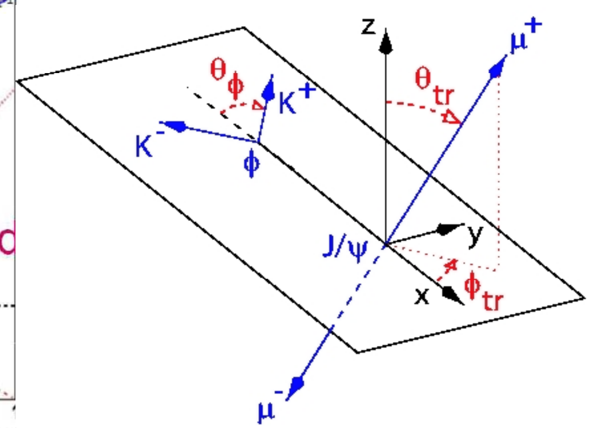
$$A_{CP}(t) = \frac{\eta_f \sin\phi_s \sin(\Delta m_s t)}{\cosh\frac{\Delta\Gamma_s t}{2} - \eta_f \cos\phi_s \sinh\frac{\Delta\Gamma_s t}{s}}$$

Decay	Yield (2 fb^{-1})	σ (ϕ_s)
$J/\psi\ \eta_{\gamma\gamma}$	8.5 k	0.109
$J/\psi\eta_{\pi\pi\pi}$	3 k	0.142
$J/\psi\ \eta'_{\pi\pi\eta}$	2.2 k	0.154
$J/\psi\ \eta'_{\rho\gamma}$	4.2 k	0.08
$\eta_c\ \phi$	3 k	0.108
$D_s^+ D_s^-$	4k	0.133
All CP eig	-	0.046
$J/\psi\ \phi$	130 k	0.023
All	-	0.021

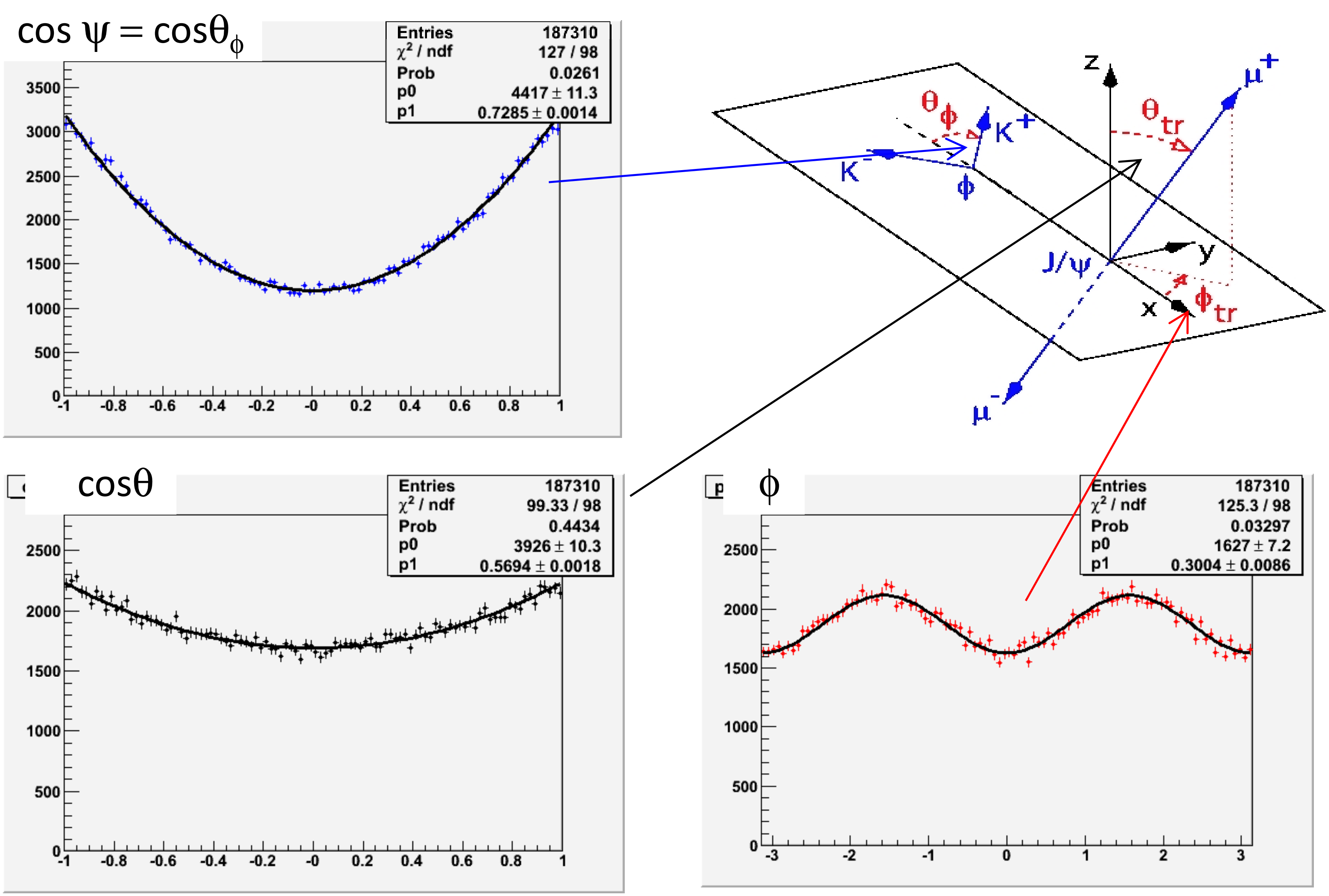


1. ***Pure CP eigenstates***
   Low yield, high background
2. ***Admixture of CP eigenstates***: $B_s \to J/\psi\ \phi$
   "Golden mode": Large yield, nice signature
   However PS->VV requires angular analysis
   to disentagle η=+1 (CP-even) ,-1 (CP-odd)



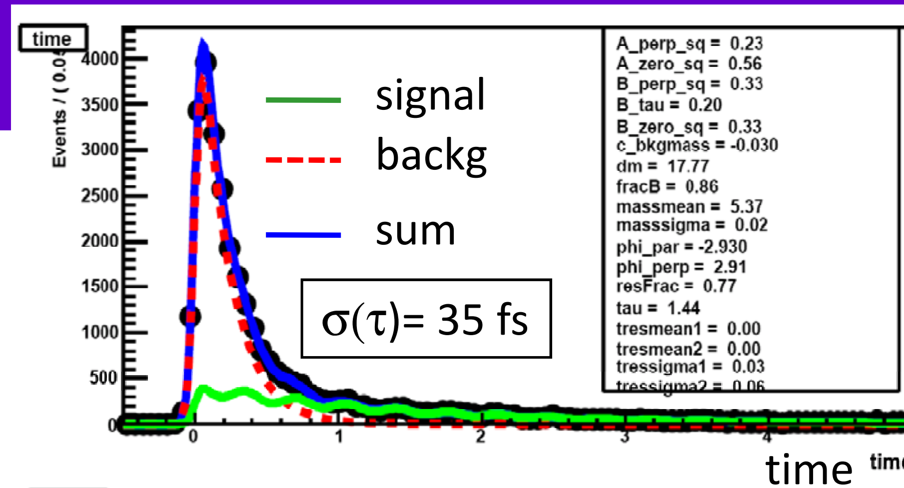


Full 3D Angular analysis



Study possible systematics of LHCb acceptance and reconstruction on distributions.

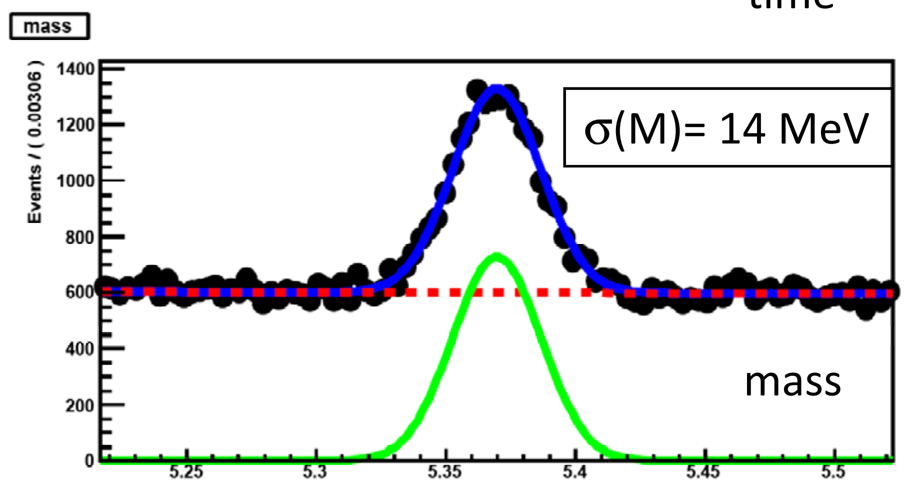
$B_s \rightarrow J/\psi\, \phi$

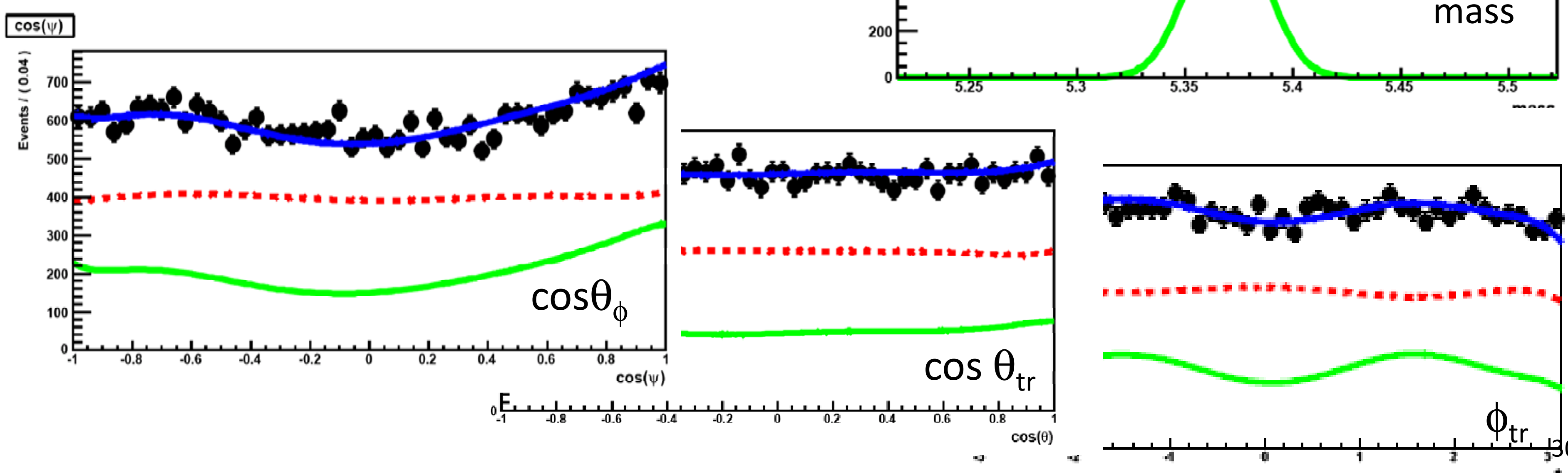


- Simultaneous likelihood analysis in time, mass, full 3d-angular distribution
- Include mass sidebands to model the time spectrum and angular distribution of the background
- Model the τ resolution

➔ $\sigma\ (\phi_s)=0.02$

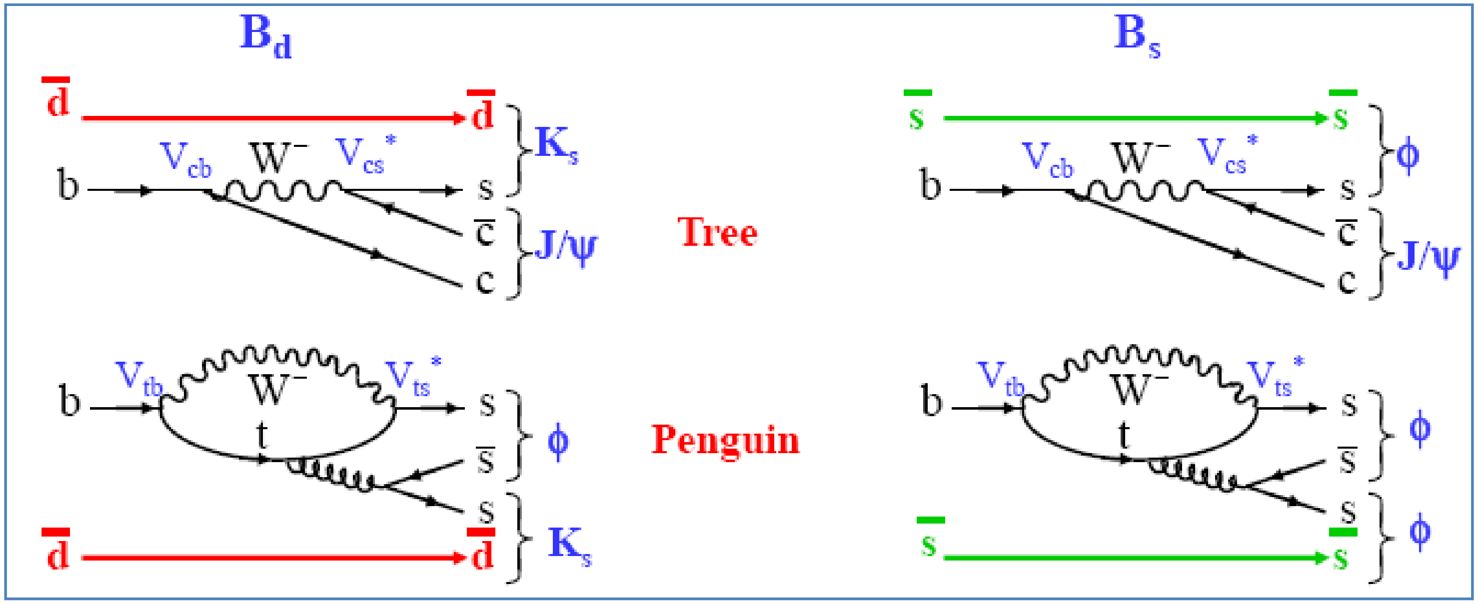
See talk of Olivier Leroy





4. β & β_s from Penguins

• Compare observed phases in tree decays with those in penguins



$$B^0 \to \phi K_s : \ \phi_d^{eff} = 2\beta^{mix} + 2\beta_s^{decay}$$

$$B_s \to \phi\phi : \ \phi_s^{eff} = -2\beta_s^{mix} + 2\beta_s^{decay}$$

• Bs → φ φ requires time dependent CP asymmetry (PS→VV angular analysis a la J/ψφ)

See talk of Olivier Leroy

Channel	Yield (2 fb^{-1})	B/S	Weak phase precision
B→ φ K_s	920	0.3 < B/S < 1.1	$\sigma(\sin(\phi_d^{eff}) \approx 0.23$
B_s → φ φ	3.1 k	< 0.8	$\sigma(\phi_s^{eff}) = 0.11$

Physics Programme

LHCb is a heavy flavour precision
Experiment searching for new physics
in CP-Violation and Rare Decays

- CP Violation
- Rare Decays

Rare Decays – LHCb Program

Weak B-decays described by effective Hamiltonian:

$$H_{eff} = -\frac{G_F}{\sqrt{2}} V_{CKM} \sum_i C_i(\mu) O_i$$

i=1,2: trees
i=3-6,8: g penguin
i=7: γ penguin
i=9,10: EW penguin

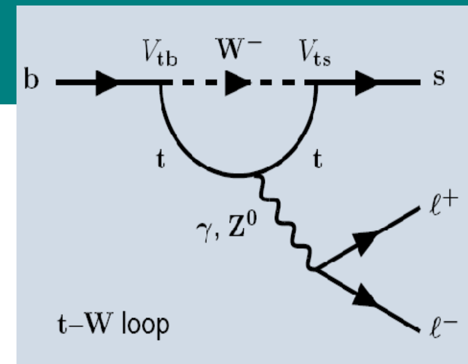
New physics shows up via **new** operators **O_i** or **modification** of Wilson coefficients **C_i** compared to SM.

Study processes that are **suppressed at tree level** to look for NP affecting observables: *Branching Ratio's, decay time asymmetries, angular asymmetries, polarizations, …*

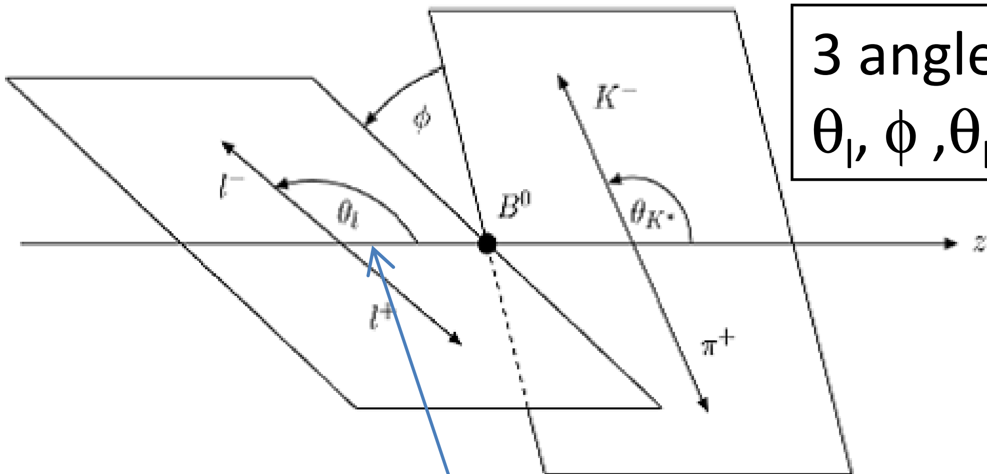
LHCb Program: Look for deviations of the SM picture in the decays:

1. $b \rightarrow s l^+ l^-$; $A_{fb}(B \rightarrow K^* \mu\mu)$, $B^+ \rightarrow K^+ ll$ (R_K), $B_s \rightarrow \phi\mu\mu$
2. $b \rightarrow s\gamma$; $A_{cp}(t)$ $B_s \rightarrow \phi\gamma$, $B \rightarrow K^*\gamma$, $\Lambda_b \rightarrow \Lambda\gamma$, $\Lambda_b \rightarrow \Lambda^*\gamma$, $B \rightarrow \rho^0\gamma$, $B \rightarrow \omega\gamma$
3. $B_q \rightarrow l^+ l^-$; BR ($B_s \rightarrow \mu\mu$)
4. LFV $B_q \rightarrow l\, l'$ (not reported here)

1. $B^0 \rightarrow K^{*0}\mu^+\mu^-$

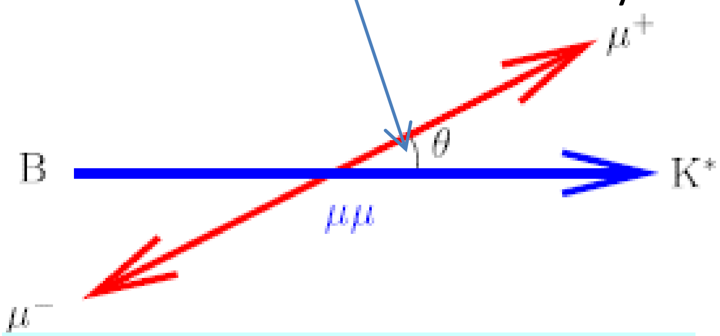


- Contributions from electroweak penguins
- Angular distribution is sensitive to NP

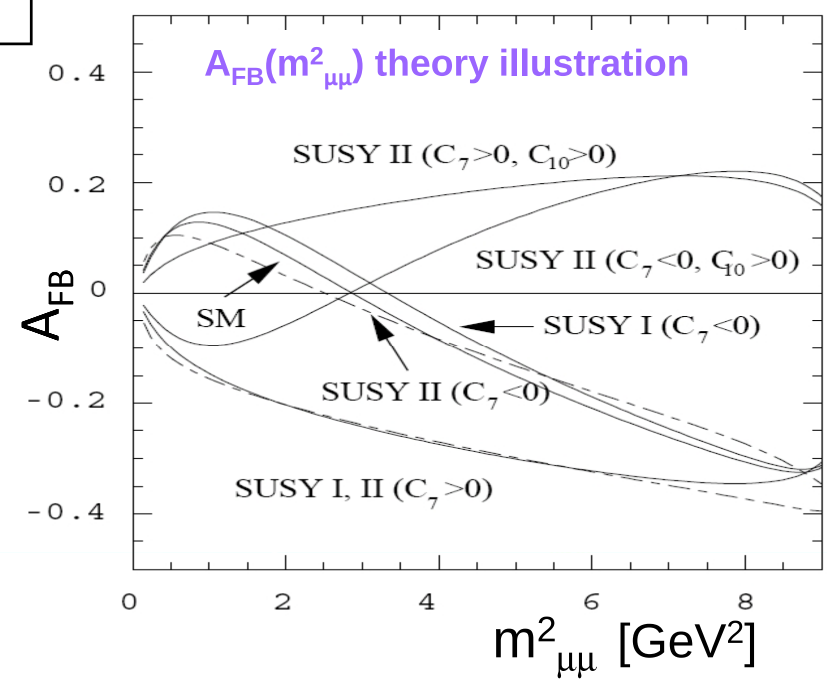


3 angles: θ_l, ϕ, θ_K

Observable: Forward-Backward Asymmetry in θ_l



$$A_{FB}\left(s = m^2_{\mu^+\mu^-}\right) = \frac{N_F - N_B}{N_F + N_B}$$



Zero crossing point (s_o) well predicted:

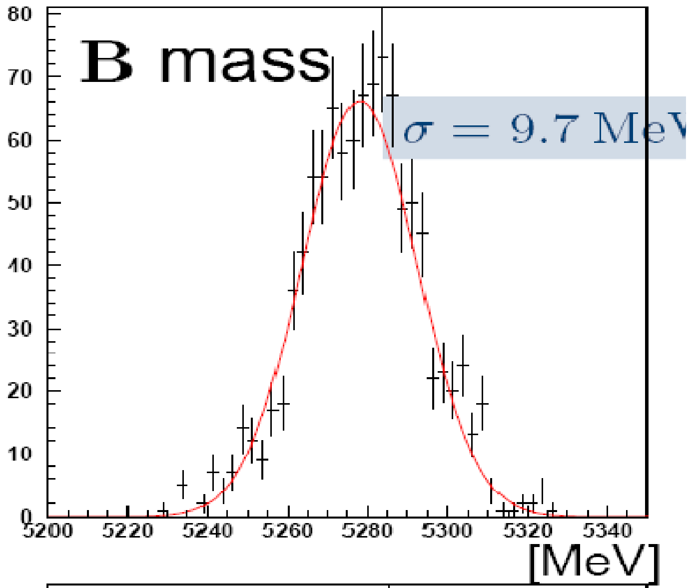
$$\text{SM: } s_0 = 4.39^{+0.38}_{-0.35}\, GeV^2$$

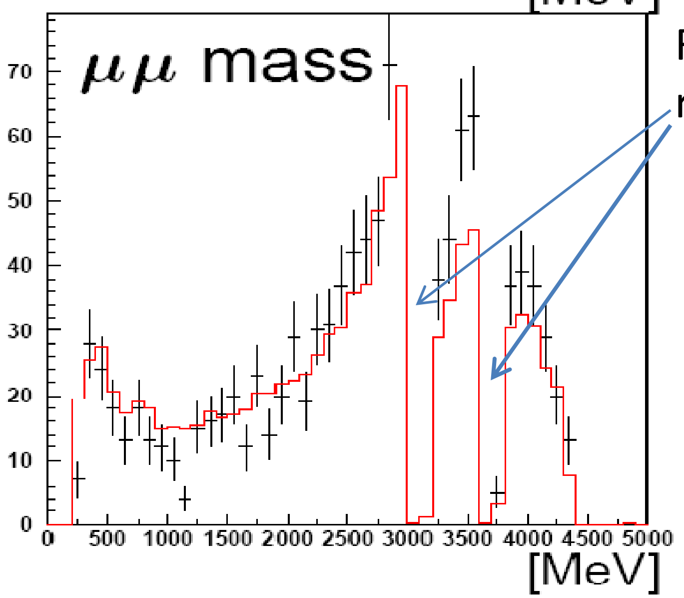
hep-ph:0106067v2

$B^0 \to K^{*0}\mu^+\mu^-$

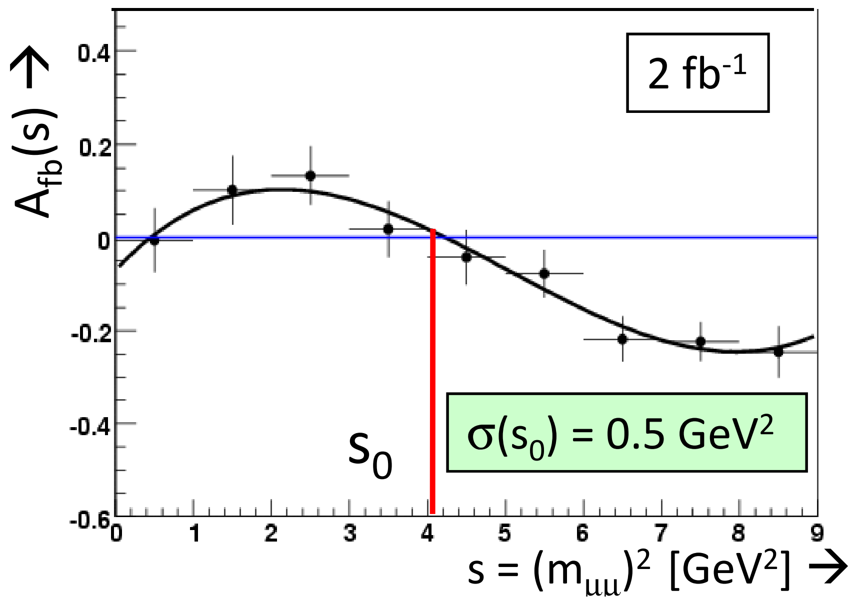
See talk Mitesh Patel

Event Selection:





Channel	Yield (2 fb^{-1})	BG (2 fb^{-1})
$Bs \to K^*\mu^+\mu^-$	7200+-2200 (BR)	1770+-310

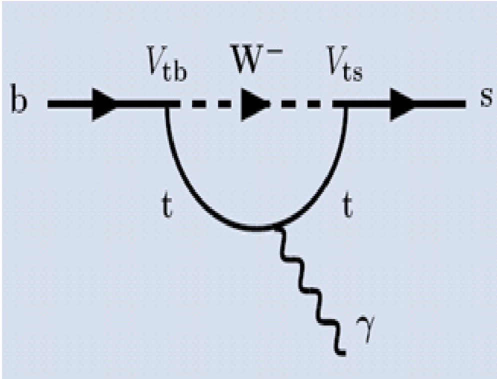


<u>Systematic study:</u>

- Selection should not distort $m^2_{\mu\mu}$
- s_0 point to first order not affected

2. $B_s \to \phi\gamma$

See talk Mitesh Patel



$b \to \gamma(L) + (m_s/m_b) \times \gamma(R)$

- Probes the exclusive b →s radiative penguin
  Measure time dependent CP asymmetry:

$$A_{CP}(t) = \frac{\Gamma(\overline{B}_s \to \phi\gamma) - \Gamma(B_s \to \phi\gamma)}{\Gamma(\overline{B}_s \to \phi\gamma) + \Gamma(B_s \to \phi\gamma)} = \frac{A_{dir}\cos\Delta mt + A_{mix}\sin\Delta mt}{\cosh\left(\frac{\Delta\Gamma t}{2}\right) + A_{\Delta}\sinh\left(\frac{\Delta\Gamma t}{2}\right)}$$

In SM b→s γ is predominatly (O(m_s/m_b)) left handed
Observed CP violation depends on the γ polarization

SM: $A_{dir} \approx 0$, $A_{mix} \approx \sin 2\psi \sin 2\phi$, $A_{\Delta} \approx \cos 2\psi \cos\phi$
$\tan\psi = |b \to s\gamma_R| / |b \to s\gamma_L|$, $\cos\phi \approx 1$

Event selection:

Channel	Yield (2 fb^{-1})	B/S
$Bs \to \phi\gamma$	11k	<0.55

Statistical precision after 2 fb^{-1} (1 year)
$\sigma(A_{dir}) = 0.11$, $\sigma(A_{mix}) = 0.11$ (requires tagging)
$\sigma(A_{\Delta}) = 0.22$ (no tagging required)

→ Measures fraction "wrong" γ polarization

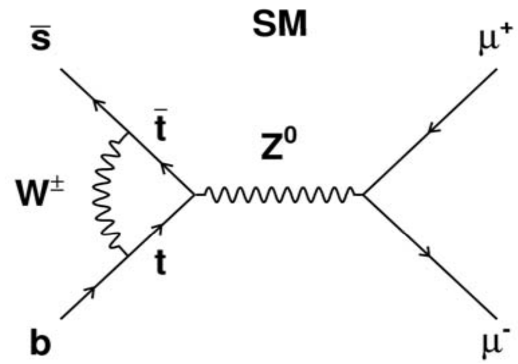
3. $B_s \rightarrow \mu^+\mu^-$

See talk Mitesh Patel

- $B_s \rightarrow \mu\mu$ is helicity suppressed
  SM Branching Ratio: $(3.35 \pm 0.32) \times 10^{-9}$

hep-ph/0604057v5

- Sensitive to NP with S or P coupling

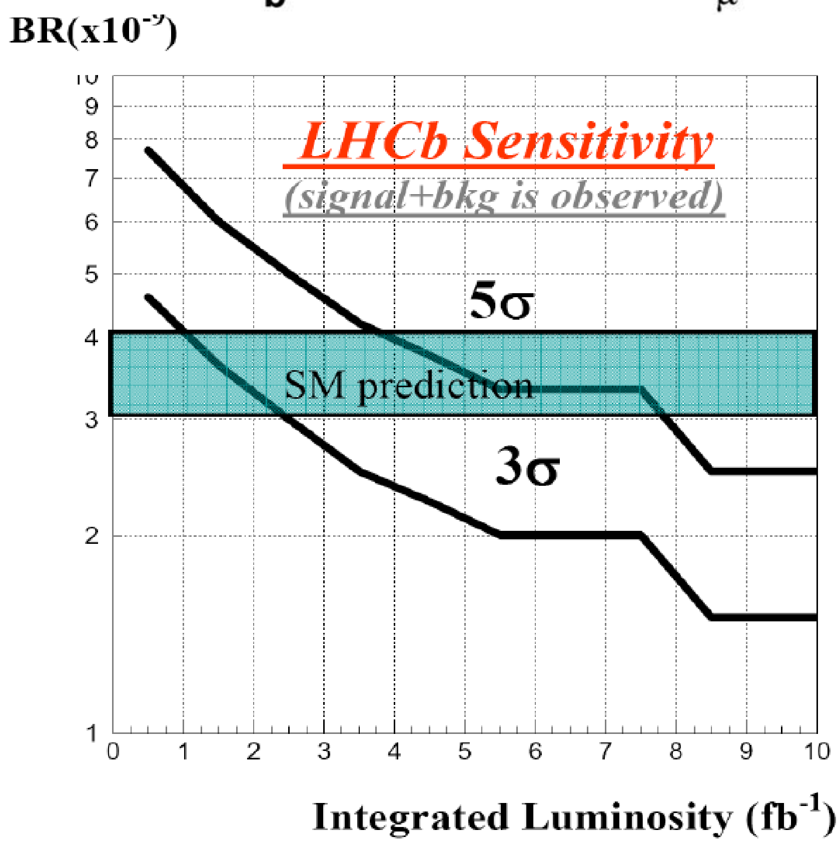


Event Selection:

Main Backgrounds:	Suppressed by:
$b\rightarrow\mu$, $b\rightarrow\mu$	Mass & Vertex resol.
$B\rightarrow hh$	Particle Identification

Channel	SM Yield ($2\ fb^{-1}$)	Background
$Bs\rightarrow \mu\mu$	30	83

With $2\ fb^{-1}$ (1 "year"):
- Observe BR: 6×10^{-9} with 5 σ
- Assuming SM BR: 3σ observation



Physics Programme

LHCb is a heavy flavour precision Experiment searching for new physics in CP-Violation and Rare Decays

- CP Violation
- Rare Decays

➡ + “Other” Physics

“Other” Physics

See the following talks for an overview:

<u>Raluca Muresan:</u>

- Charm Physics: Mixing and CP Violation

<u>Michael Schmelling:</u>

- Non CP Violation Physics:
  - B production, multiparticle production, deep inelastic scattering, …

Conclusions

LHCb is a heavy flavour precision experiment searching for New Physics in **CP Violation** and **Rare Decays**

A program to do this has been developed and the methods, including calibrations and systematic studies, are being worked out..

CP Violation: 2 fb^{-1} (1 year)*

- γ from trees: 5^o - 10^o
- γ from penguins: $\approx 10^o$
- B_s mixing phase: 0.023
- β_s^{eff} from penguins: 0.11

Rare Decays: 2 fb^{-1} (1 year)*

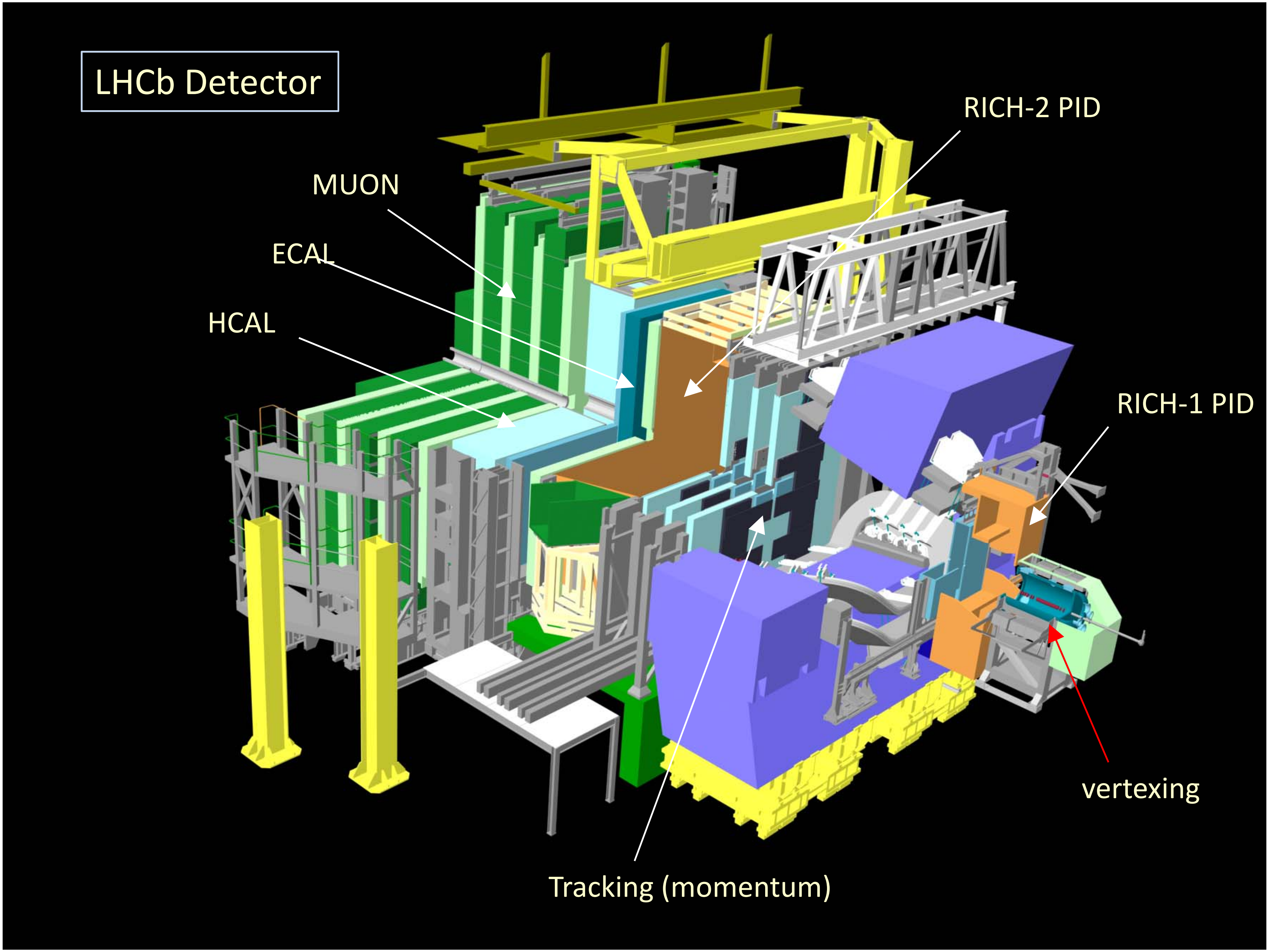
- $Bs \rightarrow K^*\mu\mu$ s_0 : 0.5 GeV^2
- $B \rightarrow s\gamma$ A_{dir} , A_{mix} : 0.11
  A_Δ : 0.22
- $B_s \rightarrow \mu\mu$ BR.: 6×10^{-9} at 5σ

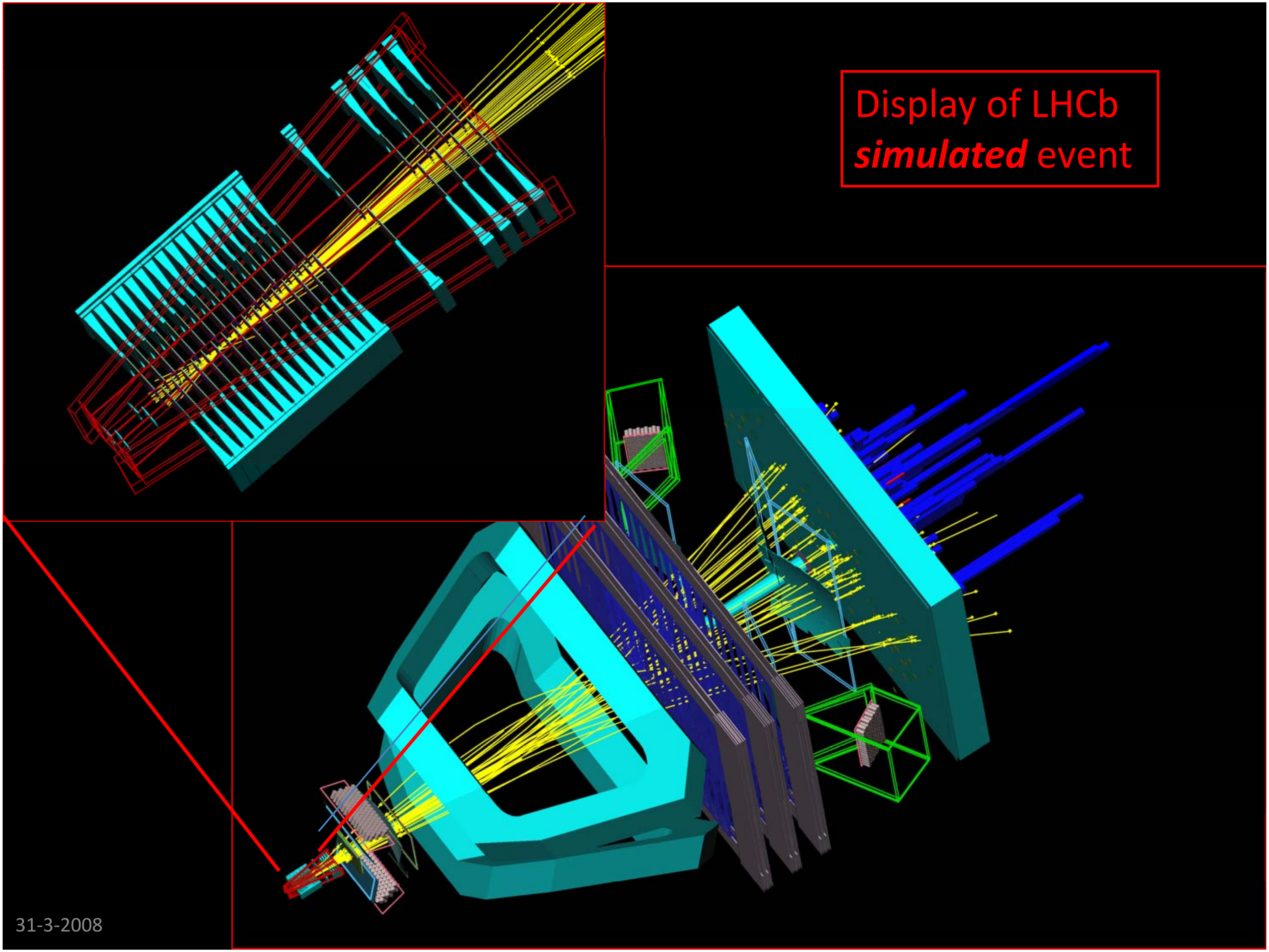
We appreciate the collaboration with the theory community to continue developing new strategies.

We are excitingly looking forward to the data from the LHC.

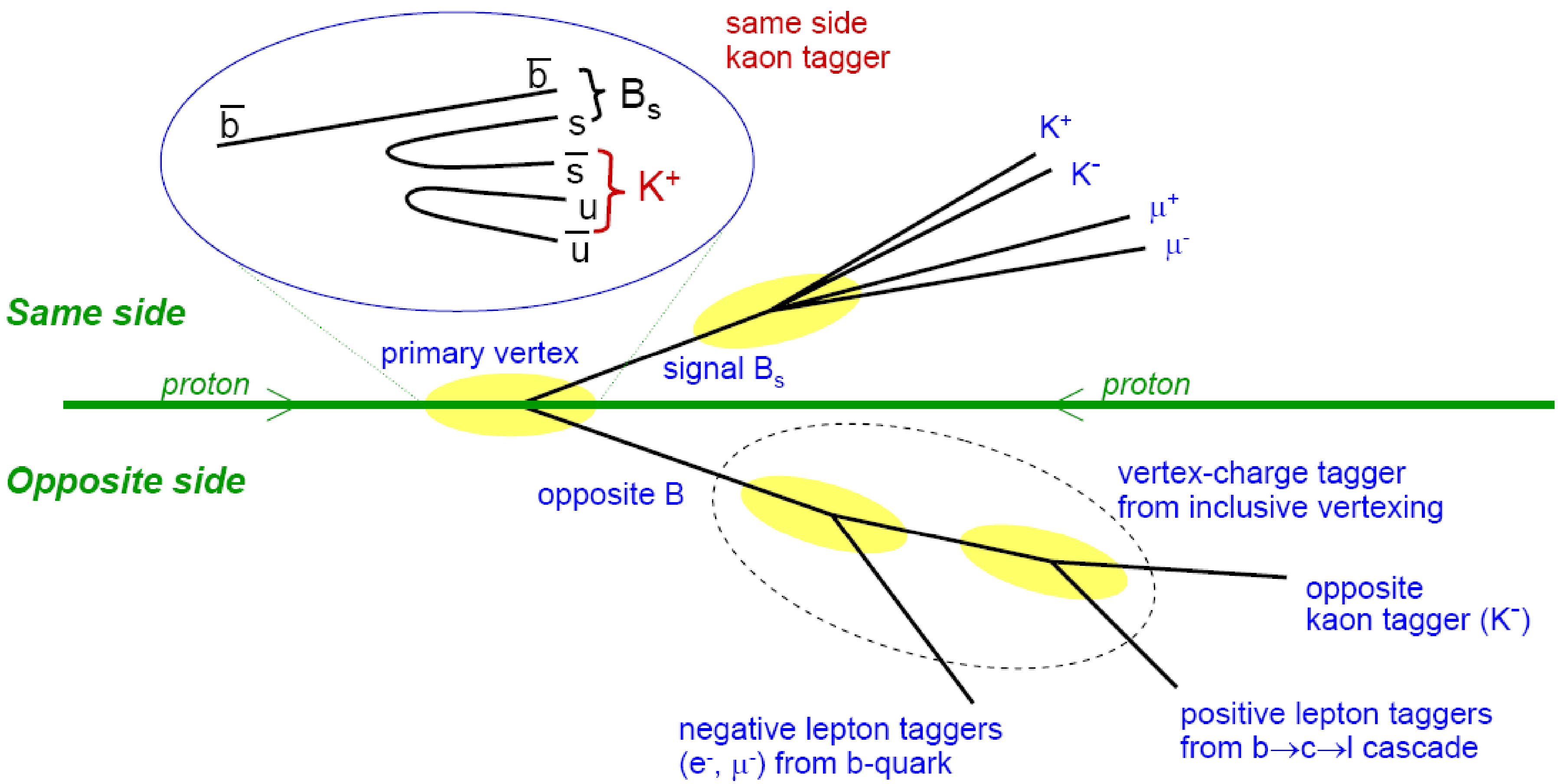
* Expect uncertainty to scale statistically to 10 fb^{-1}. Beyond: see Jim Libby's talk on Upgrade

Backup


LHCb Detector
RICH-2 PID
MUON
ECAL
HCAL
RICH-1 PID
vertexing
Tracking (momentum)


Display of LHCb
simulated event

Flavour Tagging

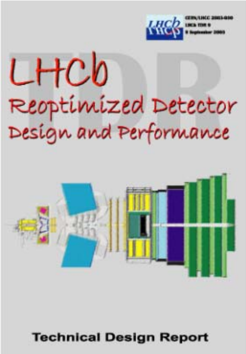


Performance of flavour tagging:

Tagging power:

$$\varepsilon D^2 = \varepsilon\left(1-2w\right)^2$$

	Efficiency ε	Wrong tag w	Tagging power
B_d	~50%		
B_s	~50%	33%	~6%



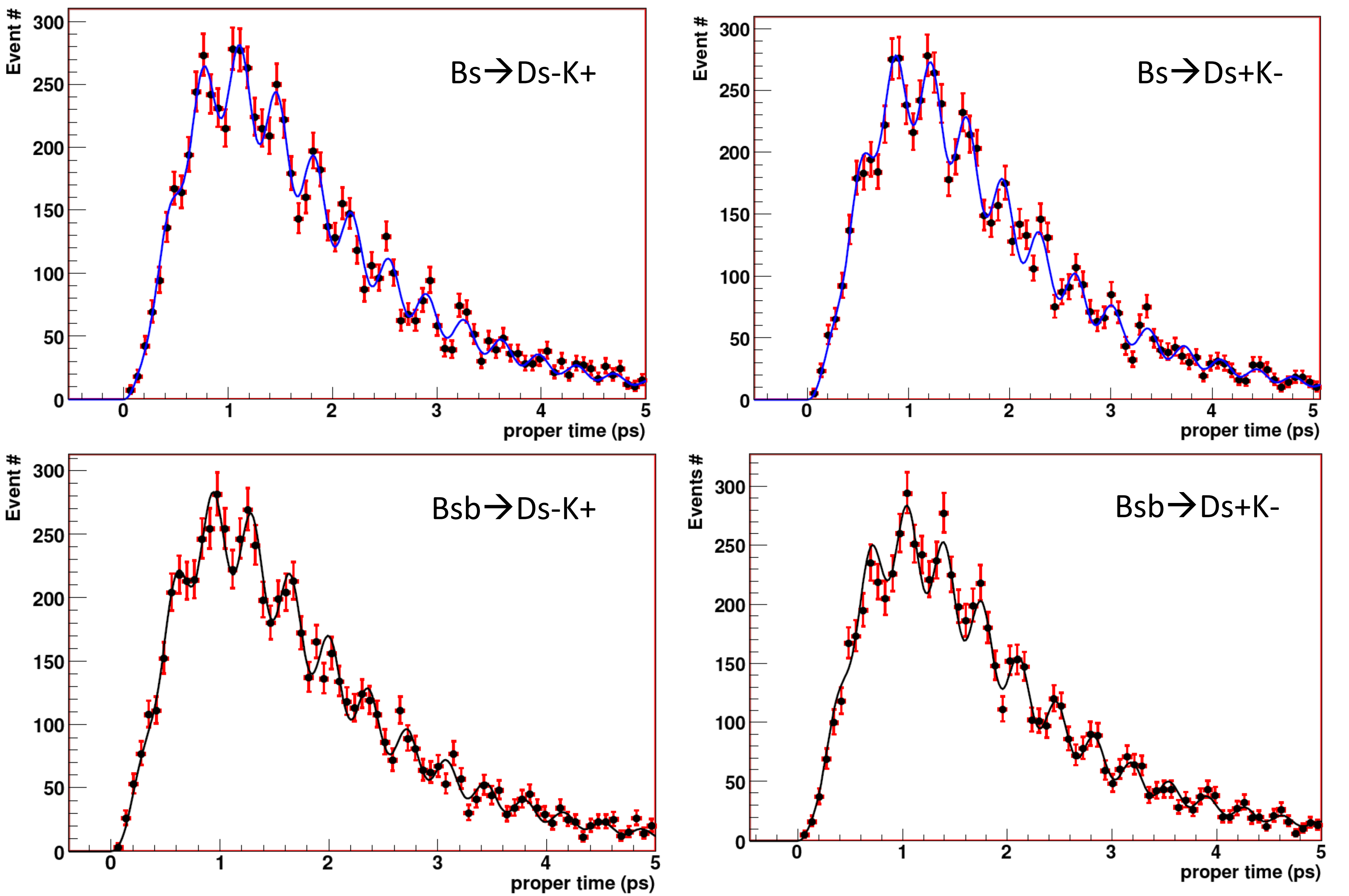
Full table of selections

	Det. eff. (%)	Rec. eff. (%)	Sel. eff. (%)	Trig. eff. (%)	**Tot. eff. (%)**	Vis. BR (10^{-6})	**Annual signal yield**	**B/S from bb bkg.**
$B^0 \to \pi^+\pi^-$	12.2	91.6	18.3	33.6	**0.69**	4.8	**26k**	**< 0.7**
$B_s \to K^+K^-$	12.0	92.5	28.6	36.7	**0.99**	18.5	**37k**	**0.3**
$B_s \to D_s^-\pi^+$	5.4	80.6	25.0	31.1	**0.34**	120.	**80k**	**0.3**
$B_s \to D_s^{-+}K^{+-}$	5.4	82.0	20.6	29.5	**0.27**	10.	**5.4k**	**< 1.0**
$B^0 \to \bar{D}^0(K\pi)K^{*0}$	5.3	81.8	22.9	35.4	**0.35**	1.2	**3.4k**	**< 0.5**
$B^0 \to J/\psi(\mu\mu)\, K^0_S$	6.5	66.5	53.5	60.5	**1.39**	20.	**216k**	**0.8**
$B^0 \to J/\psi(ee)\, K^0_S$	5.8	60.8	17.7	26.5	**0.16**	20.	**26k**	**1.0**
$B_s \to J/\psi(\mu\mu)\, \phi$	7.6	82.5	41.6	64.0	**1.67**	31.	**100k**	**< 0.3**
$B_s \to J/\psi(ee)\, \phi$	6.7	76.5	22.0	28.0	**0.32**	31.	**20k**	**0.7**
$B^0 \to \rho\, \pi$	6.0	65.5	2.0	36.0	**0.03**	20.	**4.4k**	**< 7.1**
$B^0 \to K^{*0}\gamma$	9.5	86.8	5.0	37.8	**0.16**	29.	**35k**	**< 0.7**
$B_s \to \phi\, \gamma$	9.7	86.3	7.6	34.3	**0.22**	21.	**9.3k**	**< 2.4**

+ few more channels in TDR

Nominal year = 10^{12} bb pairs produced (10^7 s at $L=2\times10^{32}$ $cm^{-2}s^{-1}$ with σ_{bb}=500 μb)
Yields include factor 2 from CP-conjugated decays
Branching ratios from PDG or SM predictions

Bs→DsK 5 years data



Angle γ in Summary

B mode	D mode	Method	$\sigma(\gamma)$ with 2 fb^{-1}
$B^+ \rightarrow DK^+$	$K\pi$ + $KK/\pi\pi$ + $K3\pi$	ADS+GLW	5^o–13^o
$B^+ \rightarrow D^*K^+$	$K\pi$ ($D^* \rightarrow D+\pi, \gamma$)	ADS+GLW	Under study
$B^+ \rightarrow DK^+$	$K_S\pi\pi$	Dalitz	~8-12^o
$B^+ \rightarrow DK^+$	$KK\pi\pi$	4-body "Dalitz"	18^o
$B^+ \rightarrow DK^+$	$K\pi\pi\pi$	4-body "Dalitz"	Under study
$B^0 \rightarrow DK^{*0}$	$K\pi$ + KK + $\pi\pi$	ADS+GLW	~6-12^o
$B^0 \rightarrow DK^{*0}$	$K_S\pi\pi$	Dalitz	Under study
$B_s \rightarrow D_sK$	$KK(\phi)\pi$	tagged, A(t)	~10^o
$B^0 \rightarrow \pi^+\pi^-$, $B_s \rightarrow K^+K^-$	N/A	U-spin symmetry	5^0 – 10^0