Status of the LHCb Upgrade

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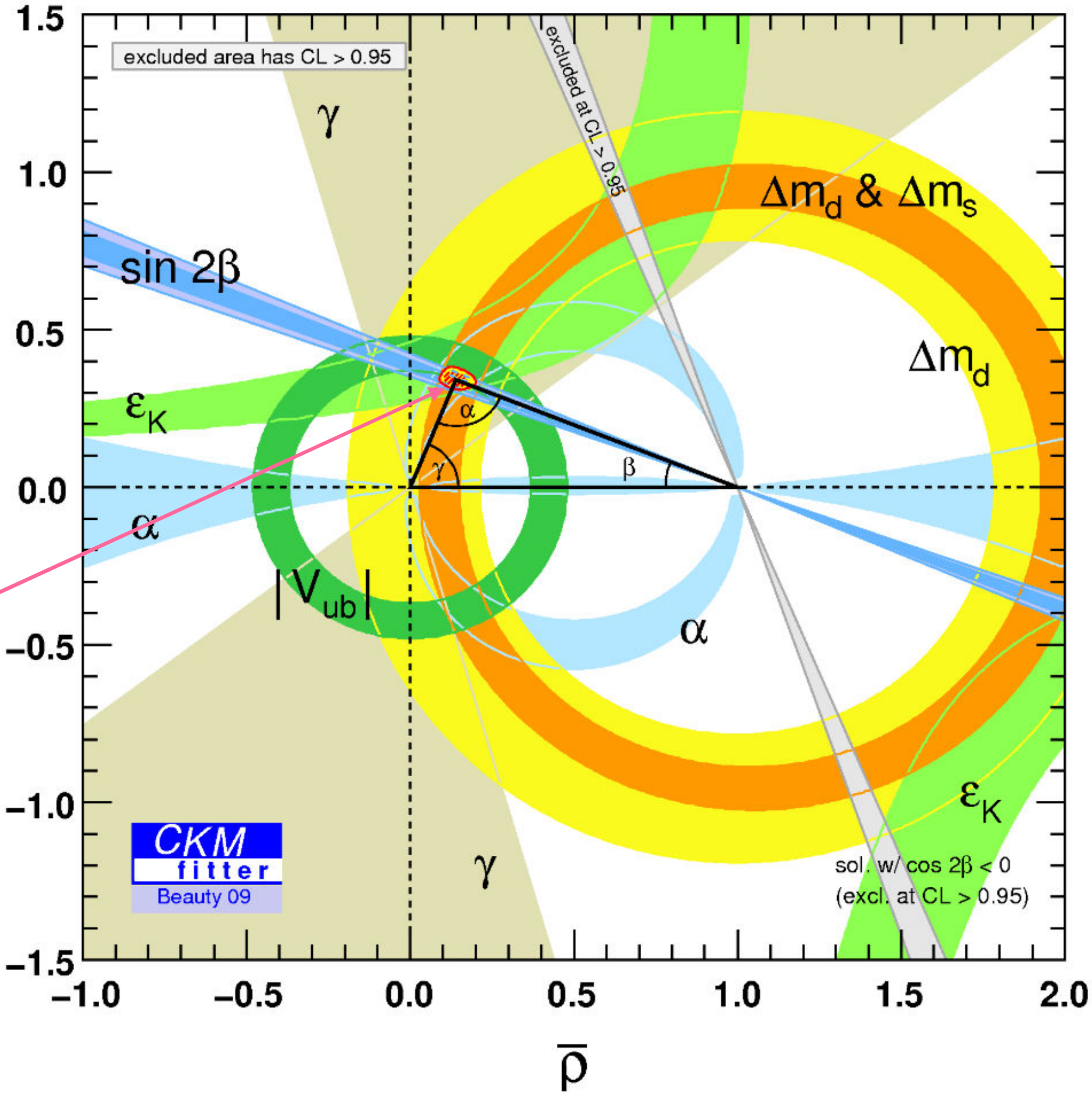
General Physics Justification

- Expect New Physics will be seen at LHC
  - Standard Model is violated by the Baryon Asymmetry of Universe & by Dark Matter
  - Hierarchy problem (why $M_W << M_{Planck}$)
- However, it will be difficult to characterize this physics
- How the new particles interfere virtually in the decays of b's (& c's) with W's & Z's can tell us a great deal about their nature

Current Status of CP & Other Measurements

- SM CKM parameters are: A~0.8, λ=0.22, ρ & η
- CKM Fitter results using CP violation in $J/\psi\ K_S$, $\rho^+\rho^-$, DK^-, K_L, & V_{ub}, V_{cb} & ΔM_q
- The overlap region includes CL>95%
- Similar situation using UTFIT
- Measurements "consistent"



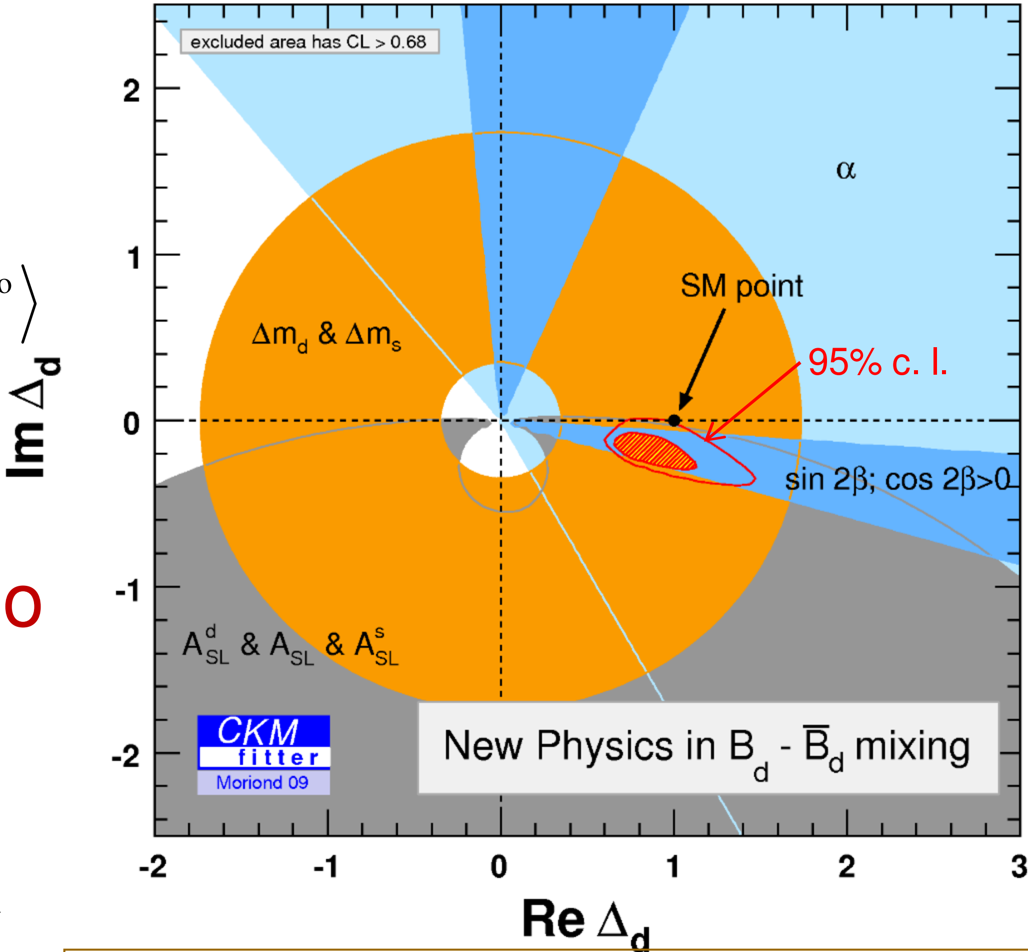
Consistency?

- It is often said that studies of b & c decays are all consistent with the Standard Model
  - Since all measurements are reflections of nature, i.e. SM + NP, what does this statement actually mean?
  - SM predictions are made using combinations of several measurements since there are many parameters. It is important to distinguish the type of decay used, i.e. tree or loop, since tree decays are likely to have only small NP contributions compared to loop level processes
  - The fit in the previous page doesn’t allow for any NP contributions

Limits on New Physics From B^o Mixing

- Is there NP in B^o-$\bar{B}^o$ mixing?
- $\langle B^o | H^{SM+NP}_{\Delta B=2} | \bar{B}^o \rangle = \Delta_d^{NP} \langle B^o | H^{SM}_{\Delta B=2} | \bar{B}^o \rangle$

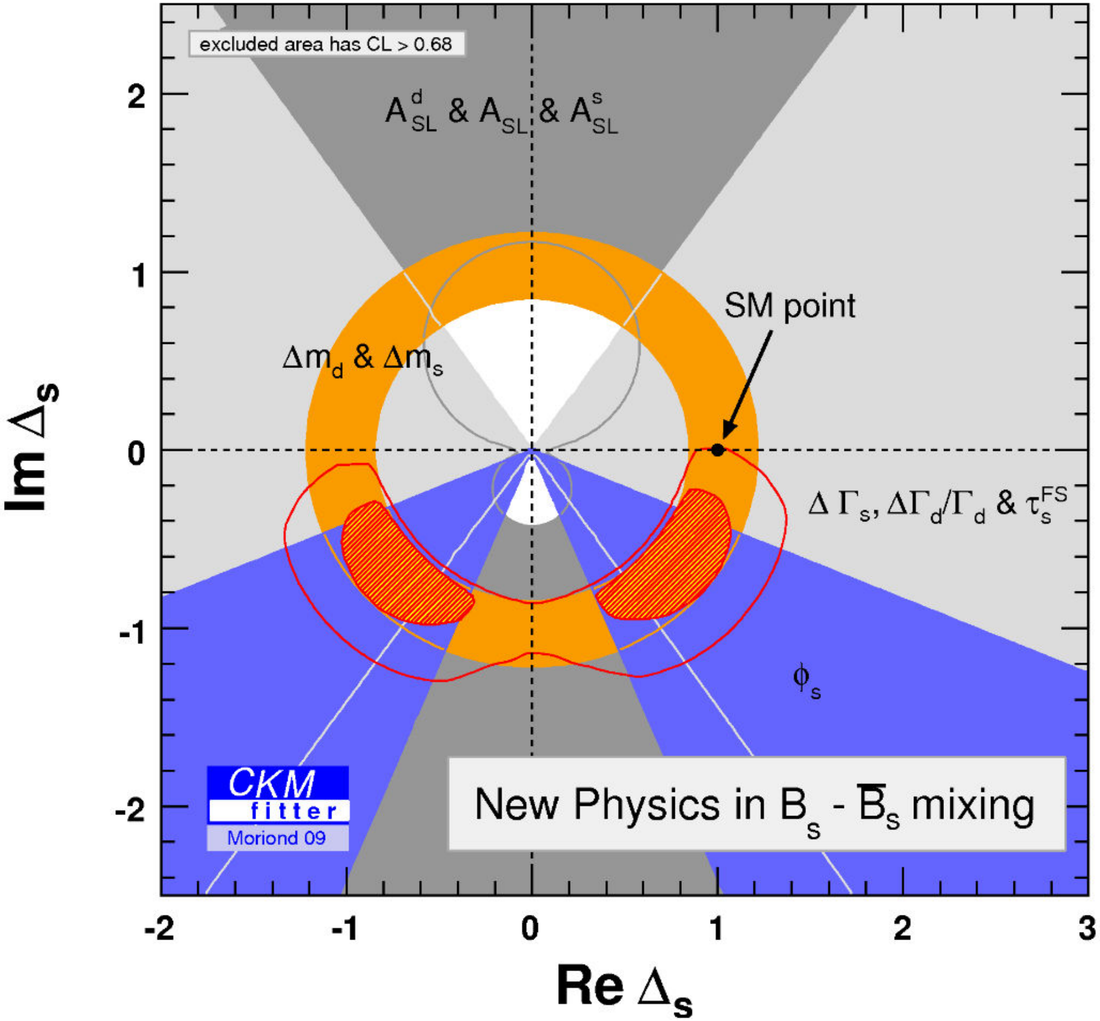
  $\Delta_d^{NP} = \mathrm{Re}\,\Delta_d + i\mathrm{Im}\Delta_d$
- Assume NP in tree decays is negligible, so no NP in $|V_{ij}|$, γ from $B^- \rightarrow D^o K^-$.
- Allow NP in Δm, weak phases, A_{SL}, & $\Delta\Gamma$.



- Room for new physics, in fact SM is only at 5% c.l.

Limits on New Physics From B_S Mixing

- Similarly
- Here again SM is only at 5% c.l.
- Much more room for NP due to less precise measurements

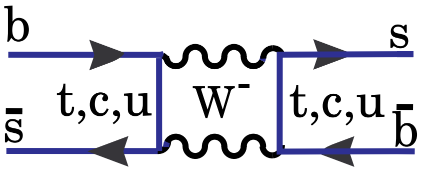


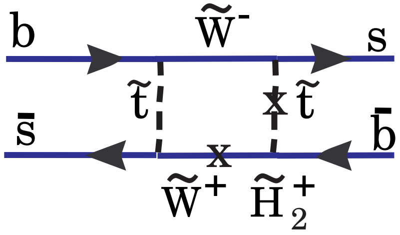
New Physics Models

- There is, in fact, still lots of room for "generic" NP
- What do specific models predict?
    - Supersymmetry: many, many different models
    - Extra Dimensions: "
    - Little Higgs: "
    - Left-Right symmetric models: "
- Lets go through some examples, many other interesting cases exist

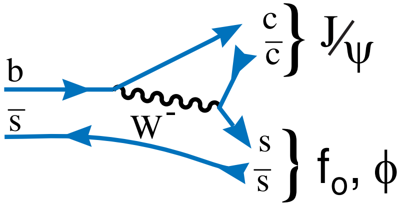
Supersymmetry: MSSM

- MSSM from Hinchcliff & Kersting (hep-ph/0003090)
- Contributions to B_s mixing





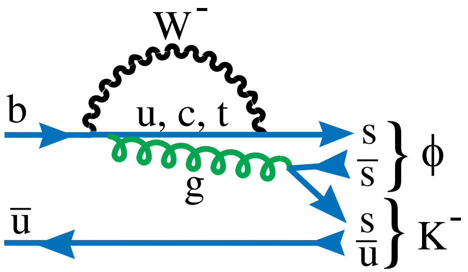
$B_s \rightarrow J/\psi f_o$ or ϕ

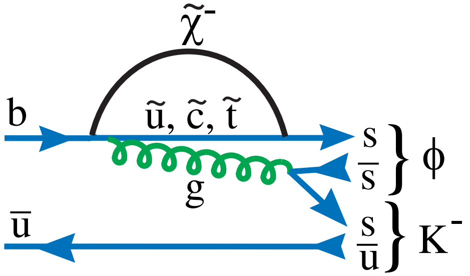


CP asymmetry $\approx 0.1 \sin\phi_\mu \cos\phi_A \sin(\Delta m_s t)$, ~10 x SM

- Contributions to direct CP violating decay

$B^- \rightarrow \phi K^-$



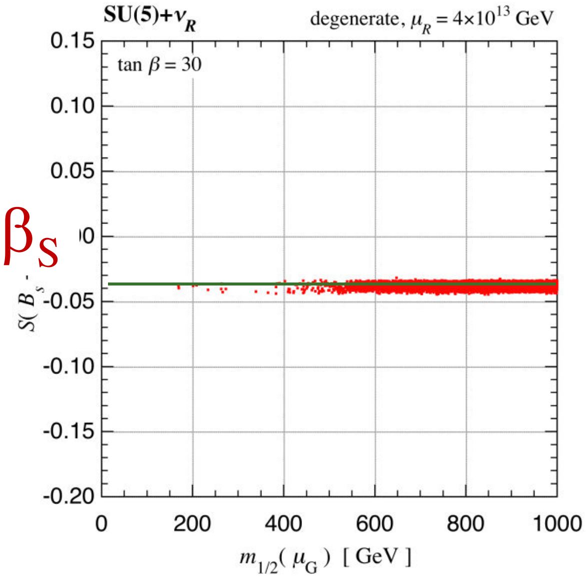


Asym=$(M_W/m_{squark})^2 \sin(\phi_\mu)$, ~0 in SM

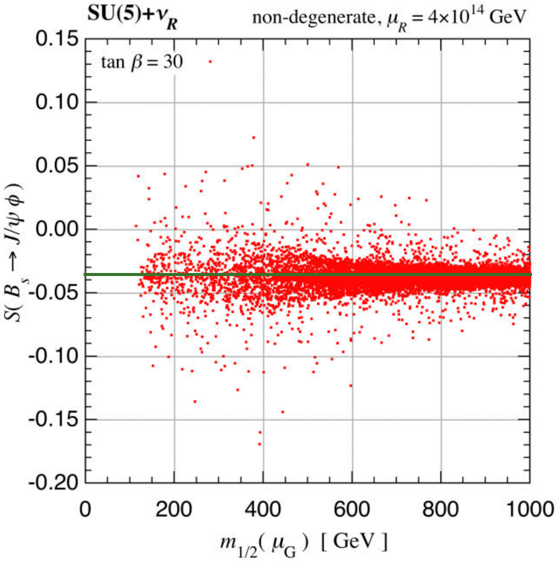
Supersymmetry: SU(5) &U(2)

SU(5) GUT
Degenerate

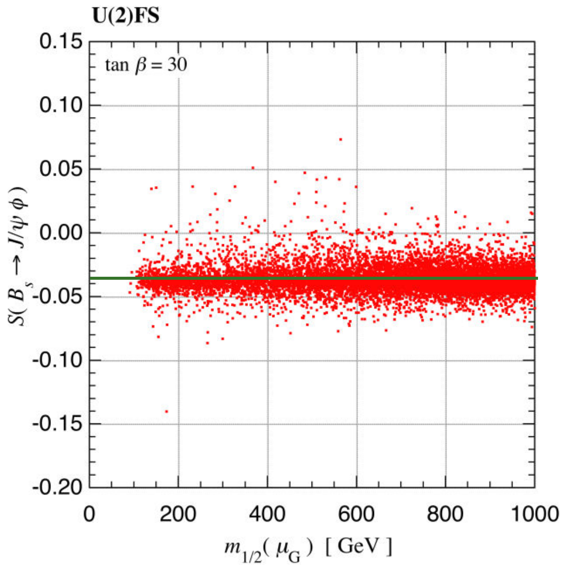
$-2\beta_s$



SU(5) GUT
Non-degenerate



U(2) FS



- $-2\beta_s$ can deviate from the “SM” value of -0.036 in SU(5) GUT non-degenerate case, and the U(2) model. From Okada’s talk at BNMII, Nara Women’s Univ. Dec., 2006

Okada Models Summary

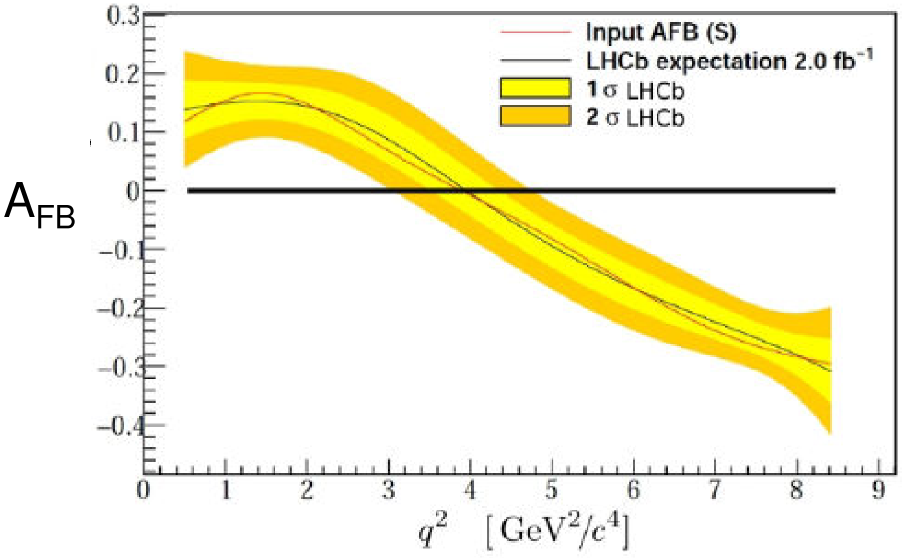
Possible deviations from the SM prediction

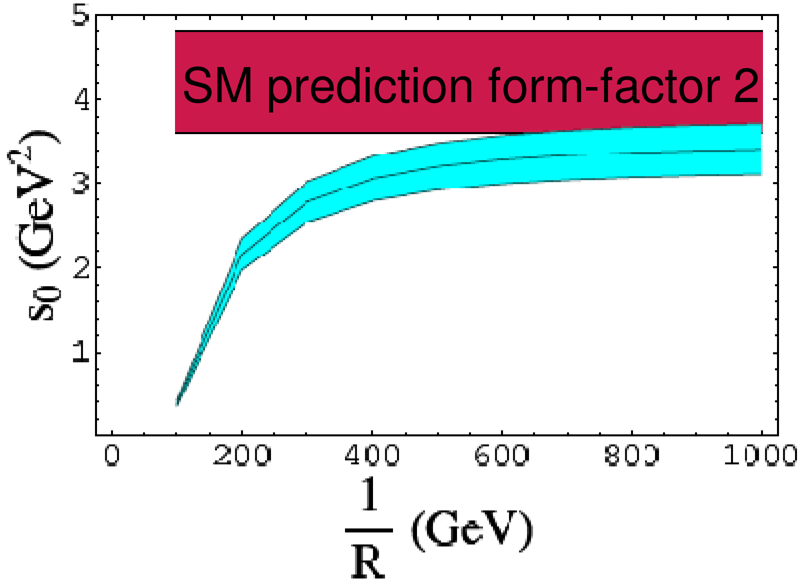
	B_d - unitarity Triangle test	T-dep CPV in $B\to\phi K_s$, $B\to K^*\gamma$	$b\to s\gamma$ direct CP	T-dep CPV in $B_S\to J/\psi\phi$	LFV
mSUGRA	-	-	-	-	-
SU(5)SUSY GUT + νR (degenerate)	—	—	—	—	$\mu\to e\gamma$
SU(5)SUSY GUT + νR (non-degenerate)	—	<~0.05	—	<~0.05	$\mu\to e\gamma$ $\tau\to\mu\gamma$
U(2) Flavor symmetry	< a few %	<~0.05	< a few %	<~0.05	$\mu\to e\gamma$ $\tau\to\mu\gamma$

Extra Dimensions

- Using ACD model of 1 universal extra dimension, a MFV model, Colangelo et al predict a shift in the zero of the forward-backward asymmetry in $B \to K^* \mu^+ \mu^-$
- *Insensitive to choice of form-factors. Can SM calculations improve?*

LHCb measures zero to ±0.22 GeV^2 in 10 fb^{-1}





Other Angular Variables in $K^*\mu^+\mu^-$

- Supersymmetry (Egede, et al... arXiv:0807.2589)
- Use functions of the transverse polarization

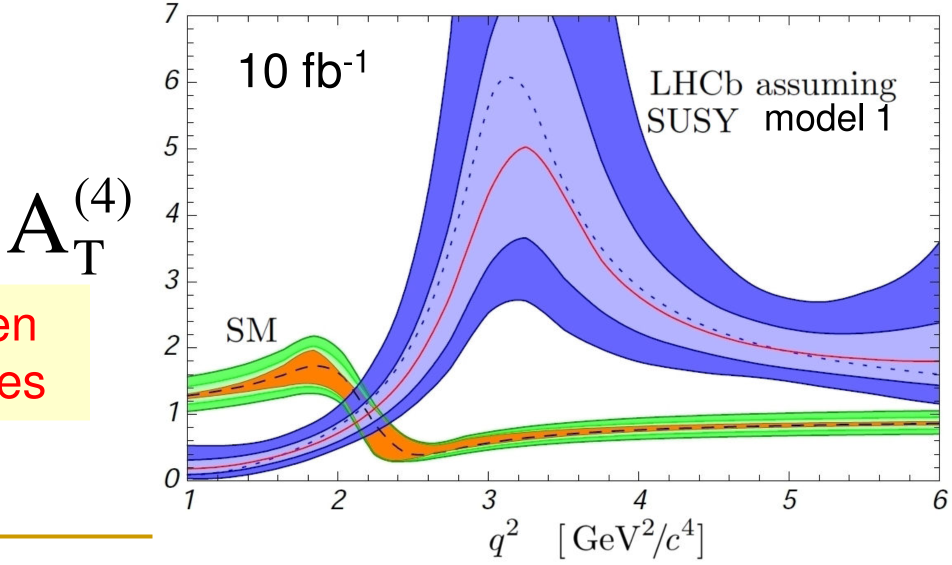
$$A_{\perp L,R} = \sqrt{2} N m_B (1-\hat{s})\left[(\mathcal{C}_9^{(\text{eff})} \mp \mathcal{C}_{10}) + \frac{2\hat{m}_b}{\hat{s}}(\mathcal{C}_7^{(\text{eff})} + \mathcal{C}_7^{\prime(\text{eff})})\right]\xi_\perp(E_{K^*}),$$

$$A_{\parallel L,R} = -\sqrt{2} N m_B (1-\hat{s})\left[(\mathcal{C}_9^{(\text{eff})} \mp \mathcal{C}_{10}) + \frac{2\hat{m}_b}{\hat{s}}(\mathcal{C}_7^{(\text{eff})} - \mathcal{C}_7^{\prime(\text{eff})})\right]\xi_\perp(E_{K^*}),$$

ξ_i are form factors

$$A_{0L,R} = -\frac{N m_B}{2\hat{m}_{K^*}\sqrt{\hat{s}}}(1-\hat{s})^2\left[(\mathcal{C}_9^{(\text{eff})} \mp \mathcal{C}_{10}) + 2\hat{m}_b(\mathcal{C}_7^{(\text{eff})} - \mathcal{C}_7^{\prime(\text{eff})})\right]\xi_\parallel(E_{K^*}),$$

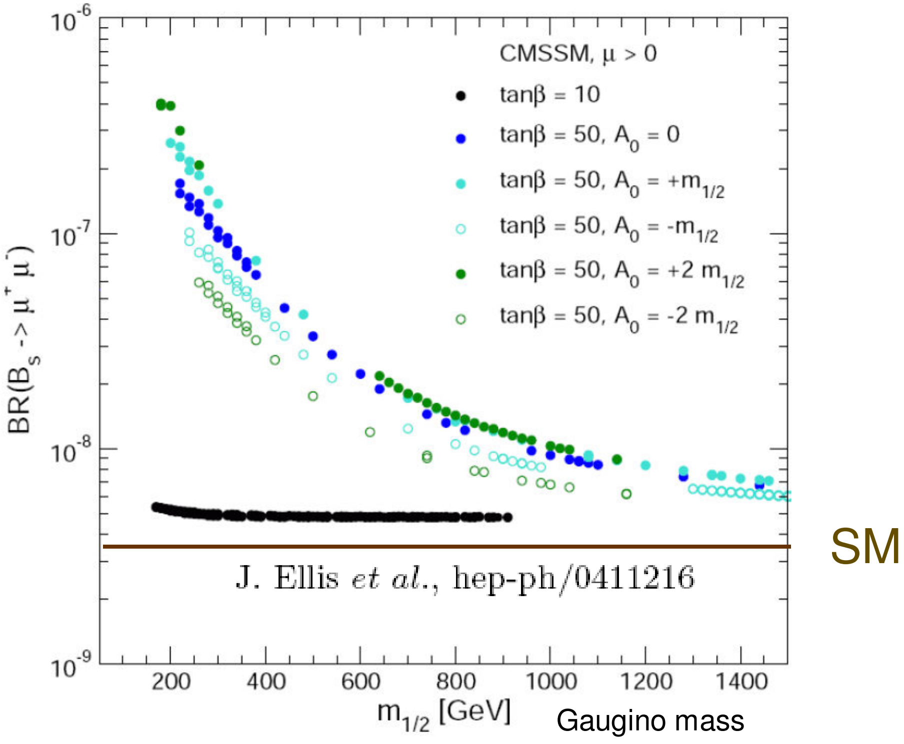
$$A_T^{(4)} = \frac{|A_{0L}A_{\perp L}^* - A_{0R}^* A_{\perp R}|}{|A_{0L}^* A_{\parallel L} + A_{0R} A_{\parallel R}^*|},$$



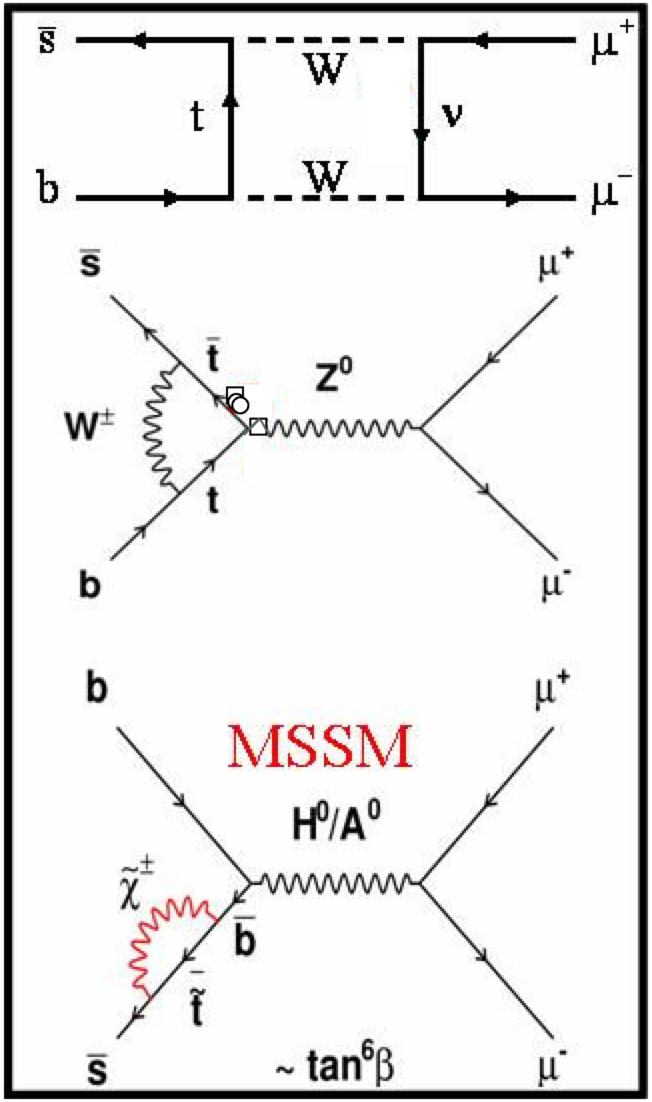
With more ∫L can distinguish between different SUSY models in some cases

$B_S \to \mu^+\mu^-$ & Supersymmetry

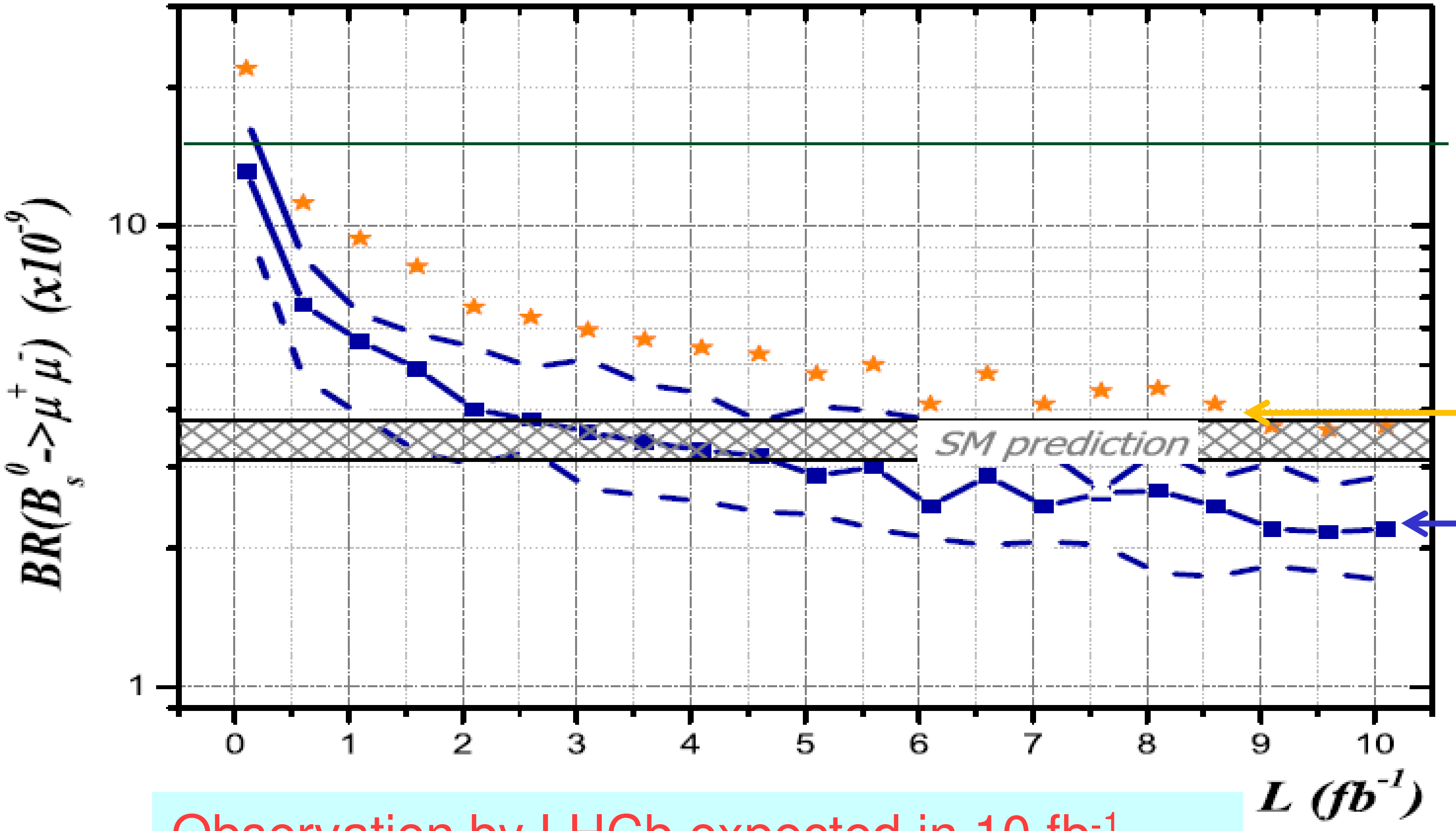
- Branching Ratio very sensitive to SUSY
- In MSSM goes as $\tan^6\beta$



J. Ellis *et al.*, hep-ph/0411216



LHCb Reach for $\mathcal{B}(B_S \to \mu^+\mu^-)$



Current CDF Limit

5σ discovery

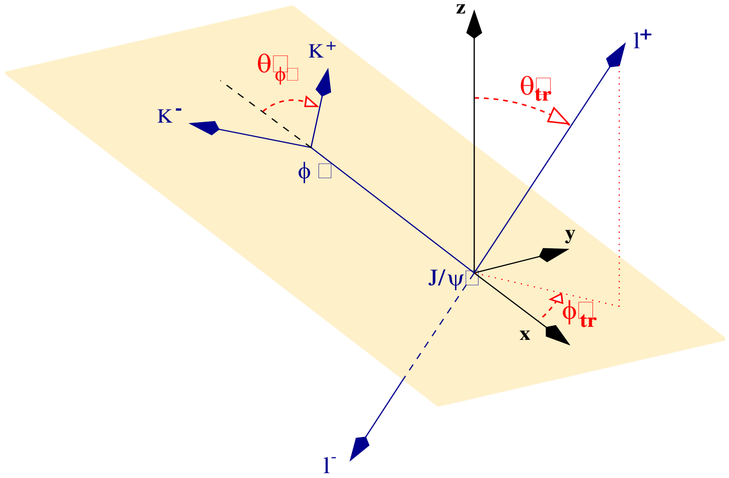
3σ observation, 90% probability Range from MC statistics

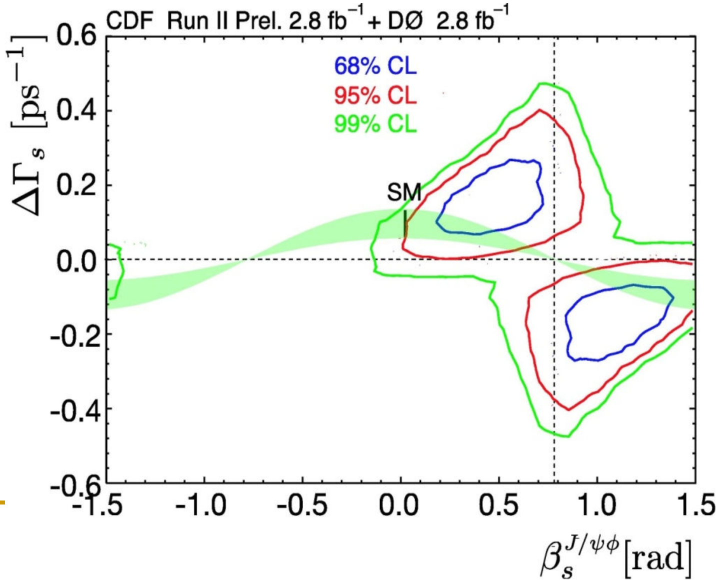
Observation by LHCb expected in 10 fb^{-1}, but 100 fb^{-1} needed for precise measurement

Background is dominated by combinations of $b \to \mu^- X$ $b \to \mu^+ X$ events.

CP Asymmetry in $B_S \to J/\psi\ \phi$

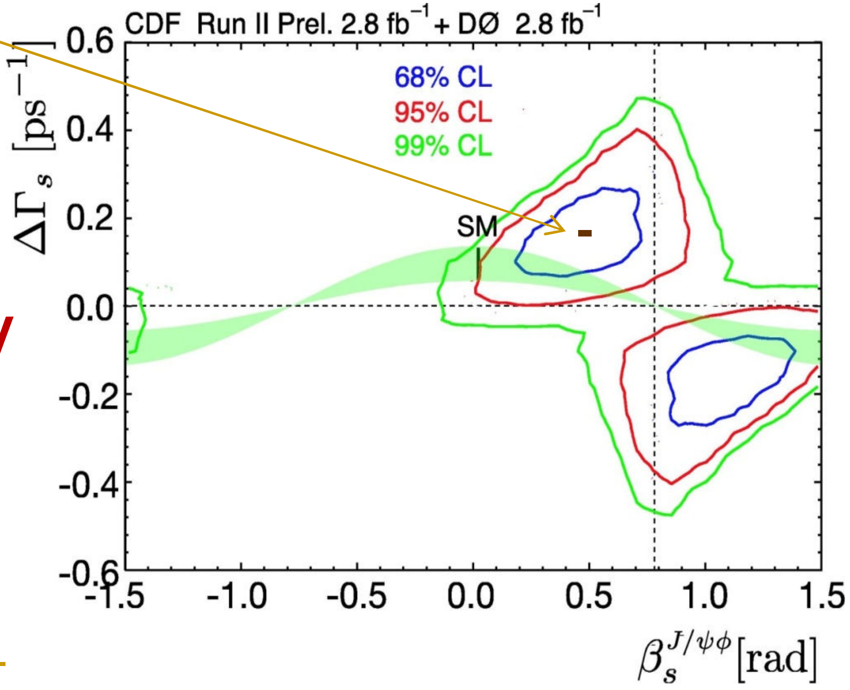
- Just as $B^o \to J/\psi\ K_S$ measures CPV phase 2β $B_S \to J/\psi\ \phi$ measures CPV B_S mixing phase $-2\beta_S$
- Since this is a Vector-Vector final state, must do an angular (transversity) analysis
- The width difference $\Delta\Gamma_S/\Gamma_S$ also enters in the fit
- Combined current CDF & D0 results



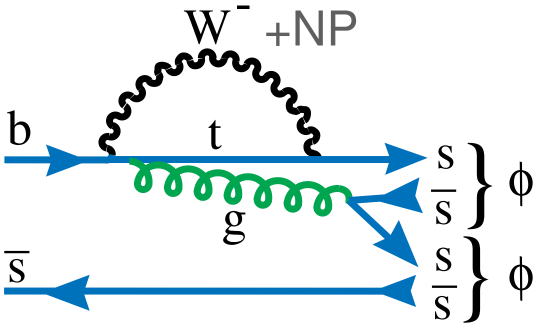


LHCb Sensitivities for $2\beta_S$

- LHCb will get 655,000 such events in 10 fb^{-1}. Projected errors are ±0.010 in $2\beta_S$ & ±0.005 in $\Delta\Gamma_S/\Gamma_S$. [Will also use $J/\psi\ f_o(980)$]
- With 100 fb^{-1} (LHCb upgrade) error in $-2\beta_S$ decreases to ±0.004 (only $\mathcal{L}$ improvement), useful to distinguish among Supersymmetry models (see slide 12)



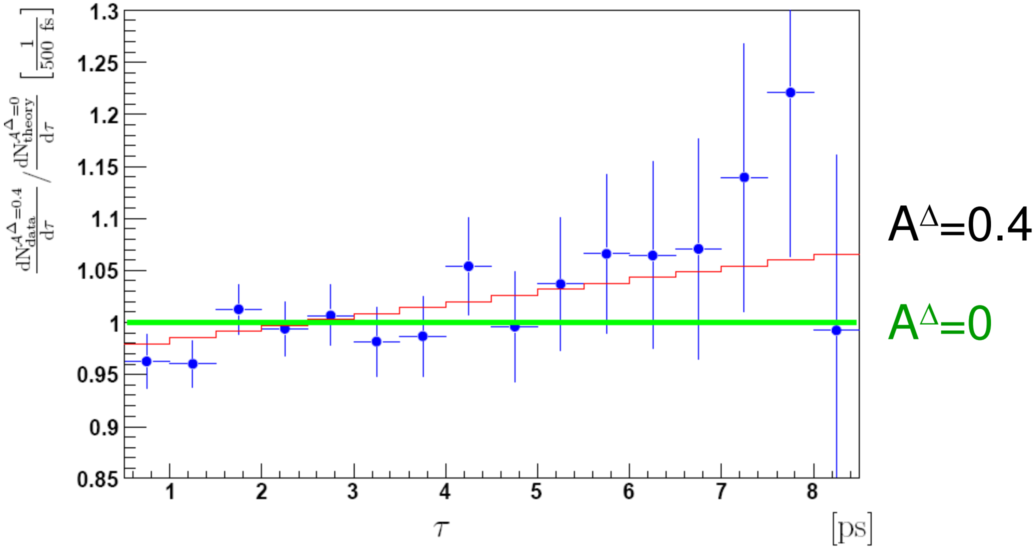
A Null Measurement



- $B_S \rightarrow \phi\phi$, similar to $B^o \rightarrow \phi K_S$
- In SM CPV=0, as decay phase cancels mixing phase. Can contrast with J/ψ φ
- Might think that Vector-Vector state is much worse due to angular analysis, but K^+K^- S-wave $f_o(980)$ can be accommodated, and $f_o(980)\rightarrow\pi^+\pi^-$ may be used if the B is large enough
- Estimated error in CP violating asymmetry (S)
  - Super B $B^o\rightarrow\phi K_S$, for 50 ab^{-1} is ±0.03
  - LHCb $B_S\rightarrow\phi K_S$, for 100 fb^{-1} is ±0.019-0.045
  - LHCb $B_S\rightarrow\phi\phi$, for 100 fb^{-1} is ±0.017

$B_S \to \phi\gamma$: Right-Handed currents

- Define $\tan\psi \equiv \left|\frac{\mathcal{A}\left(\bar{\mathrm{B}}_{(\mathrm{s})} \to \Phi^{\mathcal{CP}}\gamma_{\mathrm{R}}\right)}{\mathcal{A}\left(\bar{\mathrm{B}}_{(\mathrm{s})} \to \Phi^{\mathcal{CP}}\gamma_{\mathrm{L}}\right)}\right|$, zero in SM
- Theory $$\Gamma_{\mathrm{B}_s^0 \to \Phi^{\mathcal{CP}}\gamma}(\mathrm{t}) \approx |\mathrm{A}|^2 \mathrm{e}^{-\Gamma_s \mathrm{t}}\left(\cosh\frac{\Delta\Gamma_s \mathrm{t}}{2} - \mathcal{A}^{\Delta}\sinh\frac{\Delta\Gamma_s \mathrm{t}}{2}\right)$$ $$\Gamma_{\bar{\mathrm{B}}_s^0 \to \Phi^{\mathcal{CP}}\gamma}(\mathrm{t}) \approx \Gamma_{\mathrm{B}_s^0 \to \Phi^{\mathcal{CP}}\gamma}(\mathrm{t})$$ where $A^{\Delta}=\sin 2\psi$
- Sensitivity (assume $\Delta\Gamma_S/\Gamma_S=0.12$)
- $\sigma(\sin 2\psi)=0.22$ 2fb^{-1}
- $\sigma(\sin 2\psi)=0.10$ 10fb^{-1}
- $\sigma(\sin 2\psi)=0.02$ 100fb^{-1}



Detector Requirements - General

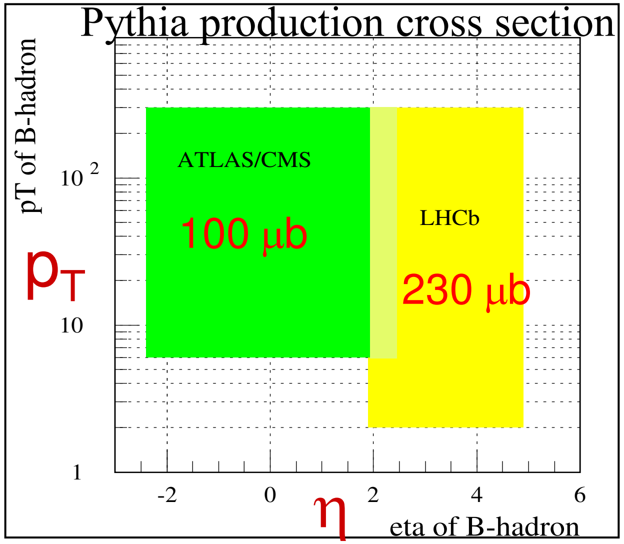
- Every modern heavy quark experiment needs:
  - Vertexing: to measure decay points and reduce backgrounds, especially at hadron colliders
  - Particle Identification: to eliminate insidious backgrounds from one mode to another where kinematical separation is not sufficient
  - Muon & electron identification because of the importance of semileptonic & leptonic final states including J/ψ decay
  - γ, π^o & η detection
  - Triggering, especially at hadronic colliders
  - High speed DAQ coupled to large computing for data processing
  - An accelerator capable of producing a large rate of b & anti-b hadrons in the detector solid angle

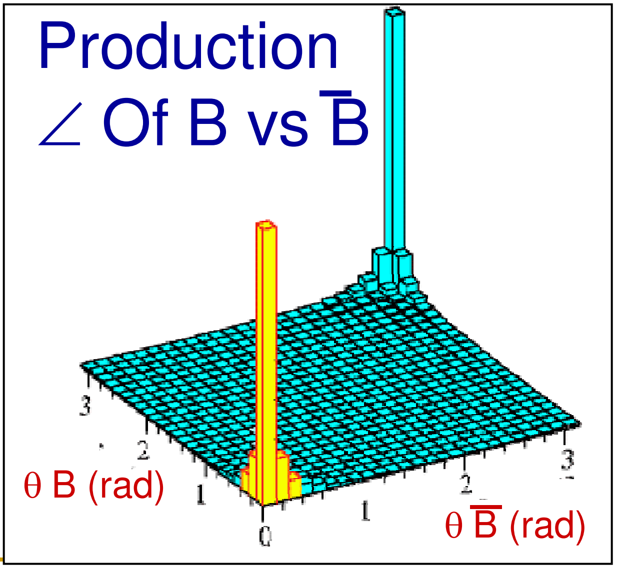
Basics For Sensitivities

- # of b's into detector acceptance
- ***Triggering***
- Flavor tagging
- Background reduction
  - Good mass resolution
  - Good decay time resolution
  - Particle Identification

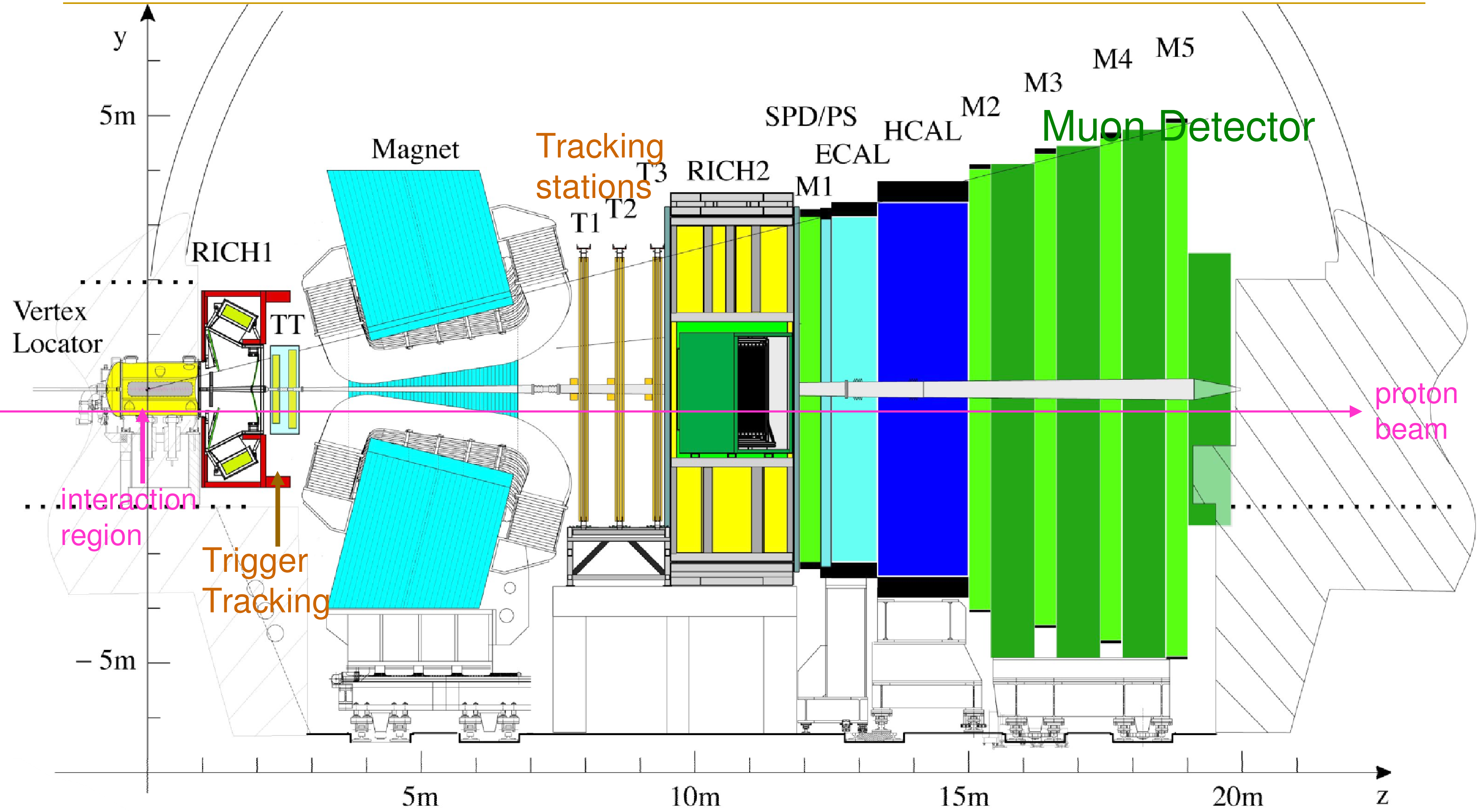
The Forward Direction at LHC

- In the forward region at LHC the $b\bar{b}$ production σ is large
- The hadrons containing the b & $\bar{b}$ quarks are both likely to be in the acceptance
- LHCb uses the forward direction, $4.9 > \eta > 1.9$, where the B's are moving with considerable momentum ~100 GeV, thus minimizing multiple scattering
- At $\mathcal{L}$=2x10^{33}/cm^2-s, we get 10^{13} B hadrons in 10^7 sec at 14 TeV





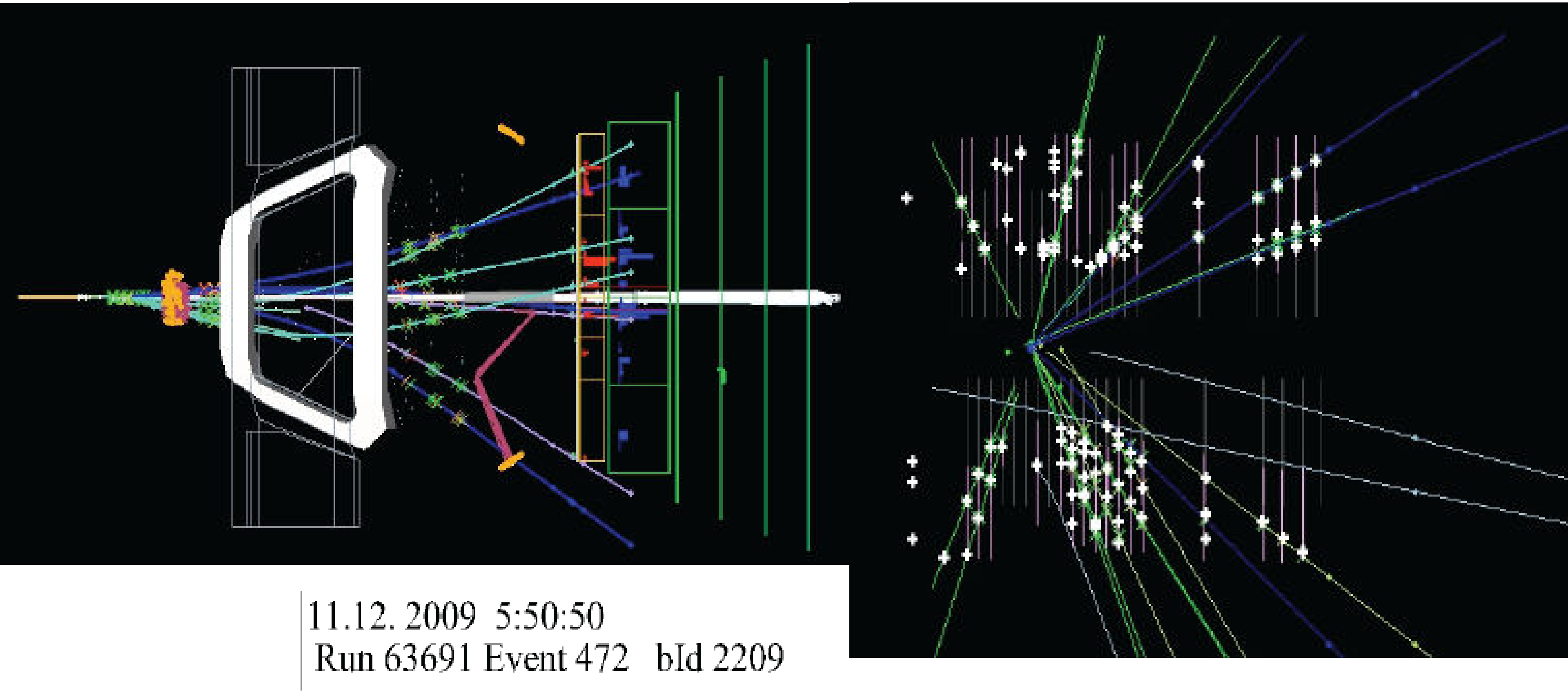
The LHCb Detector



We will need to Upgrade the detector

LHCb Data

- But first a few glimpses of real data

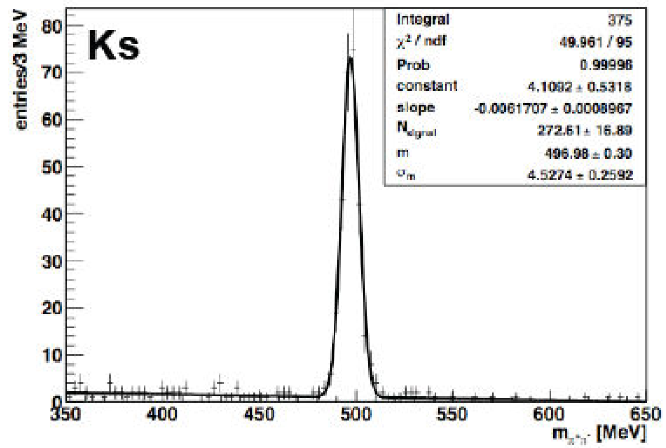


11.12. 2009 5:50:50
Run 63691 Event 472 bId 2209

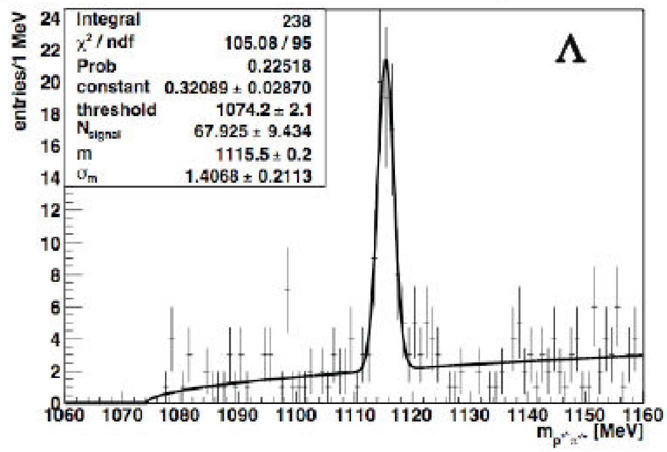
More LHCb Data

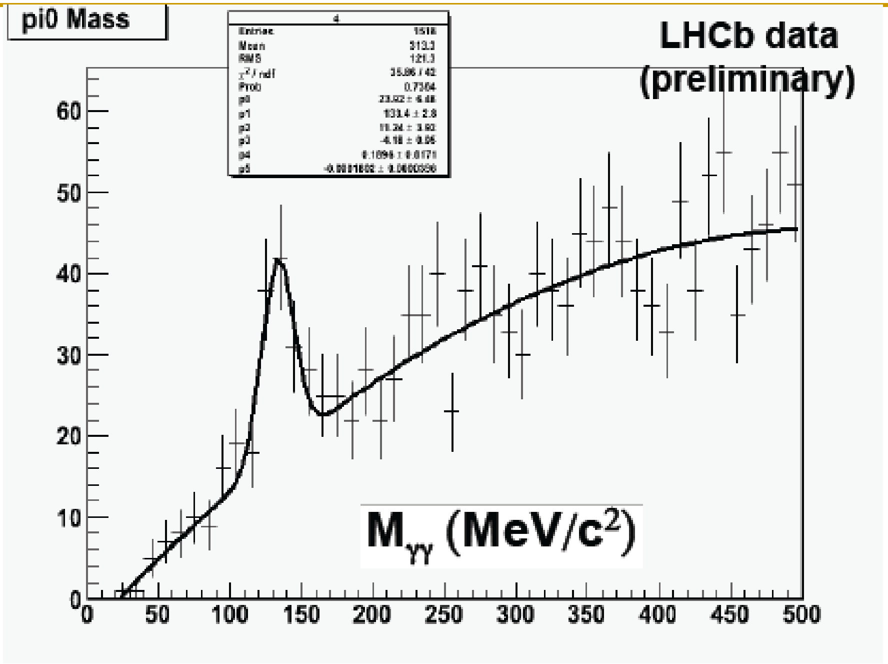
Using all tracking power, especially VELO !!!

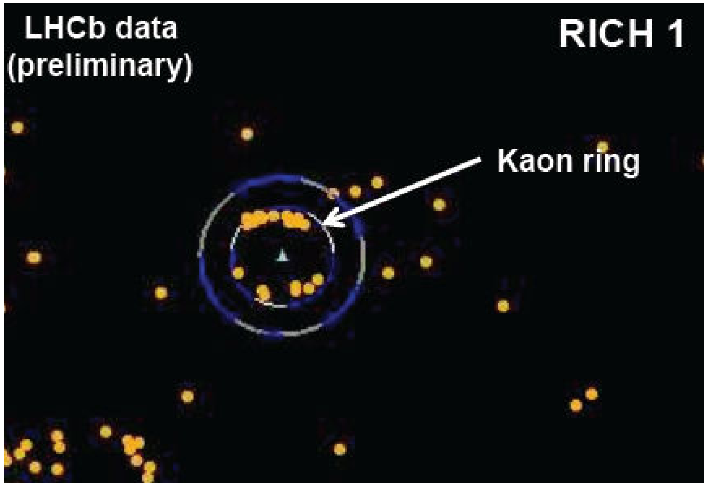
$\pi^+ \pi^-$ invariant mass (LHCb 2009 data, preliminary)



$p^{+/-} \pi^{-/+}$ invariant mass (LHCb 2009 data, preliminary)





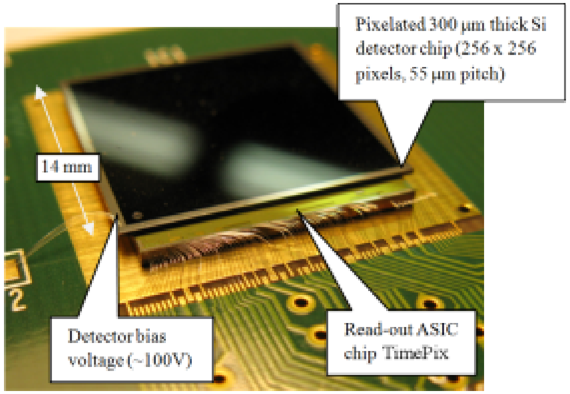


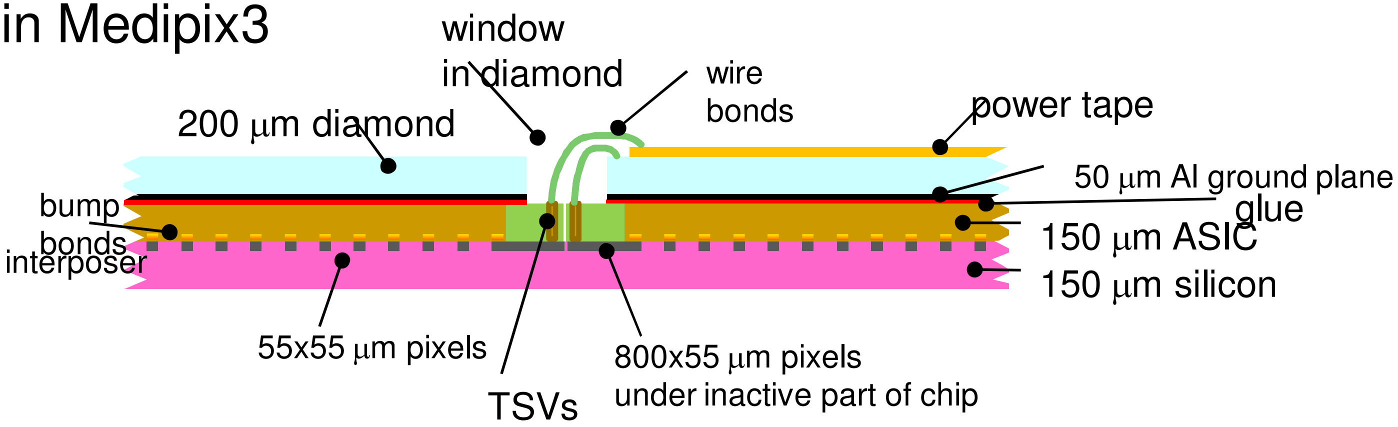
How We Can Upgrade

- Run at higher luminosity
- Improve efficiencies
  - especially for hadron trigger
  - Photon detection
  - Tracking, e.g. reduce material
- Improve resolutions
  - Photon detector
  - RICH
- Basically build a better magnifying glass!
  - New VELO, etc…

The VErtex LOcator

- Essential for establishing precision verticies
- Essential for trigger & tracking
- Upgrade baseline VELOPix is based on Medipix/Timepix Pixel readout chip
  - 256 x 256 pixels 55 μm square. Chip is 3 side buttable
  - By using TSV (Through Silicon Via) dead side can be reduced to 0.8 mm in Medipix3



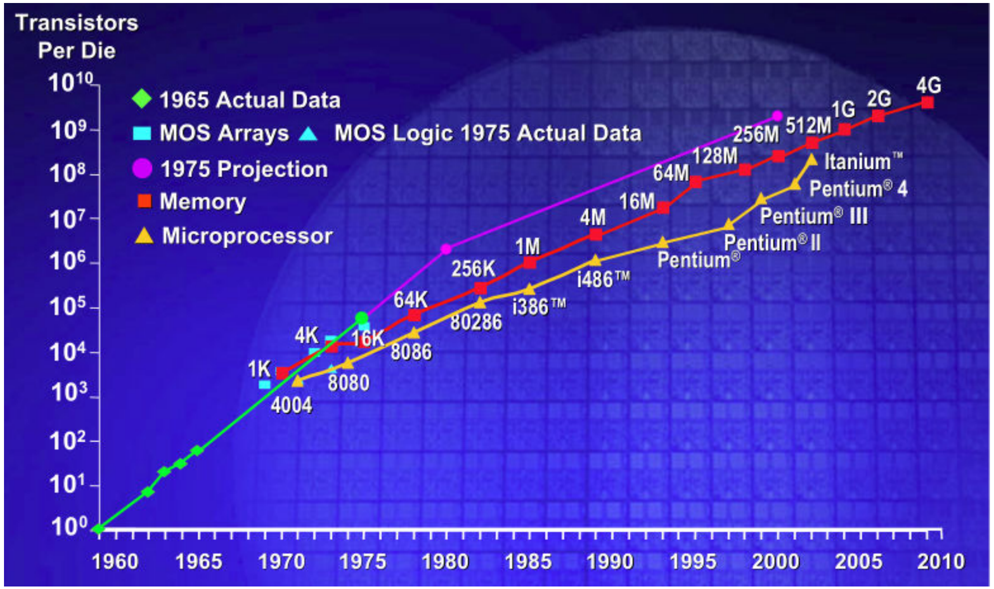


Triggering

- Necessary because b fraction is only ~1% of inelastic cross-section, & most b's are not that interesting
- At peak luminosity interaction rate is ~10 MHz, need to reduce to a few kHz. The B hadron rate into the acceptance is 50 kHz
- General Strategy - Current
  - Multilevel scheme: 1st level Hardware trigger on "moderate" p_T μ, di-muons, e, γ & hadrons, e.g. p_T μ >1.3 GeV/c; veto on multiple interactions in a crossing except for muon triggers.
  - Uses custom electronics boards with 4 μs latency, all detectors read out at 1 MHz
  - Second level and Higher Level software triggers

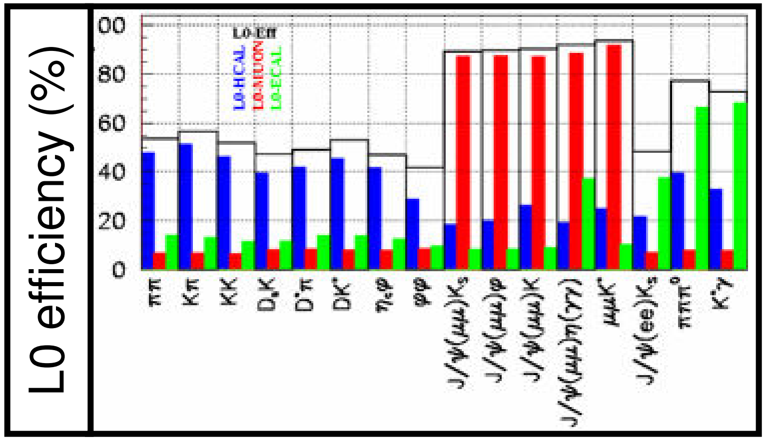
Upgrade Trigger

- Readout entire detector at 40 MHz
- Have an software based trigger
- Use detached vertex information early on in Trigger
- Take advantage of Moore's law increases in CPU & storage



Current Trigger Efficiency

- As usual define trigger ε= # events accepted by trigger / # of events found after all other analysis cuts



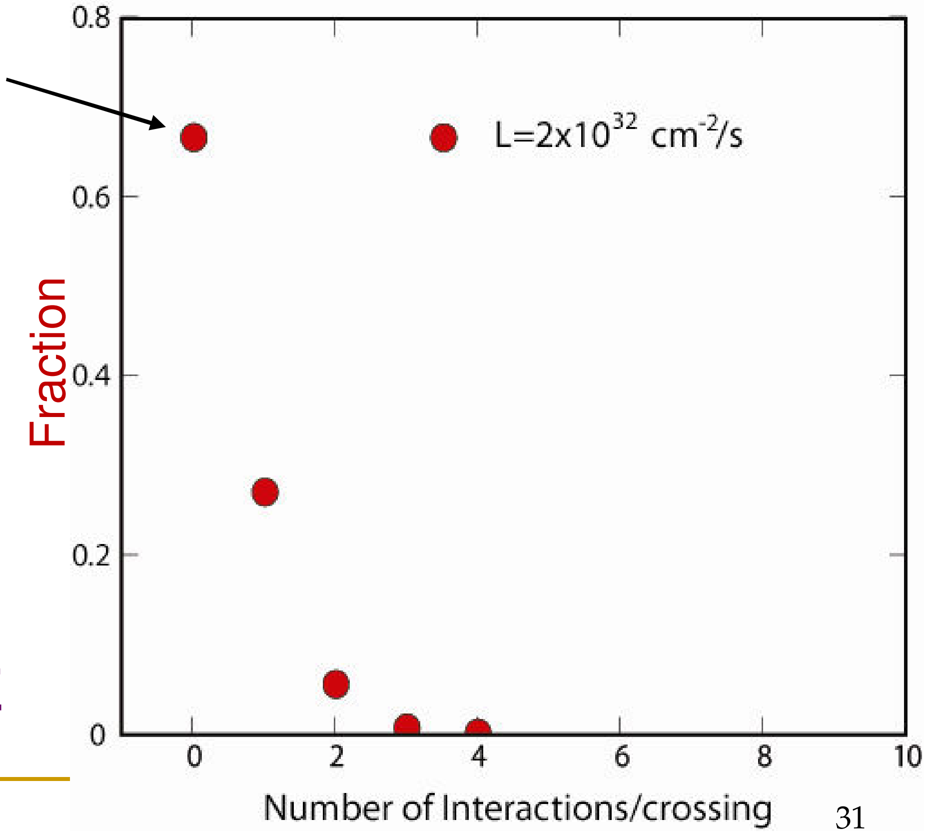
- L0 typically is 50% efficient on fully hadronic final states
- HLT1 is 60% on D_SK^-
- HLT2 is 85% on D_SK^-
- Product is 25%, room for improvement

Our Goal

- To collect signal at 20 times current rate in hadronic chanels & 10 times in dilepton channels, then we will possess the most powerful microscope known to man to probe certain physical processes
  - We will use specific channels and show rates can be increased, but the idea is to be able to increase data on a whole host of channels where new ones may become important

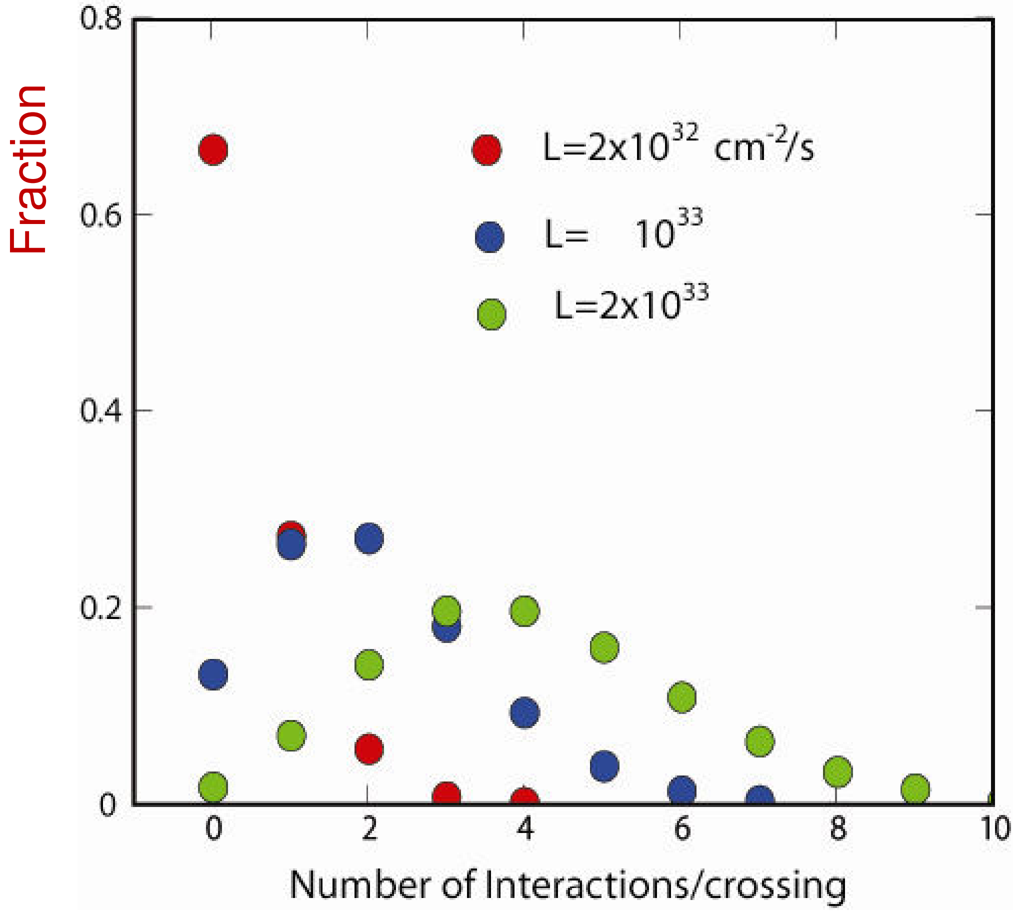
Current Running Conditions

- Luminosity 2×10^{32} cm^{-2}/s at beginning of run
- Take σ = 60 mb, [σ(total) - σ(elastic) - σ(diffractive)]
- Account for only 29.5 MHz of two filled bunches
- Most xings don't have an interaction
- Need 1st level trigger "L0" to reduce data by factor~30 to 1 MHz
- Higher Level Triggers reduce output to 2 kHz



Upgrade Running Conditions

- At $L=10^{33}$ increases average # of int/xcrossing to only ~2.3
- At $L=2x10^{33}$ increases to ~4.6

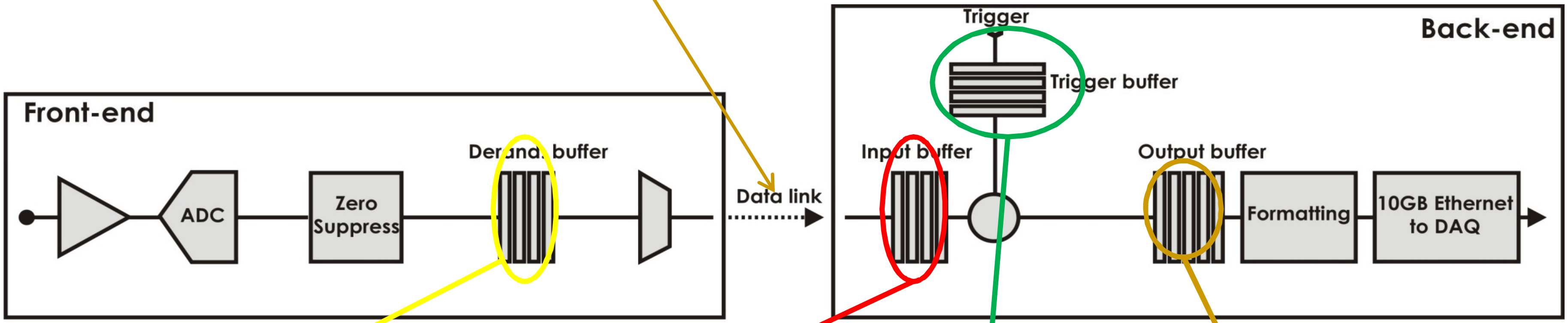


Trigger Specifications

- Projected online farm is 16,000 cores. Original spec was 1 GHz, but now getting 2.8 GHz
- For 16,000 processors we have 25 ns*16,000 = 0.4 ms to make a decision (probably will have >10 GHz cores)
- Will be able to afford a 20 kHz output rate, rather than the 2 kHz we have now
- We need a trigger strategy that executes in ⟨0.4 ms⟩ that is maximally efficient on signal and reduces the background to an acceptable level
  - Minimum bias must be reduced from 100 MHz interaction rate to <20 kHz, reduction factor is 100,000 (~same as now)
  - Aim at ε_{trig}>50% on hadronic decays

Electronics & DAQ

- Zero-suppressed readout
- GBT link used



FE derandomising buffer
Absorb statistical fluctuations in data
Needs careful monitoring
Needs careful simulation

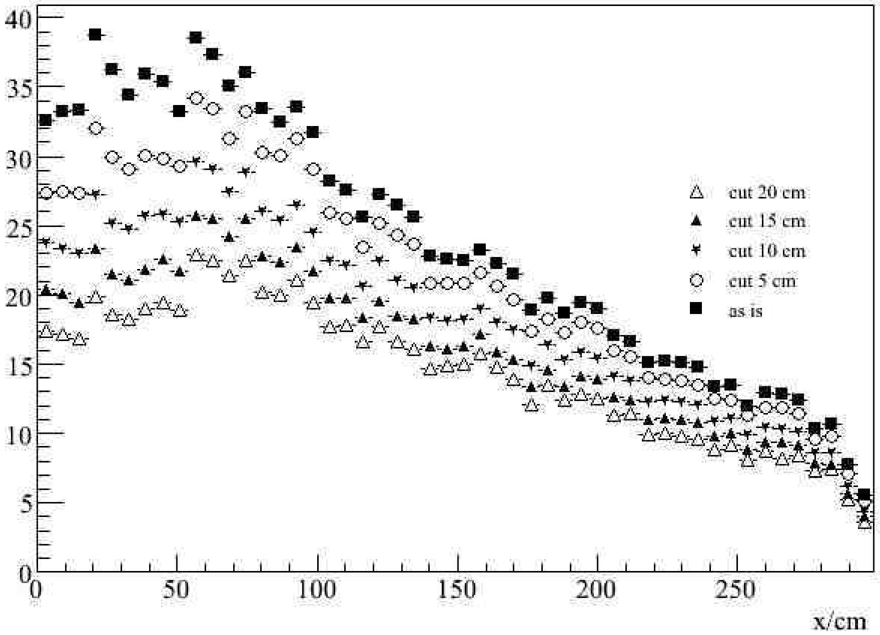
BE input buffer
Length = trigger latency
+ margin for derandomiser

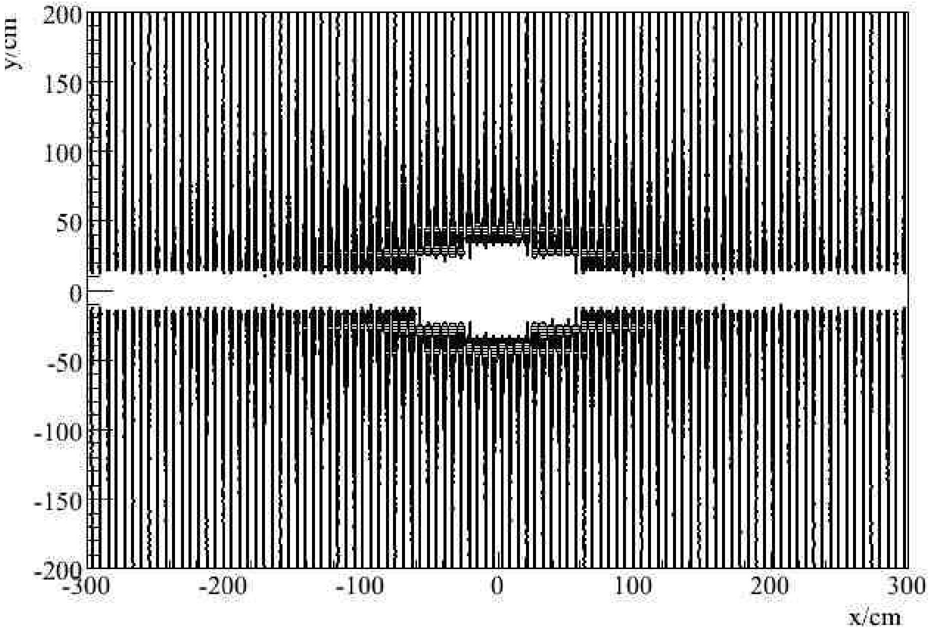
BE trigger buffer
Small, re-ordering?

BE output buffer
Depends on output protocol
eg MEP factor?

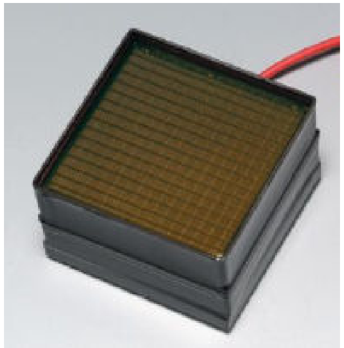
Tracking

- Outer Tracker occupancies will become unacceptably high
- Solutions
  - Enlarge Inner tracker
  - Use faster gas to reduce spillover





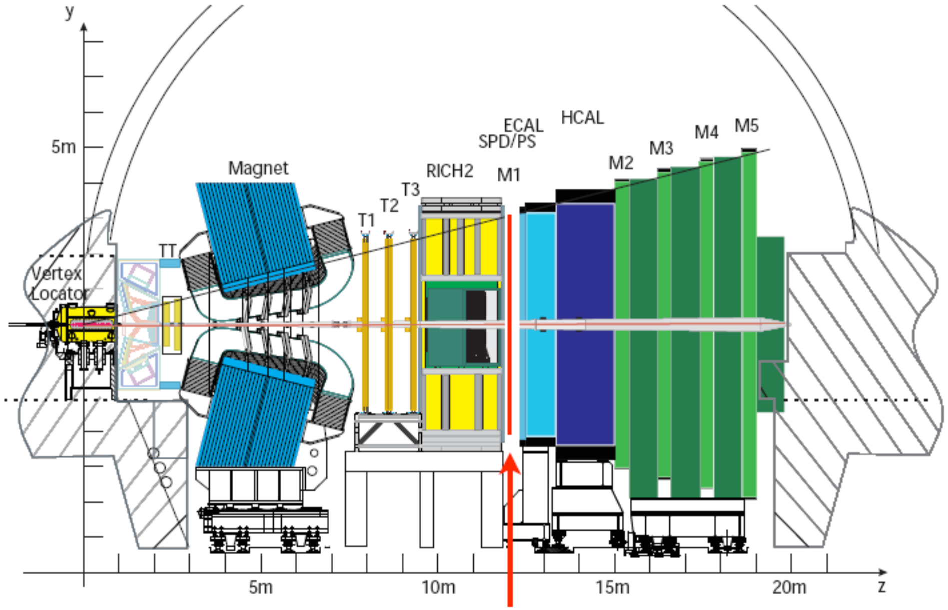
RICH

- HPD silicon readout is tied to 1 MHz, must be replaced. Possibly Flat panel PMT, MCH, HPD'
- 

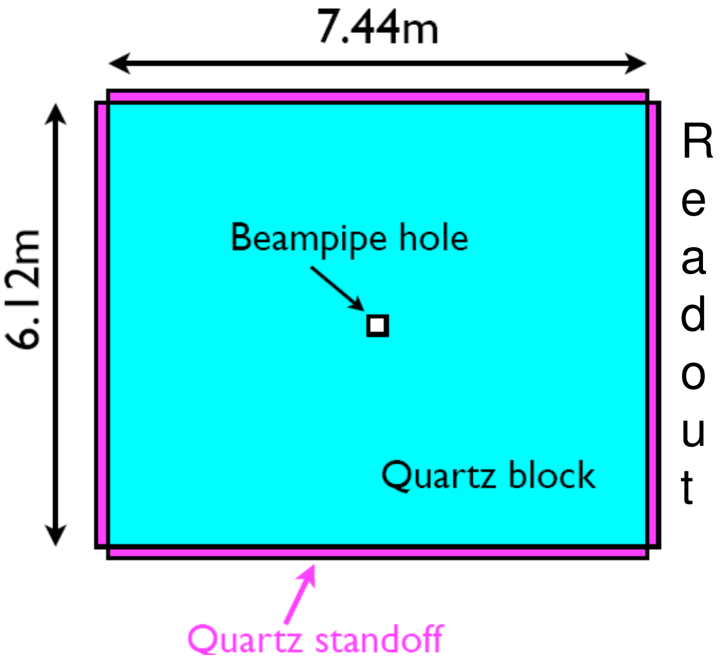
  Hamammatsu

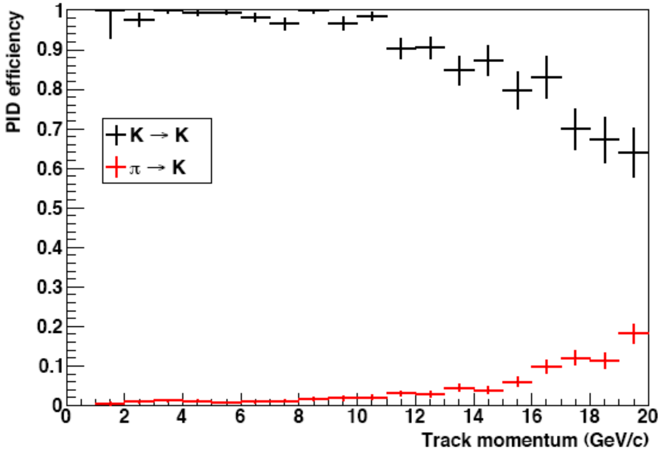
  H9500
- Stress on RICH I due to increased occupancies, especially Aerogel
- New Idea: Time of Flight

The Torch (TOF detector)



1cm-thick quartz plate at z=12m





- TOF for p<10 GeV/c
- MCH readout ~30 ps resolution

Conclusions

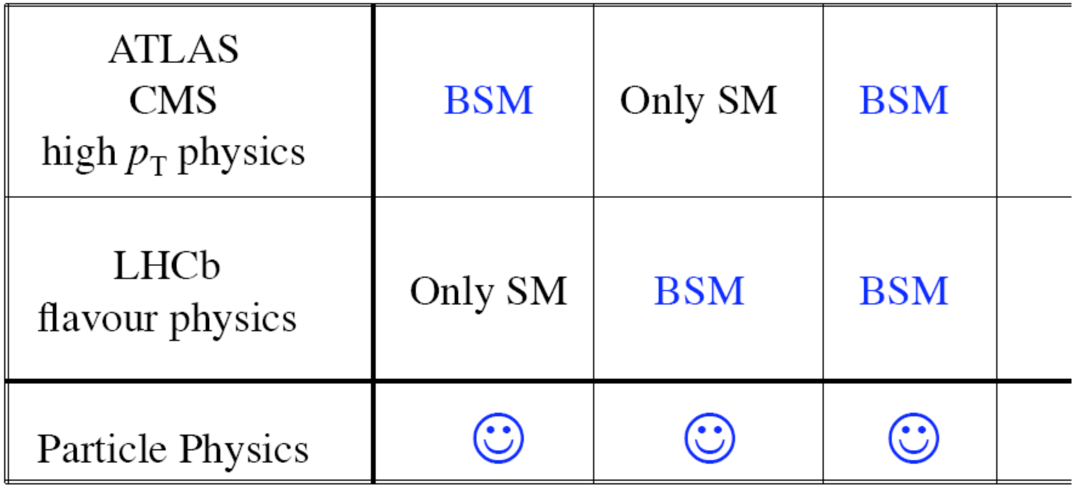
- We hope to see effects of NP found by Atlas/CMS (CD's) in "flavor" studies in our1st 10 fb^{-1}
- Upgrading will allow us to precisely measure these effects
- Complementary to CD's, forward η region, sensitive to objects $\rightarrow b\bar{b}$, e.g. "Hidden Valleys"
- Complementary to SuperB:
  - LHCb – B_S
  - SuperB – τ's
  - Healthy overlap - B^o, B^-

Upgraded Sensitivities (100 fb^{-1})	
Observable	Sensitivity
CPV($B_s \rightarrow \phi\phi$)	0.017
CPV($B_d \rightarrow \phi K_s$)	0.019-0.045
CPV($B_s \rightarrow J/\psi\phi$) ($2\beta_s$)	0.003
CPV($B_d \rightarrow J/\psi K_s$) ($2\beta$)	0.003-0.010
CPV($B \rightarrow DK$) (γ)	<1°
CPV($B_s \rightarrow D_s K$) (γ)	1-2°
$\mathcal{B}$($B_s \rightarrow \mu^+\mu^-$)	~10% of SM
A_{FB}($B \rightarrow K^* \mu^+\mu^-$)	Zero to ±0.07 GeV^2
σ(sin2ψ)($B_s \rightarrow \phi\gamma$)	0.02
Charm mixing x'^2	$2\mathrm{x}10^{-5}$
Charm mixing y'	$2.8\mathrm{x}10^{-4}$
Charm CP y_{CP}	$1.5\mathrm{x}10^{-4}$

The Future

- Yogi Berra: “Its difficult to make predictions, especially about the future”

- Possibilities after 10 fb-1:

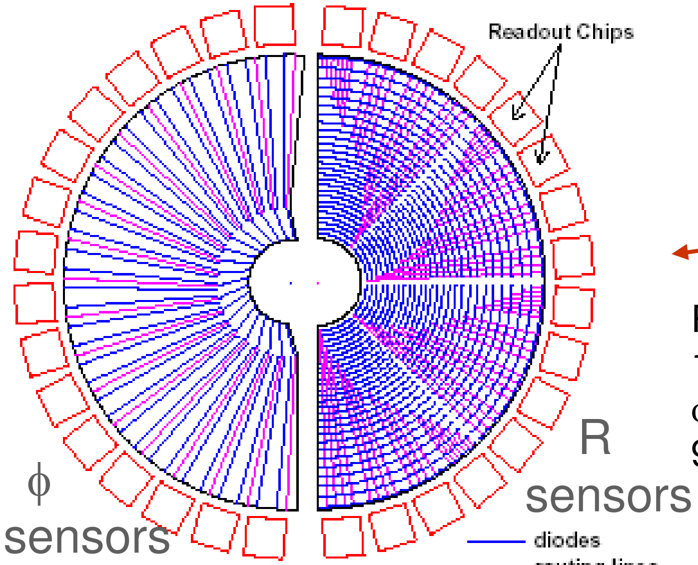


ATLAS CMS high p_T physics	BSM	Only SM	BSM
LHCb flavour physics	Only SM	BSM	BSM
Particle Physics	☺	☺	☺

- Fourth possibility too depressing to list, but LHCb measurements could set the scale of where we would have to go next

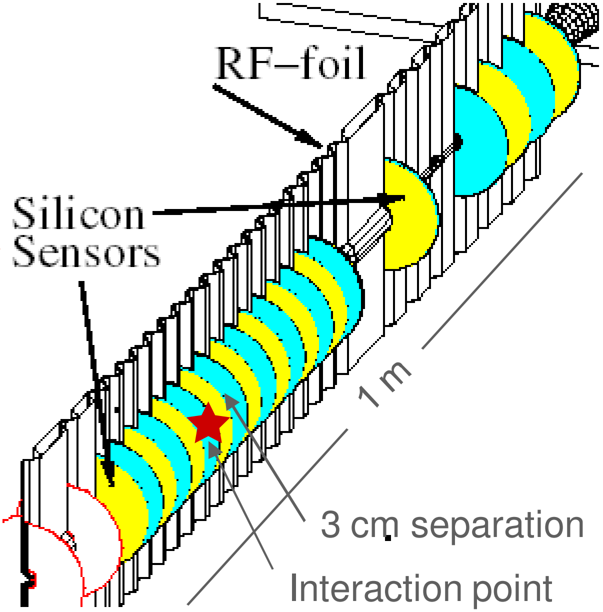
The End

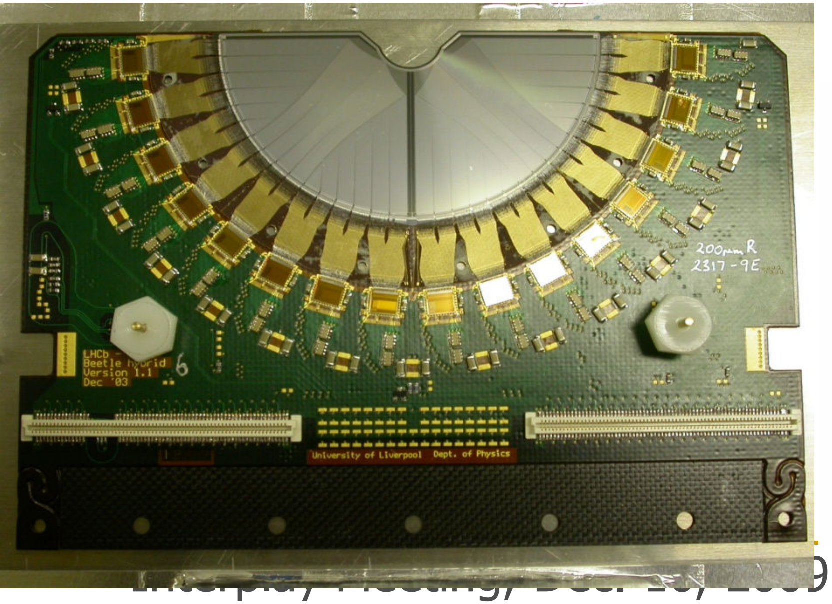
The VELO

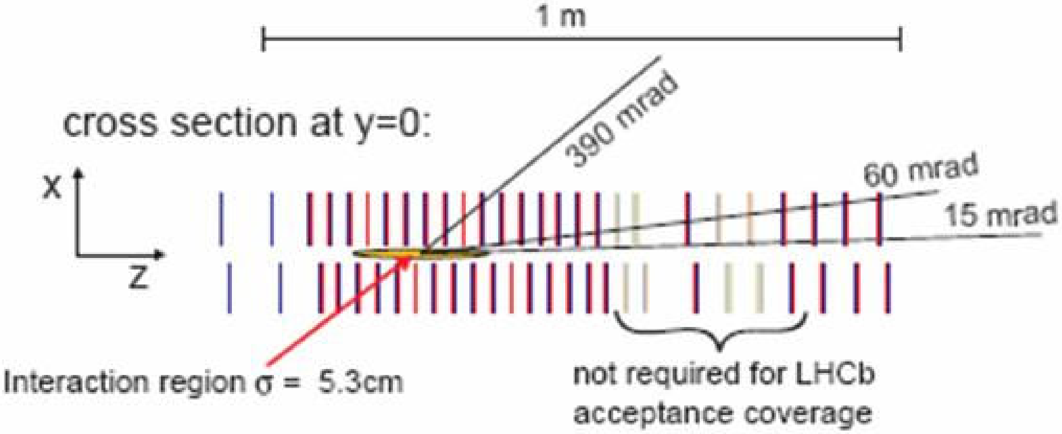


Geometry

R sensor: 38 μm pitch inside to 103 μm outside
φ sensor: 39 μm pitch inside to 98 μm outside







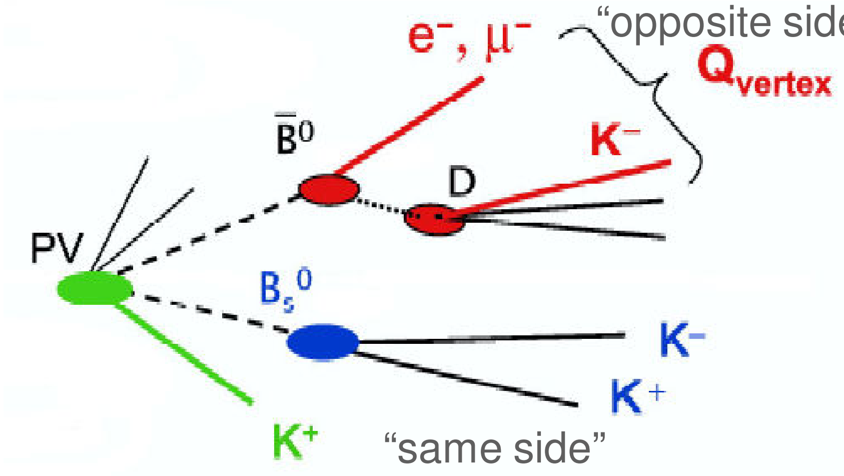
Trigger Output

Output rate	**Trigger Type**	**Physics Use**
200 Hz	Exclusive B candidates	Specific final states
600 Hz	High Mass di-muons	J/ψ, $b \to J/\psi X$
300 Hz	D* Candidates	Charm, calibrations
900 Hz	Inclusive b (e.g. $b \to \mu$)	B data mining

- Rough guess at present (split between streams still to be determined)
- Large inclusive streams to be used to control calibration and systematics (trigger, tracking, PID, tagging)

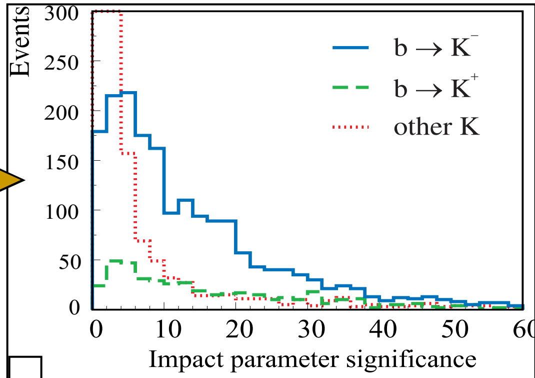
Flavor Tagging

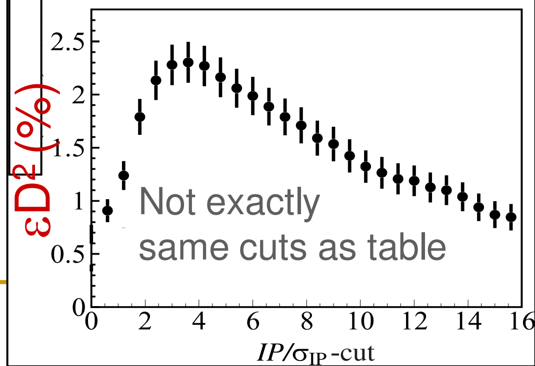
- For Mixing & CP measurements it is crucial to know the b-flavor at t=0. This can be done by detecting the flavor of the other B hadron (opposite side) or by using K± (for B_S) $\pi^\pm$ (for B_d) (same side)
- Efficacy characterized by εD^2, where ε is the efficiency and D the dilution = $(1-2\omega)$
- Several ways to do this



Method (For B_S)	$\mu^\pm$	$e^\pm$	$K^\pm$ same	$K^\pm$ opp	Jet charge
εD^2(%)	1.5	0.7	3.1	2.5	0.8

Expect εD^2 ~ 7.5% for B_S & 4.3% for B_d



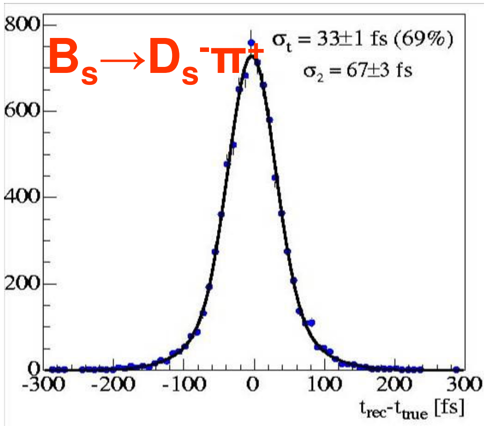


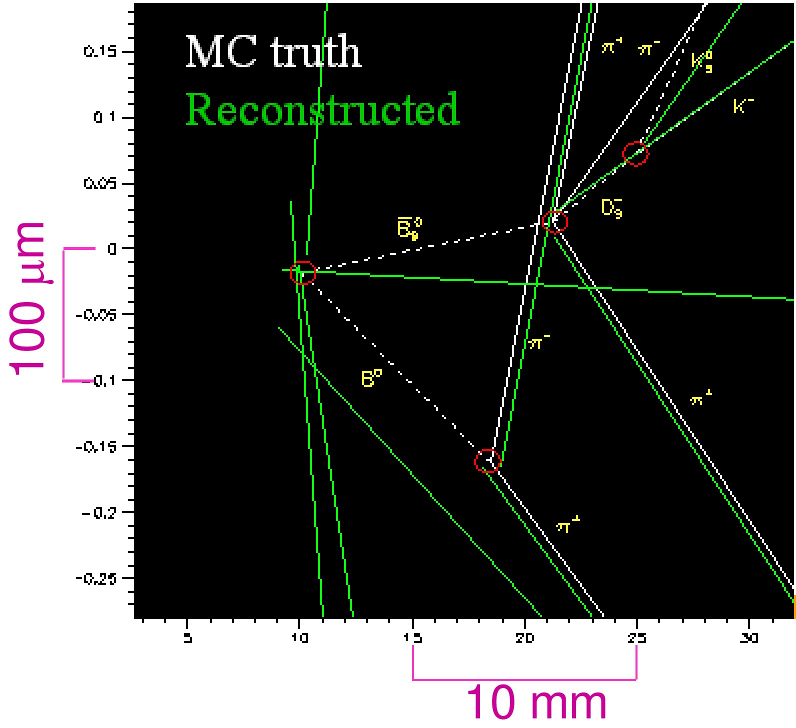
Not exactly same cuts as table

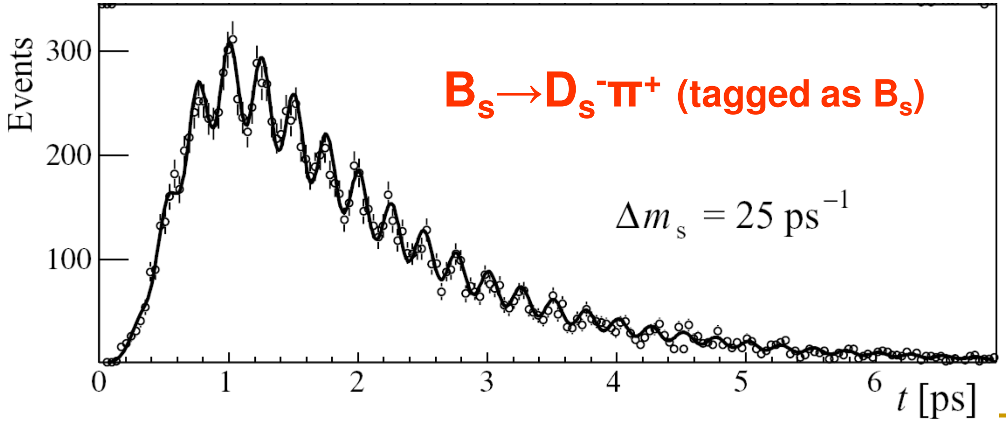
Background Reduction Using σ_t

- Excellent time resolution ~40 fs for most modes based on VELO simulation
- Example

  B_s mixing

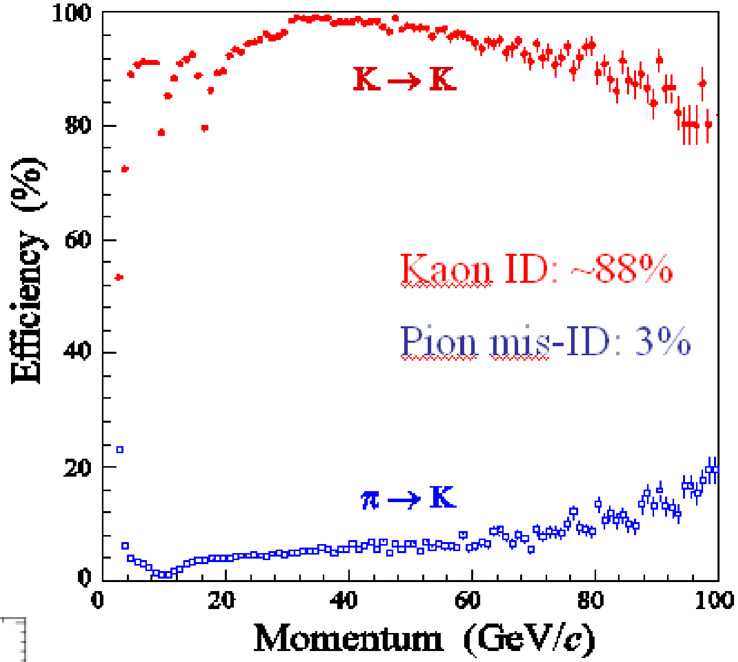






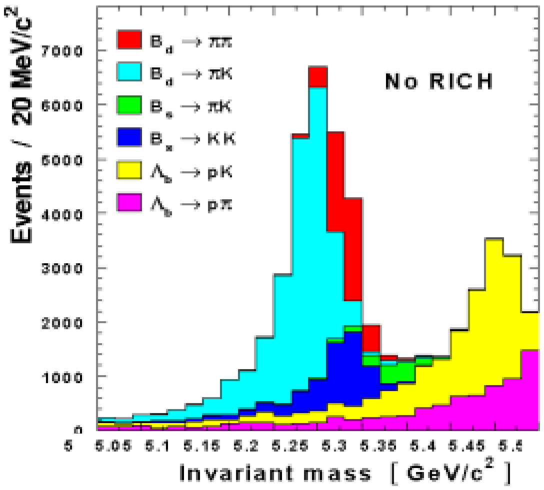
Background Reduction from Particle ID

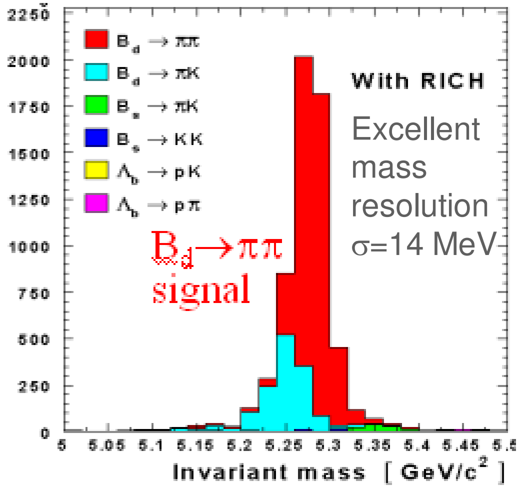
- LHCb identifies most tracks in range 100>P>2 GeV/c. Tagging kaons at lower momentum < 20 GeV/c; B→h^+h^- up to 200 GeV/c, but most below 100 GeV/c
- Good Efficiencies with small fake rates



Kaon ID: ~88%

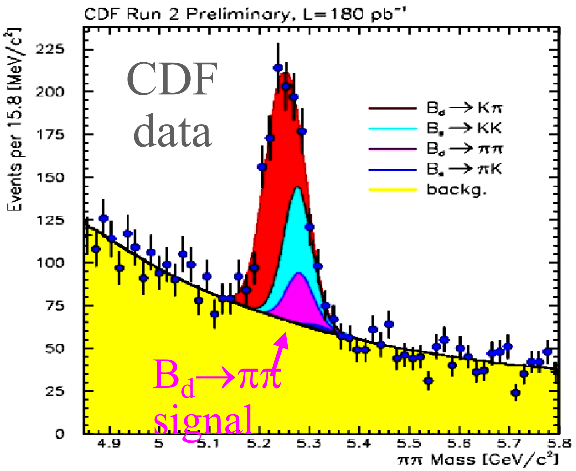
Pion mis-ID: 3%





$B_d \to \pi\pi$ signal

Excellent mass resolution σ=14 MeV



CDF data

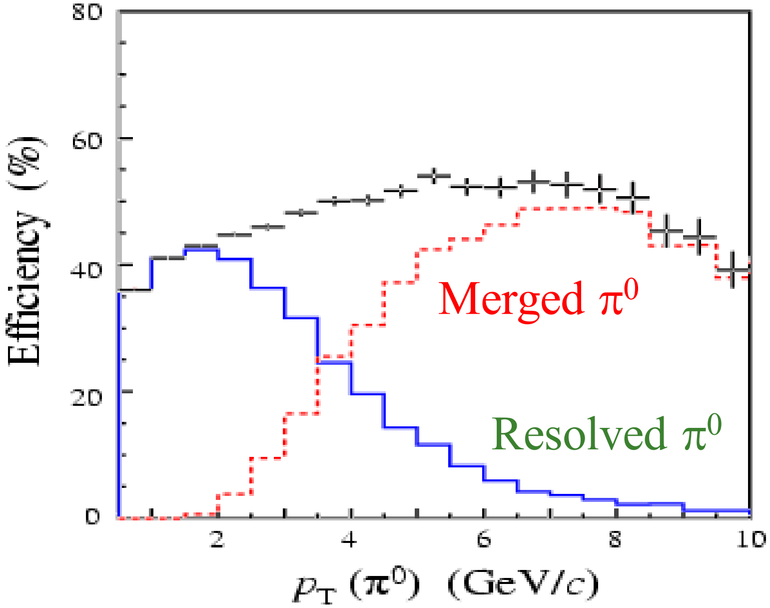
$B_d \to \pi\pi$ signal

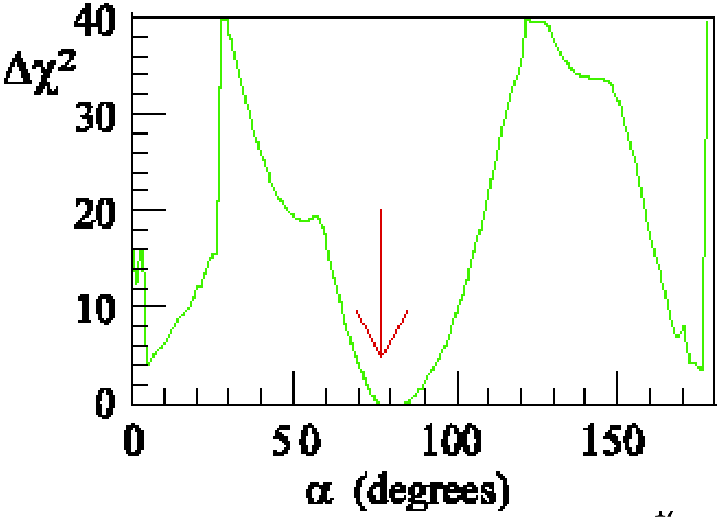
Particle Identification

- RICH detectors: two separate photon detectors and 3 Cherenkov radiators
  - Aergoel n=1.03
  - C_4F_{10} n= 1.0014
  - CF_4 n= 1.0005
- Identifies π, K, p over “entire” momentum range (2-100 GeV/c)
- $\therefore$ a heavy charged particle, e.g. stau, will not radiate but anything normal, i.e. e, π, K, p, will in all 3 radiators. Thus we will know that we have new massive particle. *(Reminiscent of Sherlock Holmes: The dog did not bark.)* Tracks also will deposit energy in calorimeters & muon detector, so may get some idea of its energy and good measurement of its momentum

Neutral Reconstruction

- Mass resolution is a useful ~9-12 MeV σ
- Efficiency within solid angle is OK using both merged and resolved π^o's
- Example: time dependent Dalitz Plot analysis ala' Snyder & Quinn for $B^o \rightarrow \rho\pi \rightarrow \pi^+\pi^-\pi^o$
- 14K signal events in 10^7 s with S/B 1/3, yielding $\sigma(\alpha)=10^o$





Other Physics Sensitivities

	Channel	**Yield**	**B/S**	**Precision**
γ	$B_s \to D_s^{-+} K^{+-}$	5.4k	< 1.0	$\sigma(\gamma) \sim 14^{\circ}$
	$B_d \to \pi^+ \pi^-$	36k	0.46	$\sigma(\gamma) \sim 4^{\circ}$
	$B_s \to K^+ K^-$	36k	< 0.06	
	$B_d \to D^0 (K\pi, KK) K^{*0}$	3.4 k, 0.5 k, 0.6 k	<0.3, <1.7, < 1.4	$\sigma(\gamma) \sim 7^{\circ} - 10^{\circ}$
	$B^- \to D^0 (K^- \pi^+, K^+ \pi^-) K^-$	28k, 0.5k	0.6, 1.5	$\sigma(\gamma) \sim 5^{\circ} - 15^{\circ}$
	$B^- \to D^0 (K^+ K^-, \pi^+ \pi^-) K^-$	4.3 k	1.0	
	$B^- \to D^0 (K_S \pi^+ \pi^-) K^-$	1.5 - 5k	< 0.7	$\sigma(\gamma) \sim 8^{\circ} - 16^{\circ}$
α	$B_d \to \pi^+ \pi^- \pi^0$	14k	< 0.8	$\sigma(\alpha) \sim 10^{\circ}$
	$B \to \rho^+ \rho^0, \rho^+ \rho^-, \rho^0 \rho^0$	9k, 2k, 1k	1, <5, < 4	
β	$B_d \to J/\psi(\mu\mu) K_S$	216k	0.8	$\sigma(\sin 2\beta) \sim 0.022$
Δm_s	$B_s \to D_s^- \pi^+$	120k	0.4	$\sigma(\Delta m_s) \sim 0.01\ \mathrm{ps}^{-1}$
ϕ_s	$B_s \to J/\psi(\mu\mu)\phi$	131k	0.12	$\sigma(\phi_s) \sim 0.023$
Rare decays	$B_s \to \mu^+ \mu^-$	17	< 5.7	Zero to $\pm 0.3\ \mathrm{GeV}^2$
	$B_d \to K^{*0} \mu^+ \mu^-$	4.4 k	< 2.6	
	$B_d \to K^{*0} \gamma$	35k	< 0.7	$\sigma(A_{CP}) \sim 0.01$
	$B_s \to \phi \gamma$	9.3 k	< 2.4	
charm	$D^{*+} \to D^0 (K^- \pi^+) \pi^+$	100 M		

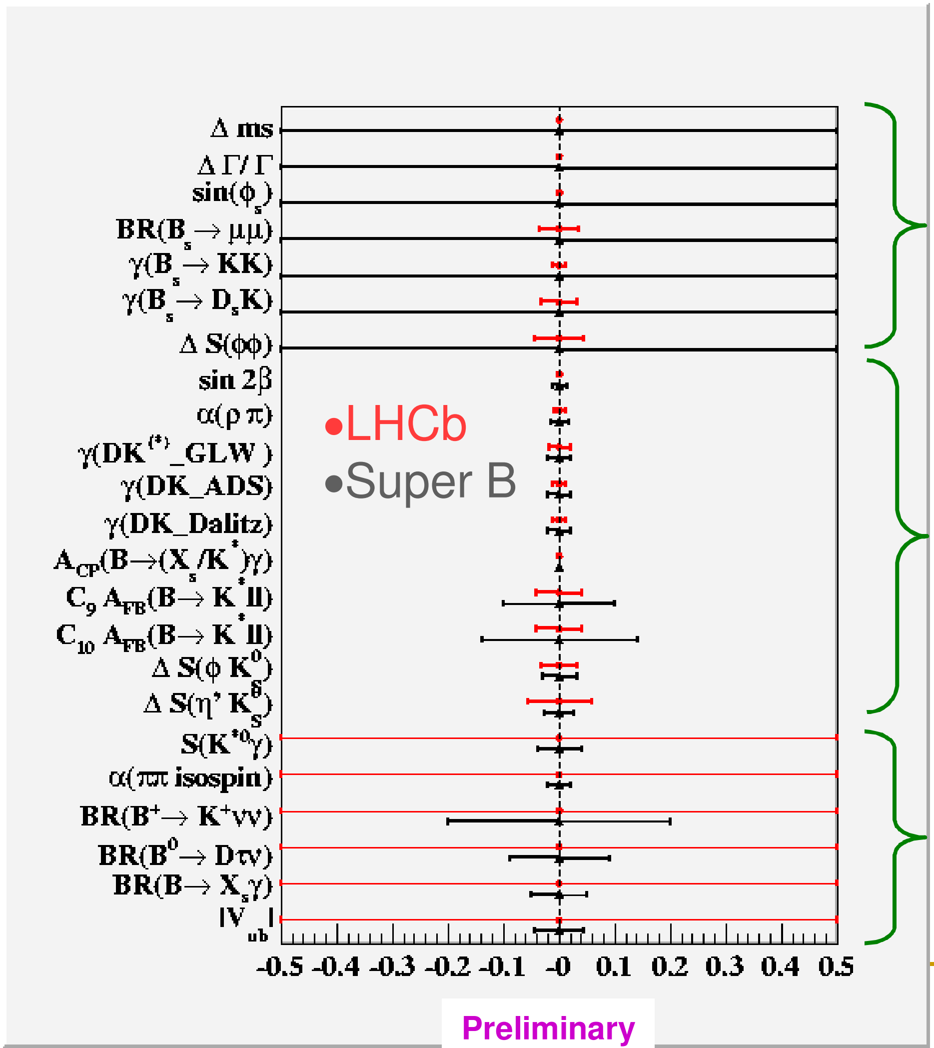
- Only a subset of modes
- For ~ 2 fb^{-1}

Comparison with Super B factory

Sensitivity Comparison ~2020

LHCb 100 fb^{-1} vs Super-B factory 50 ab^{-1}

SuperB numbers from M Hazumi - Flavour in LHC era workshop; LHCb numbers from Muheim



B$_s$ highly favored at LHCb

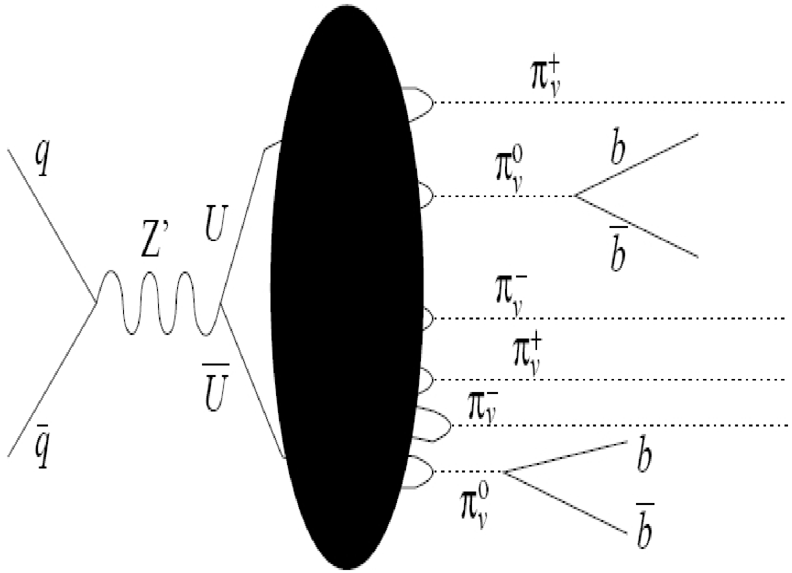
Common

No IP

Neutrals, ν

Other Possibilities: “Hidden” Gauge Sectors

- Many possible extensions to SM, SUSY, ED, etc…
- Consider here adding a U(1)′ Gauge group with a color charge v, useful for generating Electroweak Baryogenisis
  - e. g. : Barger et al [hep-ph/0702001]. Carpenter et al [hep-ph/0607204], Strassler & Zurek [hep-ph/0604261, & 0605193] & many others
  - Produce new quark(s) U_i via $Z' \rightarrow U\bar{U}$, fragmentation causes lots of particle production, with some particles containing new U_1 & U_2 with v=0. These scalar particles $\pi_v^o \rightarrow b\bar{b}$ preferentially due to helicity conservation if $2m_B < m(\pi_v) < m_{WW}$

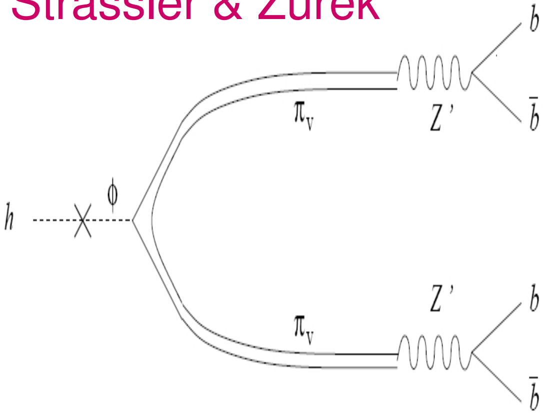

Strassler & Zurek

Higgs decays

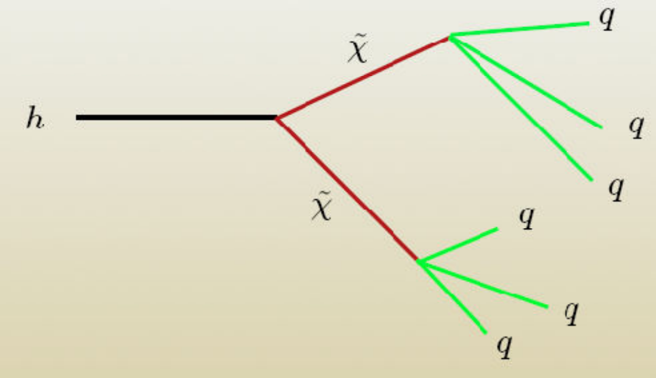
- π_v lifetime can be large or small
- Can also have

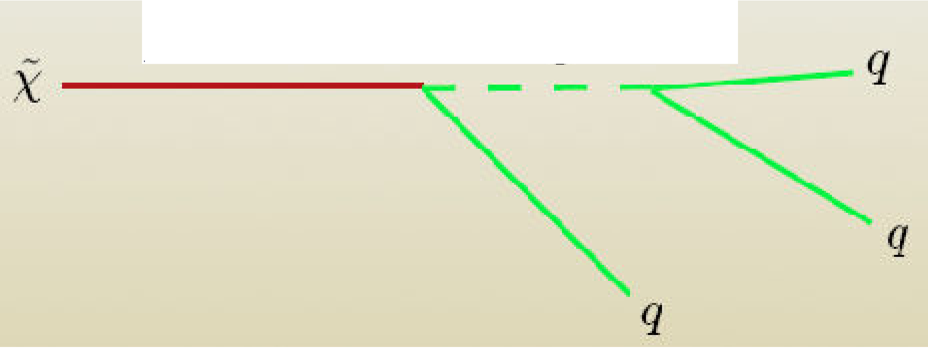
  Higgs→ π_v π_v →$b\bar{b}$ $b\bar{b}$

Strassler & Zurek



  - Or





Carpenter et al

  - Again lifetime (decay length) is unknown

Conclusions

- What do we hope to learn from LHC & LHCb
  - ATLAS/CMS: Electroweak Symmetry breaking: the Higgs, + New Physics: either SUSY, ED, or little higgs, etc…
  - LHCb: CP violation: ϕ_S, γ in $Bs \rightarrow DsK$, α in $B \rightarrow \rho\pi$, $B_{(S)} \rightarrow M\gamma$, dilepton asymmetry in B_S decays, $B_S \rightarrow \phi\phi$, $B \rightarrow \phi K_S$; Rare Decays: polarization in $K^* \mu^+\mu^-$, $B_{(S)} \rightarrow M\gamma$, $B_{(S)} \rightarrow \mu^+\mu^-$. D^o mixing & CP violation, (Hidden Valleys?)

Conclusions II

- Possible outcomes
  - ATLAS/CMS see Higgs & NP & LHCb sees some NP effects that constrain NP models – *more sensitivity required to further elucidate NP*
  - ATLAS/CMS see Higgs & NP & LHCb sees nothing beyond SM - *more sensitivity required to further elucidate NP*
  - ATLAS/CMS see Higgs but no NP & LHCb sees some NP effects that constrain NP models – *more sensitivity required to further elucidate NP*
  - ATLAS/CMS see Higgs but no NP & LHCb sees nothing beyond SM – *more sensitivity required to further elucidate NP & to try and estimate mass scale for NP*
- In all cases it is likely that *more LHCb sensitivity required to further elucidate NP*

The End

LHCb Ski Outing
March 2007
Photo credit: Tomasz Skwarnicki

A Hidden Valley?