The High Luminosity LHCb Upgrade

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Introduction

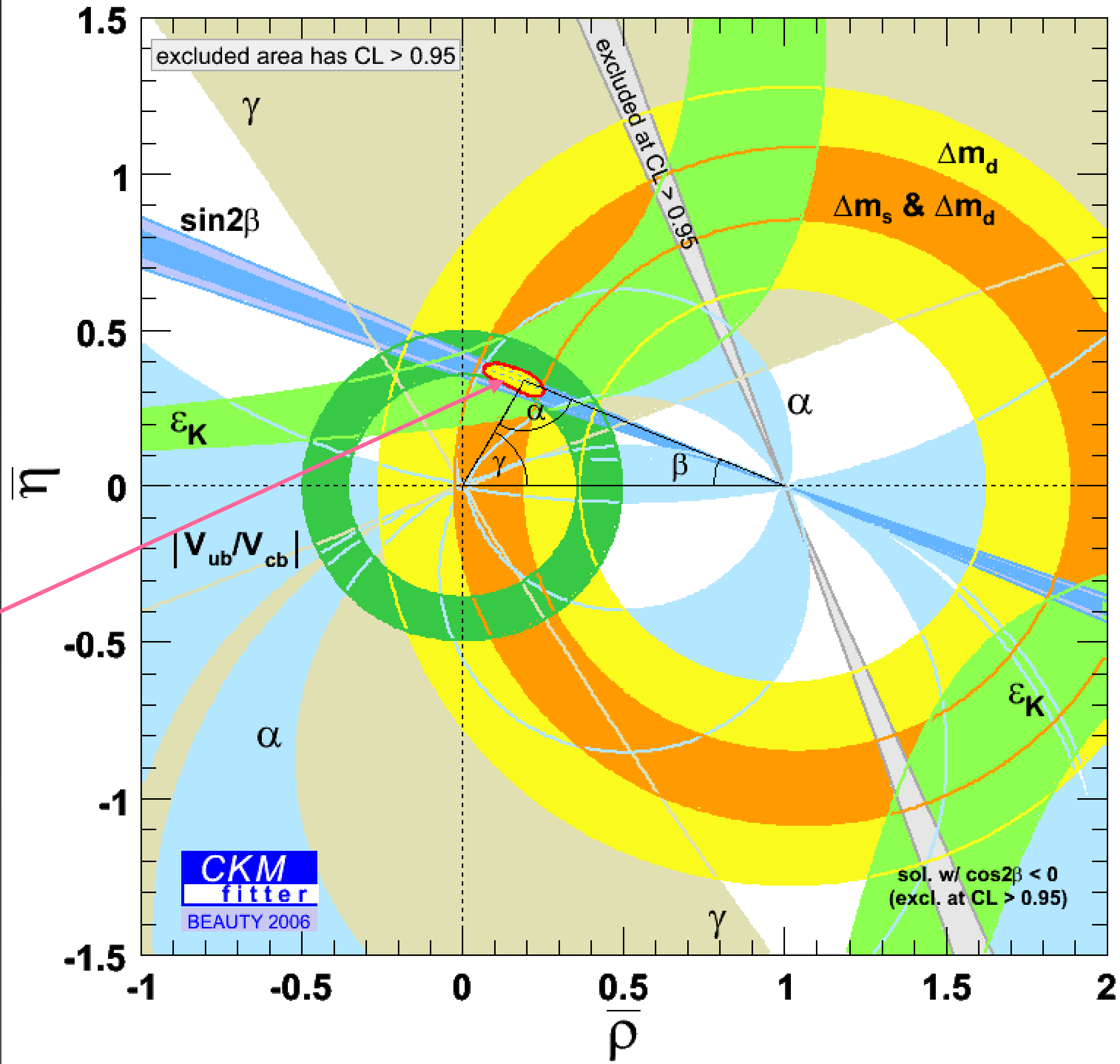
- Why are we talking about an LHCb upgrade?
- Answer: There is some insight that we will not have finished all useful b & c decay measurements
- In fact, why is the LHC considering a high luminosity upgrade before the machine is finished, and why are ATLAS & CMS already doing R&D for high $\mathcal{L}$ detector upgrades?

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 $M_{Higgs} << M_{Planck}$)
- 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_S
- The overlap region includes CL>95%
- Similar situation using UTFIT
- Measurements "consistent"



Consistency?

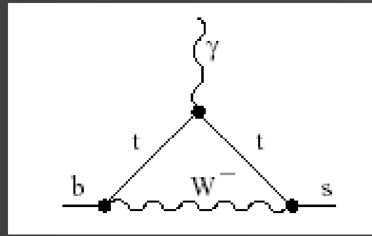
- It is often said that studies of b & c decays are all consistent with the Standard Model
  - Since all measurements are by their nature reflections of nature, i.e. SM + NP, what does this statement actually mean?
  - SM predictions are made using combinations of several measurements since there are 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

Minimal Flavor Violation

- Def MFV: New physics has exactly the same CKM structure as SM
  - Thus no effects will be seen in CPV
  - An example of such a model is the Universal Extra Dimensions model of Appelquist, Cheng & Dobrescu
- However, effects WILL be seen in the modification of decay rates
- MFV is not so much a model as a declaration. Lets ignore this paradigm for now and look at two examples of B decay processes

Rare Decay Example: $b \to s\gamma$

- Experiment:
  $\mathcal{B}(b \to s\gamma) = (3.55 \pm 0.26) \times 10^{-4}$



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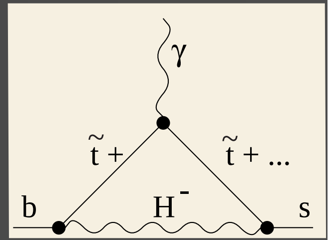
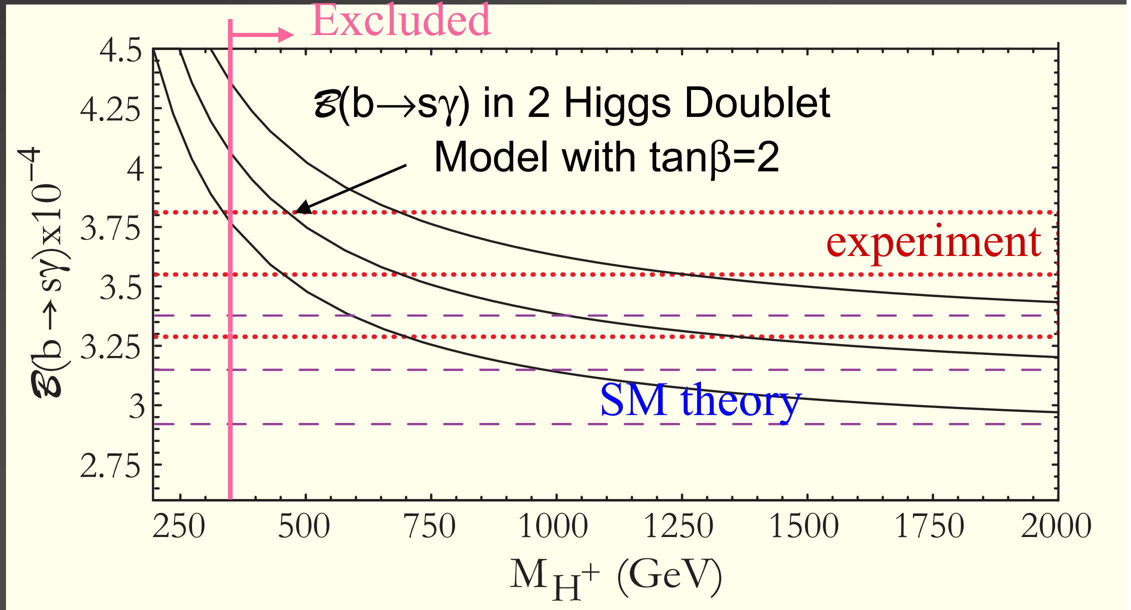
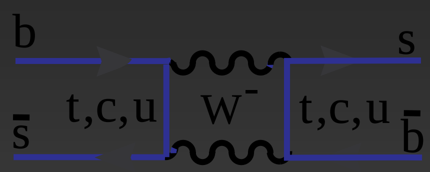


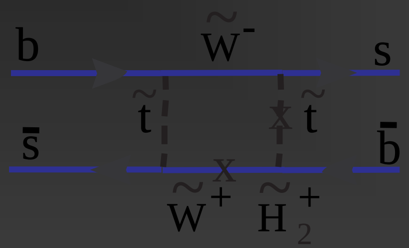
- Theory (Misiak et. al hep-ph/0609232):
  $\mathcal{B}(b \to s\gamma) = (3.15 \pm 0.23) \times 10^{-4}$
- Limit on H^+ mass >295 GeV at 95% CL for $\tan\beta$>~2
  (plot shows central Values & ±1σ bands)
- By far best limit from any source



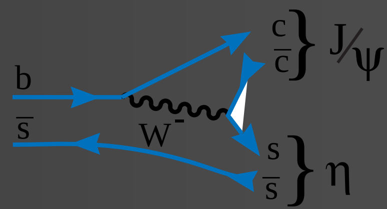
Another Example

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





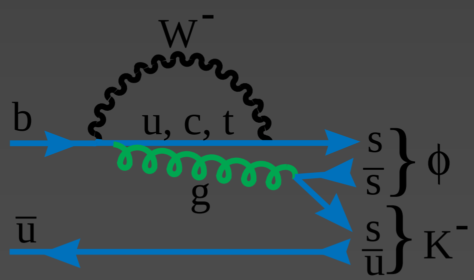
$B_s \to J/\psi\eta$ or ϕ

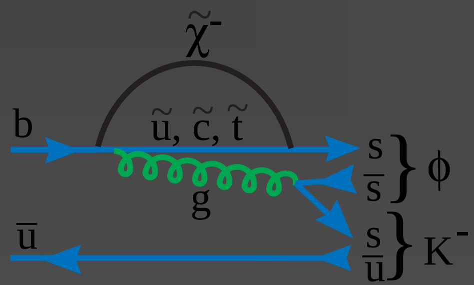


CP asymmetry $\approx 0.1\sin\phi_\mu\cos\phi_A\sin(\Delta m_s t)$, ~10 x SM

- Contributions to direct CP violating decay

$B^- \to \phi K^-$



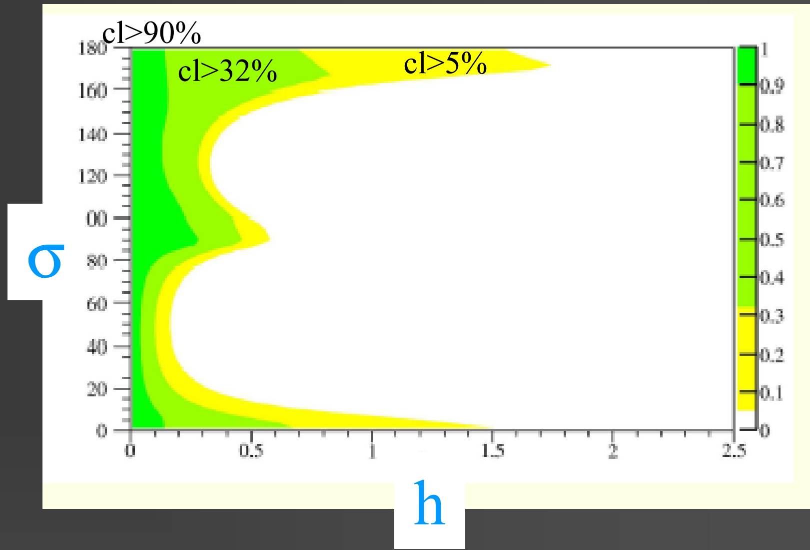


$\text{Asym} = (M_W/m_{squark})^2\sin(\phi_\mu)$, ~0 in SM

Limits on New Physics From B^o

- Is there NP in B^o-$\bar{B}^o$ mixing?
- Assume NP in tree decays is negligible
- $$1+he^{i\sigma}=\frac{\langle B^o|H^{full}|\bar{B}^o\rangle}{\langle B^o|H^{SM}|\bar{B}^o\rangle}$$
- Use V_{ub}, A_{DK}, $S_{\psi K}$, $S_{\rho\rho}$, Δm_d, A_{SL}
- Fit to η, ρ, h, σ

"Next to minimum flavor violation"

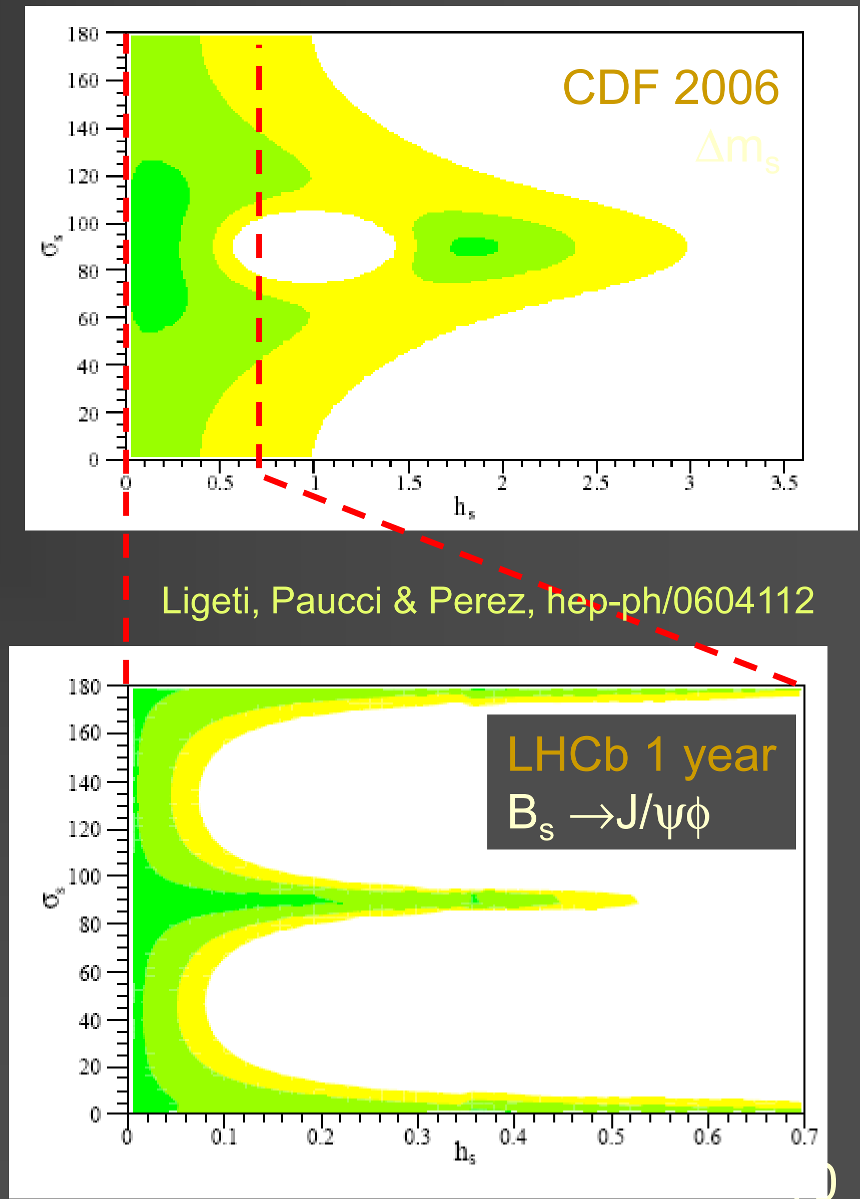


Agahse, Papucci, Perzez, Pirjol hep-ph/0509117

- For New Physics via B_d^o mixing, h is limited to ~<0.3 of SM except when σ_{Bd} is ~0° or ~180° of SM decays

Limits on New Physics From B_S

- Similar study for B_S decays including ΔM_S measurement from CDF
- Limits much weaker since phase in B_S mixing (ϕ_S) is yet to be measured



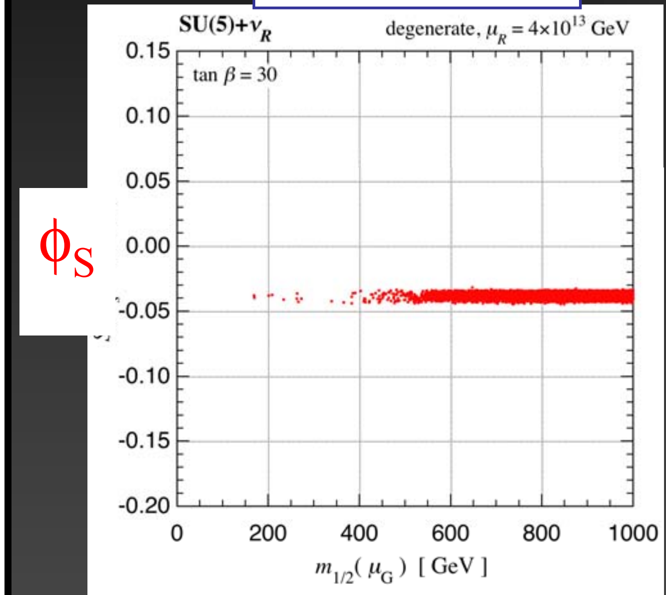
Ligeti, Paucci & Perez, hep-ph/0604112

New Physics Models

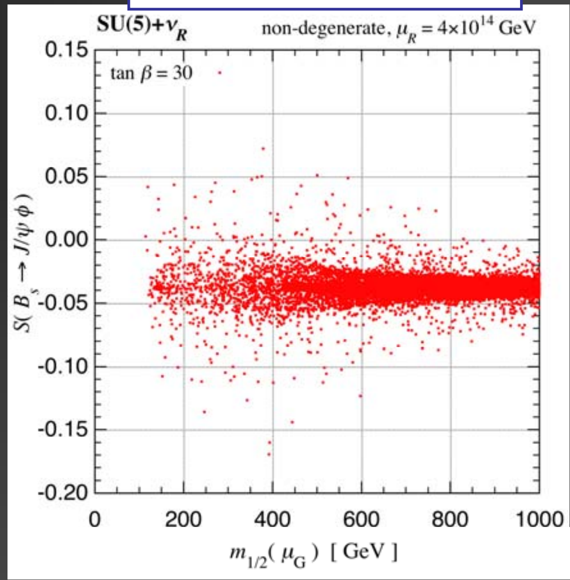
- There is, in fact, still lots of room for "generic" NP
- What do specific models predict?
  - Supersymmetry: many, many different models
  - Extra Dimensions: "
  - Little Higgs: "
  - Left-Right symmetric models: "
- Lets go through some examples, many other interesting cases exist

Supersymmetry

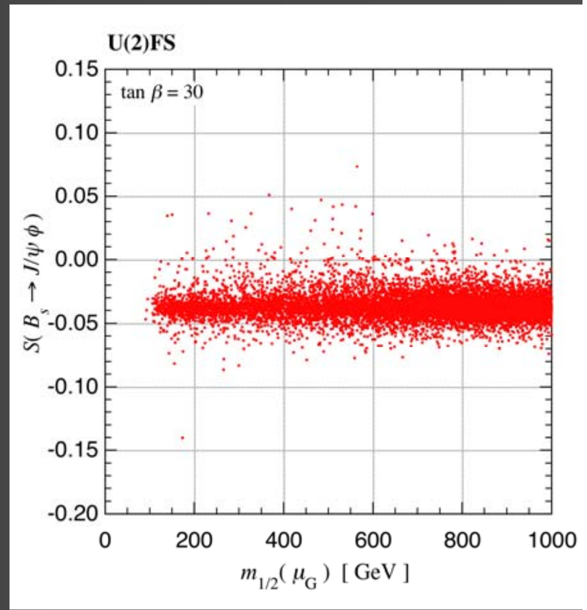
SU(5) GUT
Degenerate



SU(5) GUT
Non-degenerate



U(2) FS



- ϕ_S can deviate from the SM by 5-10% for SU(5) GUT with non-degenerate case and the U(2) model. From Okada talk at BNMII, Nara Women's Univ. Dec., 2006

Okada Models Summary

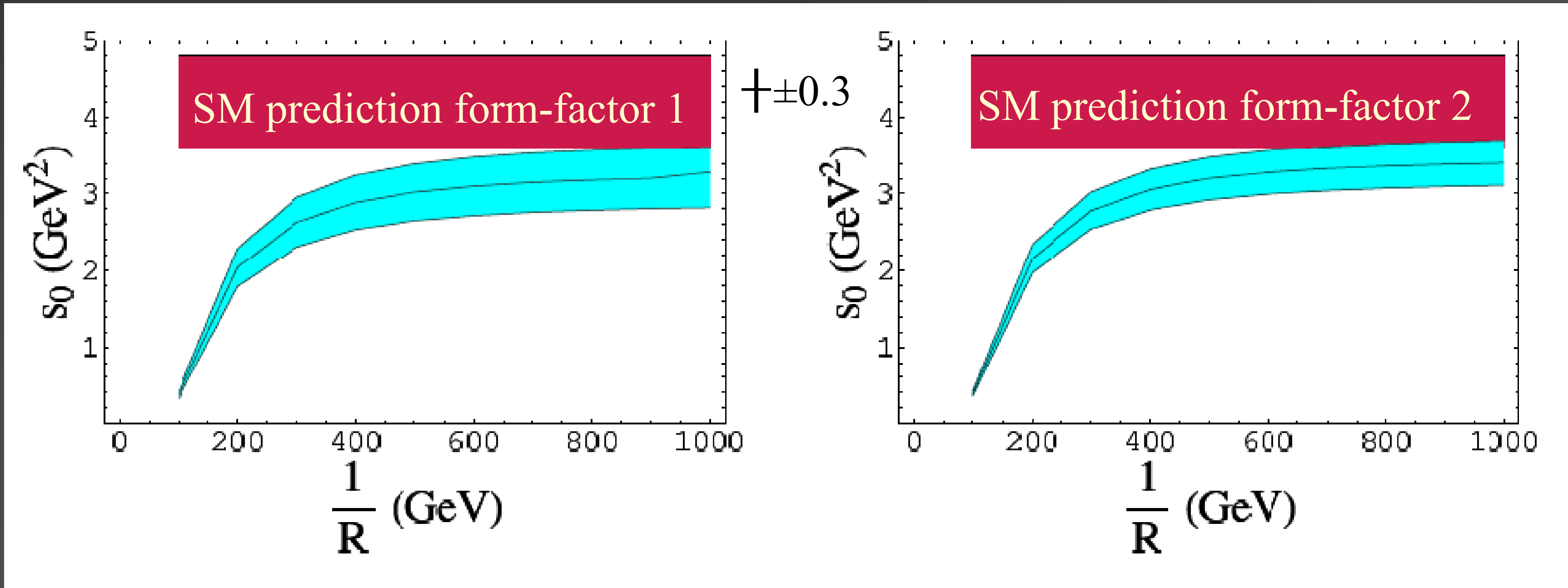
Possible deviations from the SM prediction

	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 + ν_R (degenerate)	—	—	—	—	$\mu\to e\gamma$
SU(5)SUSY GUT + ν_R (non-degenerate)	—	<O(10%)	—	<~5%	$\mu\to e\gamma$ $\tau\to\mu\gamma$
U(2) Flavor symmetry	< a few %	<O(10%)	< a few %	<~5%	$\mu\to e\gamma$ τ $\mu\gamma$

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 calculations improve?*

LHCb measures zero to ±0.3 GeV^2 in 10 fb^{-1}

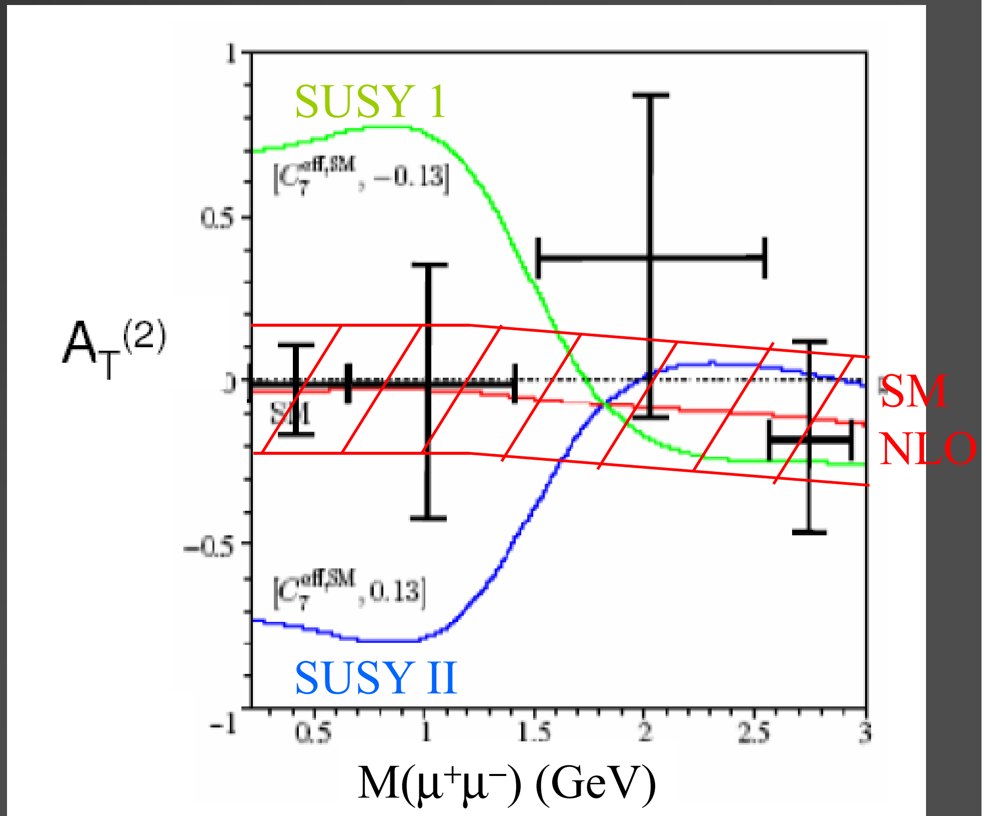


Other Angular Variables in $K^*\mu^+\mu^-$

- Right handed currents in Supersymmetry (Lunghi & Matias hep-ph/0612166)
- Use transverse polarization

$$A_T^{(2)}(s) = \frac{|A_\perp|^2 - |A_\parallel|^2}{|A_\perp|^2 + |A_\parallel|^2}$$

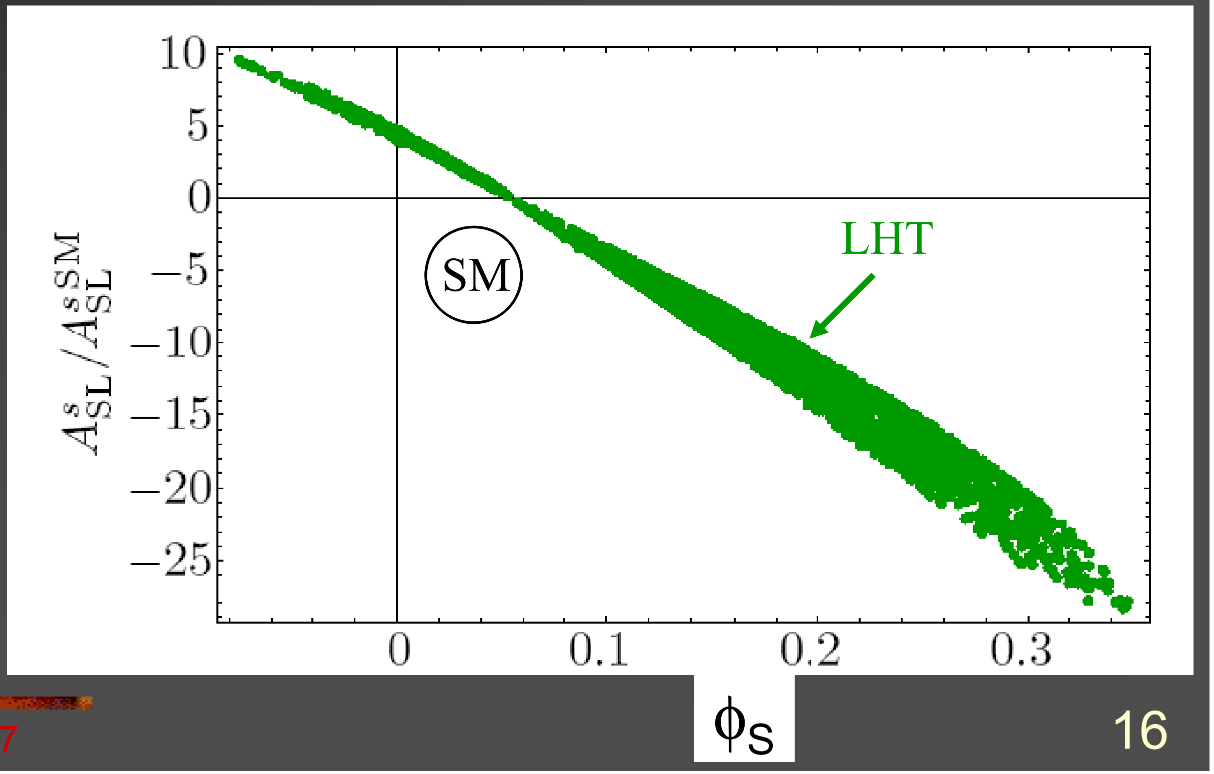
- LHCb simulation for 2 fb^{-1} looks promising



Little Higgs Model with T Parity

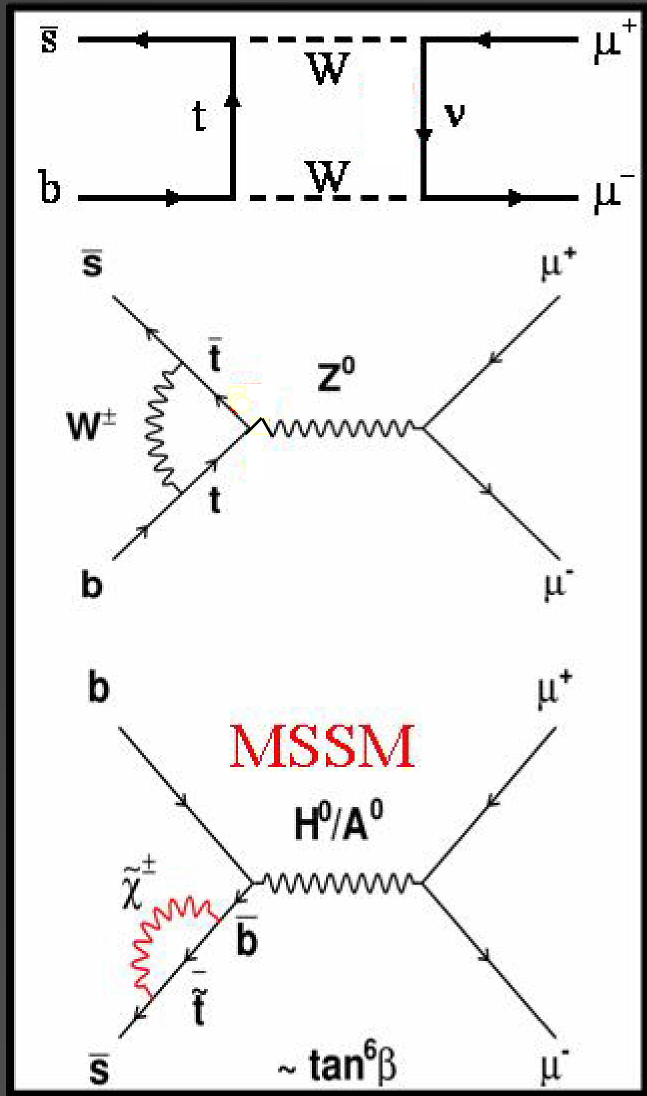
- There exist regions of parameter space consistent with measurement where large ϕ_S is predicted & ΔM_S is found somewhat smaller than in the SM.
- In particular, significant enhancement of ϕ_S & the semileptonic asymmetry $A_{SL}^{(S)}$ relative to the SM are found

•From Blanke & Buras, [hep-ph/0703117]

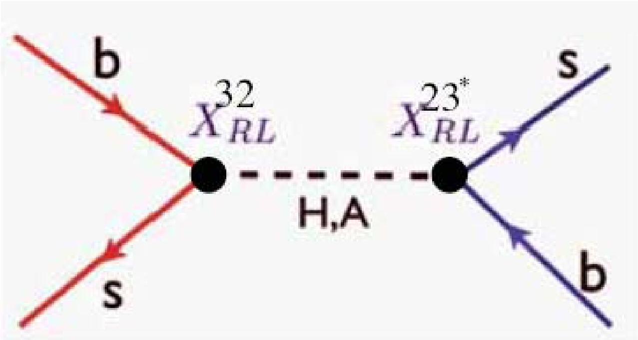


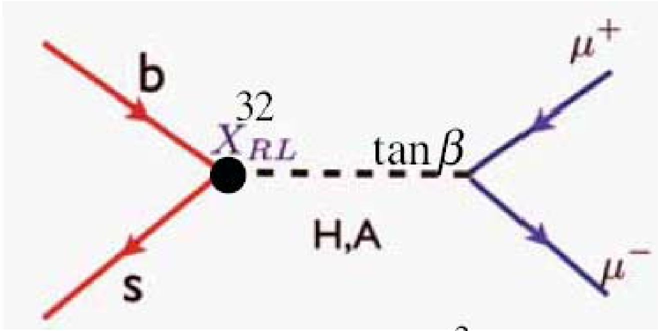
$B_S \rightarrow \mu^+\mu^-$ & Supersymmetry

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



Correlations Between ΔM_S & $B_S \rightarrow \mu^+\mu^-$





$$(\Delta M_{B_s})^{SUSY} \propto \ominus \frac{X_{RL}^{32} X_{LR}^{32}}{m_A^2}$$

Negative sign with respect to SM

$$BR(B_s \rightarrow \mu^+\mu^-)^{SUSY} \propto \frac{|X_{RL}^{32}|^2 \tan\beta^2}{m_A^4} \propto \frac{|\mu A_t|^2 \tan\beta^6}{m_A^4}$$

with $$\left(X_{RL}^{H/A}\right)^{ji} \approx -\frac{\overline{m}_{d_j}\, h_t^2\, \varepsilon_Y\, x_{\phi_1}^{H/A} \tan\beta^2}{v\left(1+\varepsilon_0^j \tan\beta\right)\left(1+\Delta_b\right)} V_{CKM}^{3j*} V_{CKM}^{3i} \Longrightarrow \frac{\Delta M_{B_S}}{BR(B_S \rightarrow \mu^+\mu^-)} \propto \frac{m_A^2}{\tan\beta^2}$$

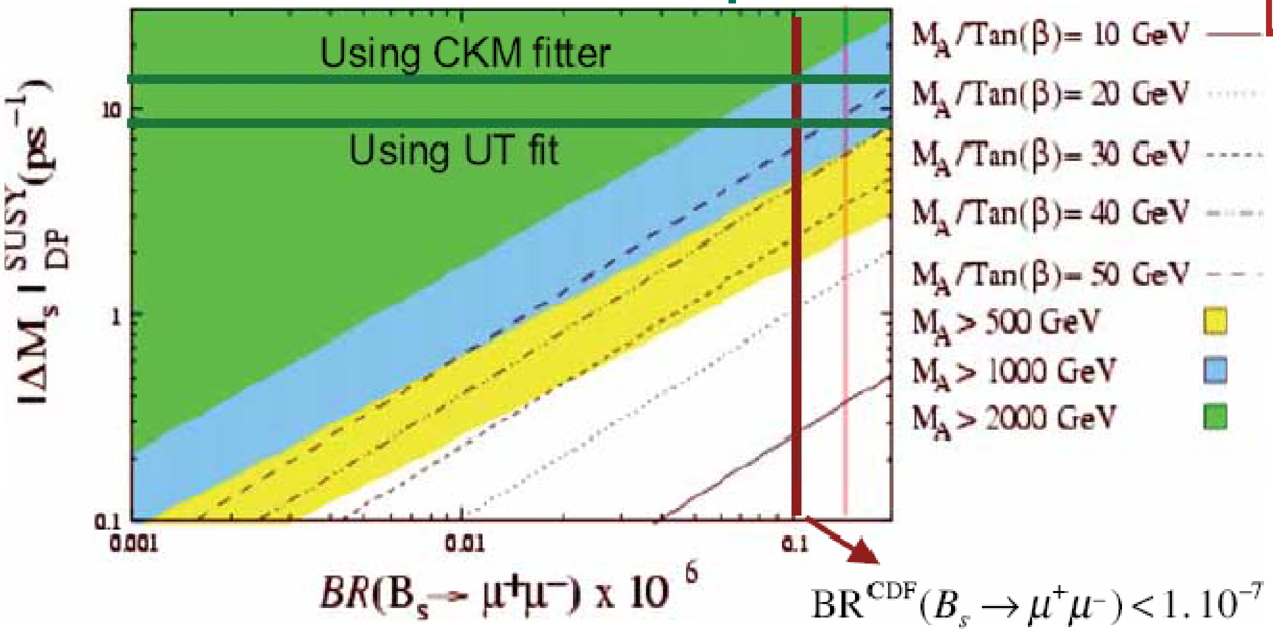
- In MSSM, SUSY contributions strongly correlated; from M. Carena (Moriond 2007).

How Strong is the Bound on $\mathcal{B}(B_S \to \mu^+\mu^-)$?

Upper bound on NP from CDF ==> $\Delta M_S = 17.7 \pm 0.10 \pm 0.07\, ps^{-1}$

$\Delta M_S^{CKM} = 18.9^{+12.2}_{-5.5}\, ps^{-1}$

$\Delta M_S^{UT} = 20.9 \pm 5.2\, ps^{-1}$



$BR^{CDF}(B_s \to \mu^+\mu^-) < 1.10^{-7}$

D0 <0.93x10^{-7}

M. C., Menon, Papaqui, Zsynkman, Wagner 06

$BR(B_s \to \mu^+\mu^-)_{SM}$ of order 10^{-9}

↓

at the reach of LHC with about 10fb^{-1}

↓

SUSY corrections can enhance it by 2 orders of magnitude.

For natural values of m_A< 1000 GeV ==> largest contributions at most a few ps-1

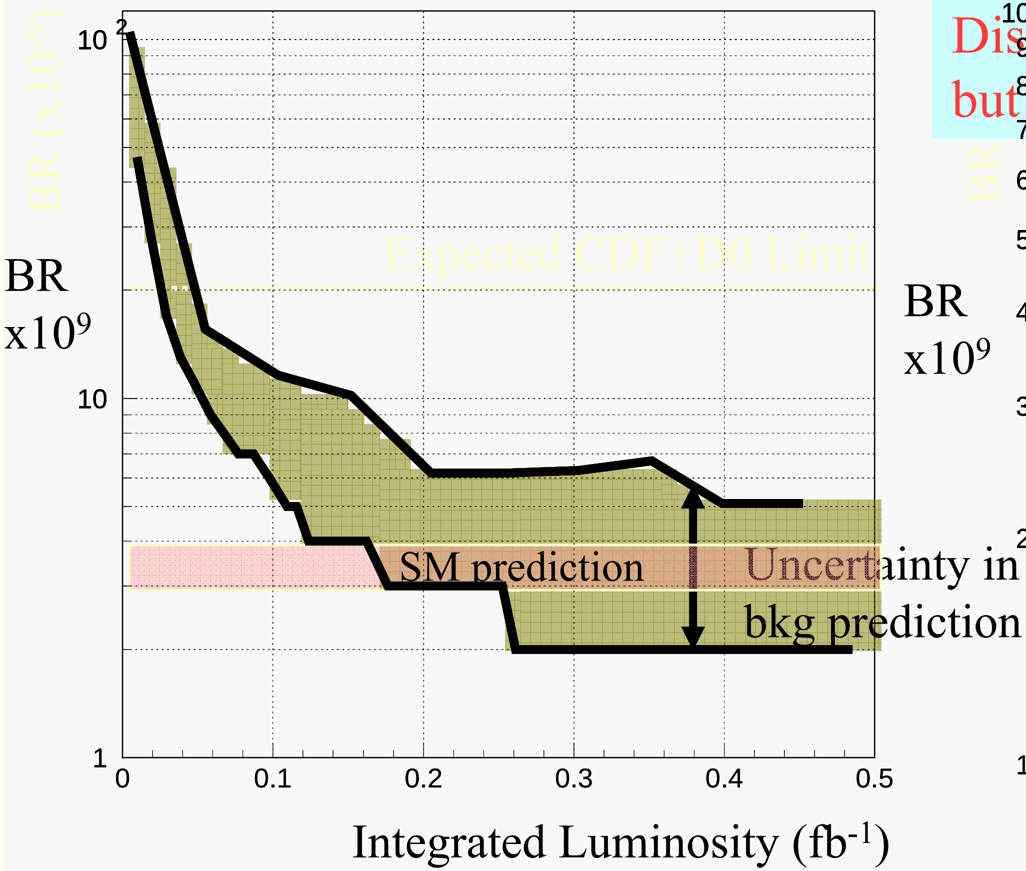
↕

A/H at the reach of the Tevatron or the LHC <==> strong constraints on $|\Delta M_S|^{SUSY}_{DP}$

Precision Measurement of $\mathcal{B}(B_S \rightarrow \mu^+\mu^-)$

Limit at 90% C.L.

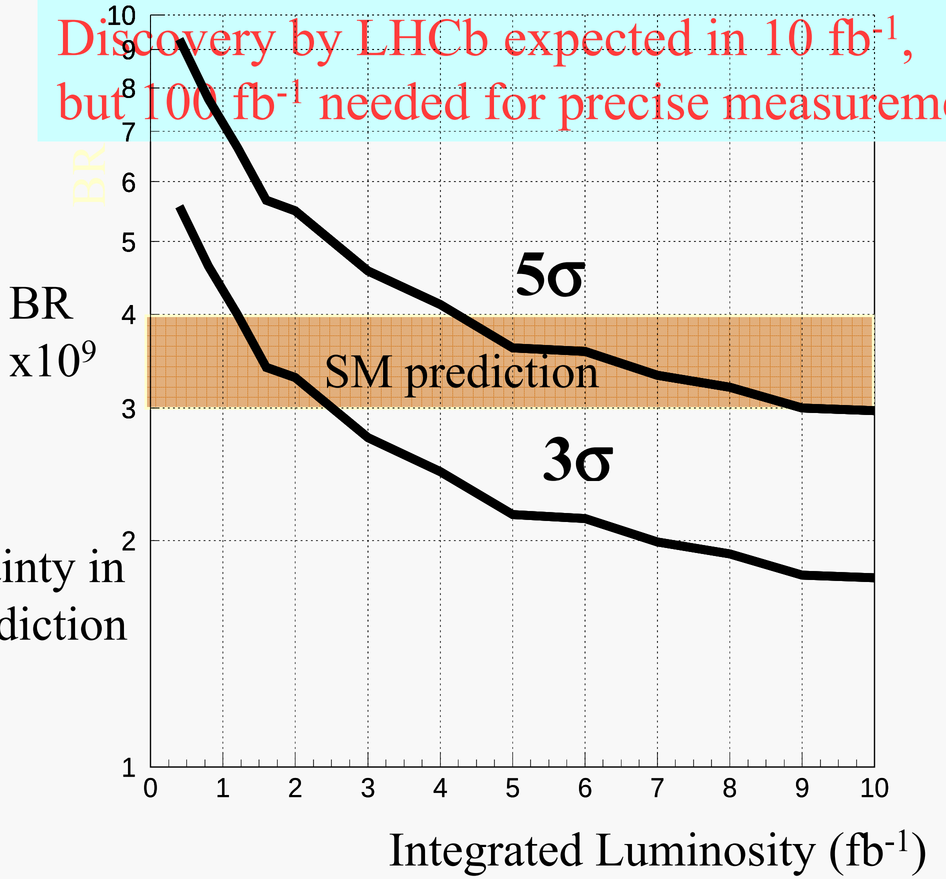
(only bkg is observed)



LHCb Sensitivity

(signal+bkg is observed)

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



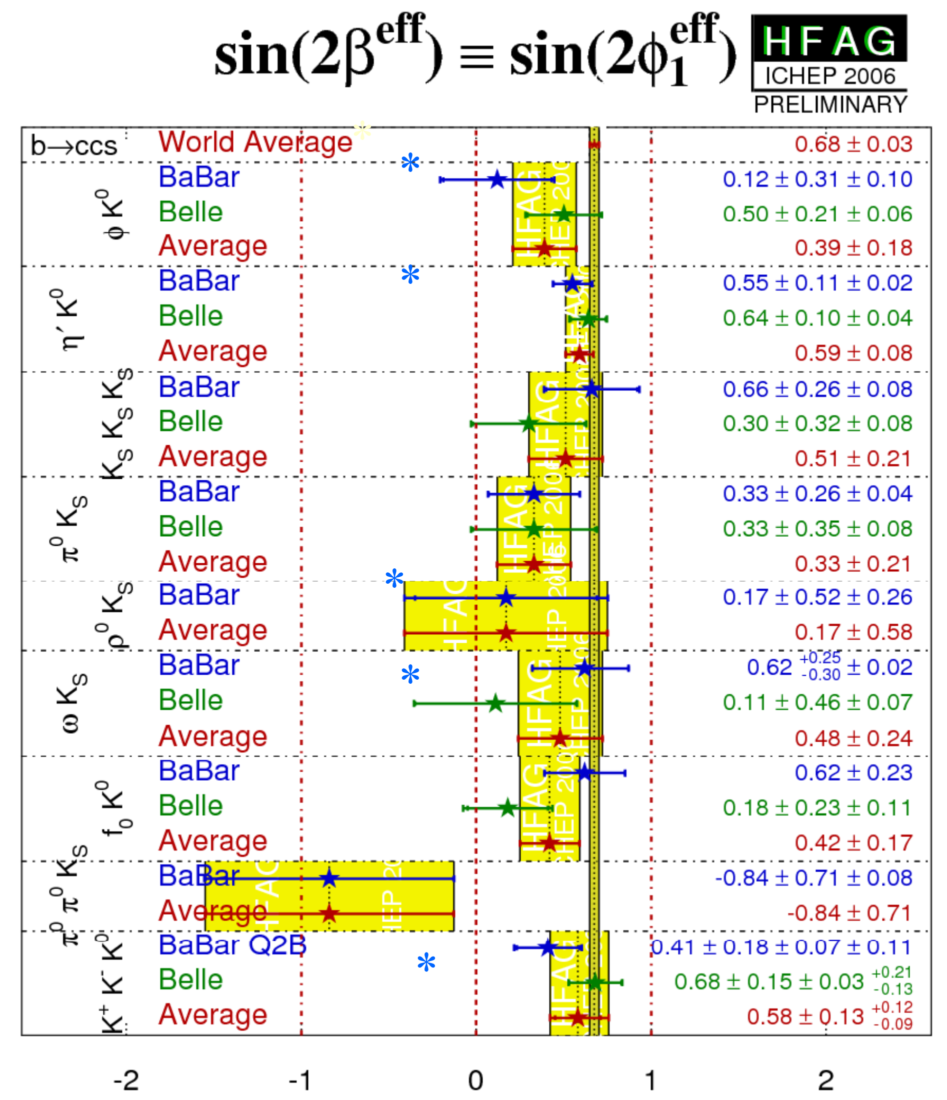
Background is dominated by combinations of $b \rightarrow \mu^- X$ $b \rightarrow \mu^+ X$ events.

Most Currently Desirable Modes

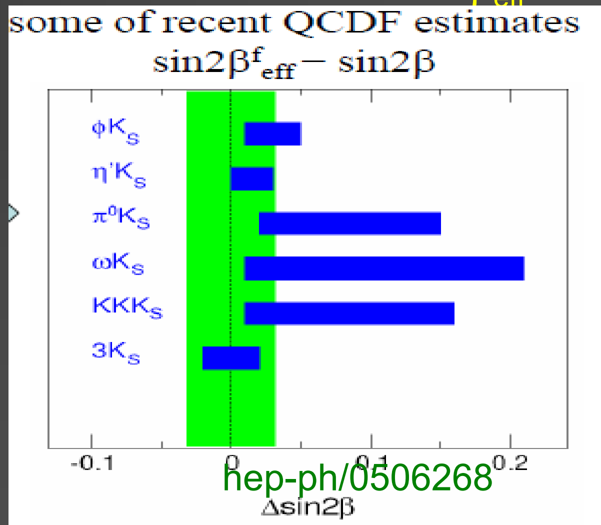
- $B_{(S)} \rightarrow \mu^+\mu^-$
- High Statistics Measurement of forward-backward asymmetry in $B \rightarrow K^*\mu^+\mu^-$
- Precision measurements of CP $\angle$'s
  - CP violating phase in B_S mixing using $B_S \rightarrow J/\psi\phi$
  - γ (or ϕ_3) Using $B^- \rightarrow D^o K^-$ tree level decays
  - γ using $B_S \rightarrow D_S^+ K^-$ time dependent analysis
  - α especially measurement of $B^o \rightarrow \rho\pi$ & $B^o \rightarrow \rho^o\rho^o$
  - β at high accuracy to pin down other physics
- CPV in various rare decay modes including $M\gamma$, $\Lambda\gamma$
- $B_S \rightarrow \phi\phi$
- Important: Other modes, not currently in vogue

One Big Hint: Penguins

LHCb can measure $B_S \to \phi\phi$ & compare with $J/\psi\phi$



- **Compare sin2β measurements**
  - in $B_d \to \phi K_S$ with $B_d \to J/\psi K_S$
  - Individually, each decay mode in reasonable agreement with SM
  - But all measurements lower than sin2β from $J/\psi K_S$
- **Naïve b → s penguin average**
  - $\sin 2\beta_{eff} = 0.52 \pm 0.05$
  - 2.6 σ discrepancy from SM
- **Theory models**
  - Predict to increase $\sin 2\beta_{eff}$ in SM



hep-ph/0506268

* LHCb accessible

Detector Requirements - General

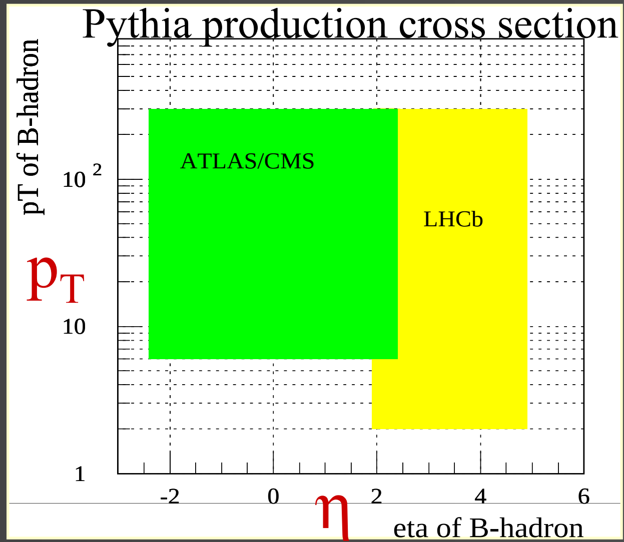
- Every modern heavy quark experiment needs:
  - Vertexing: to measure decay points and reduce backgrounds, especially at hadron colliders
  - Particle Identification: to eliminate insidious backgrounds from one mode to another where kinematical separation is not sufficient
  - Muon & electron identification 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

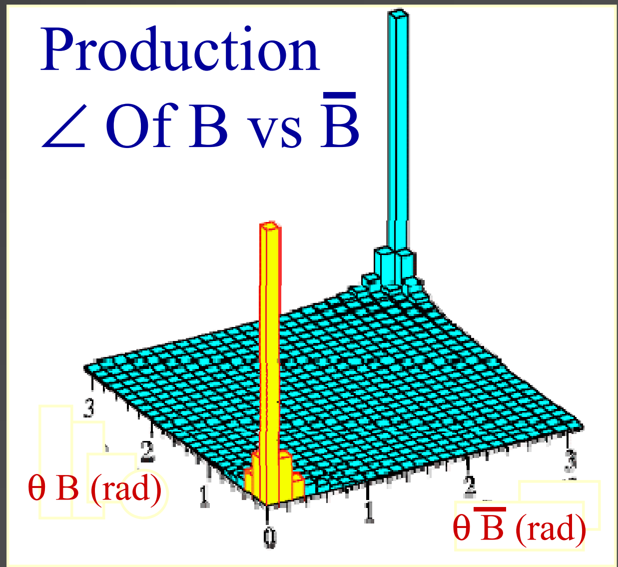
Basics For Sensitivities

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

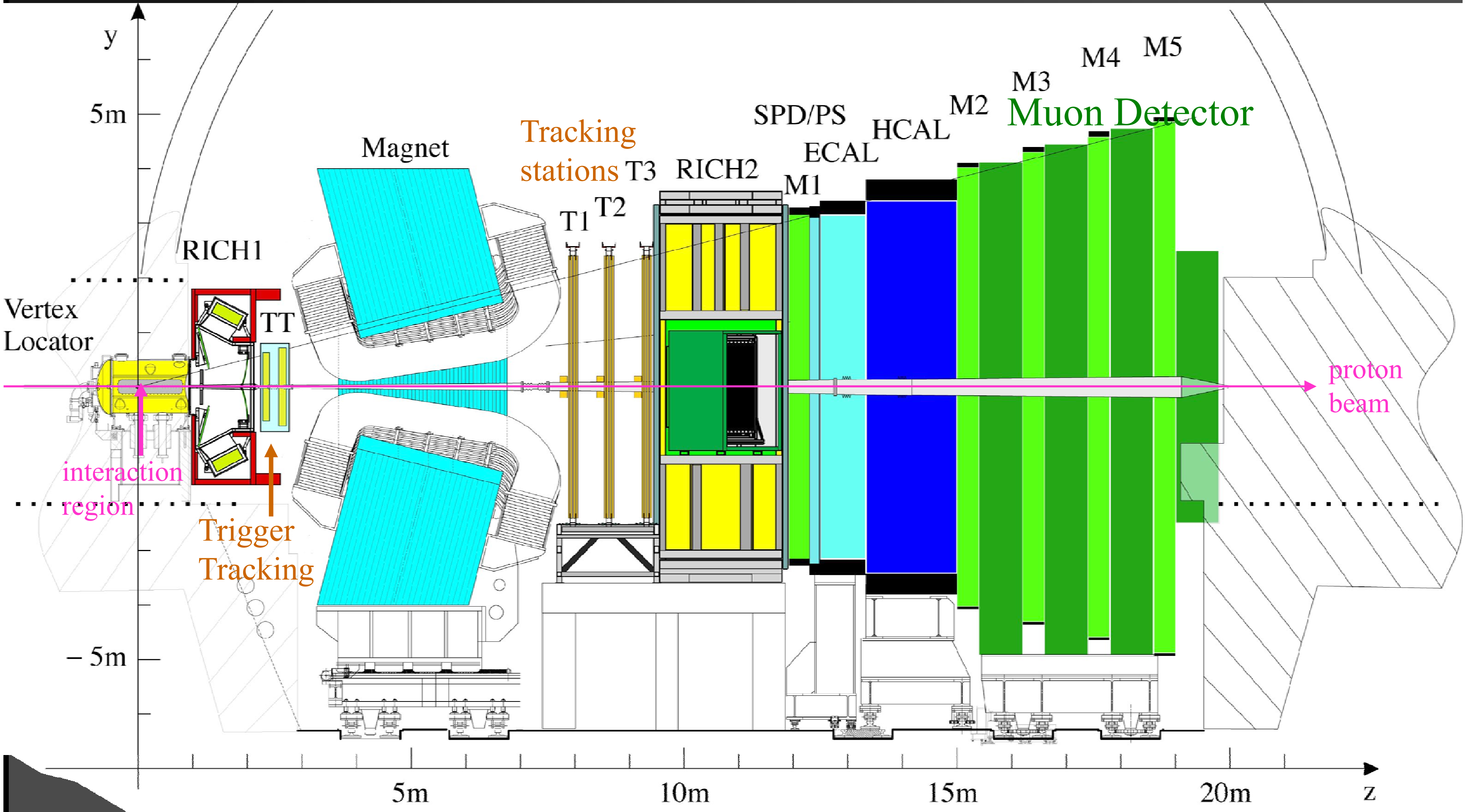
The Forward Direction at LHC

- 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 > η >1.9, where the B's are moving with considerable momentum ~100 GeV, thus minimizing multiple scattering
- At $\mathcal{L}$=2x10^{32}/cm^2-s, we get 10^{12} B hadrons in 10^7 sec

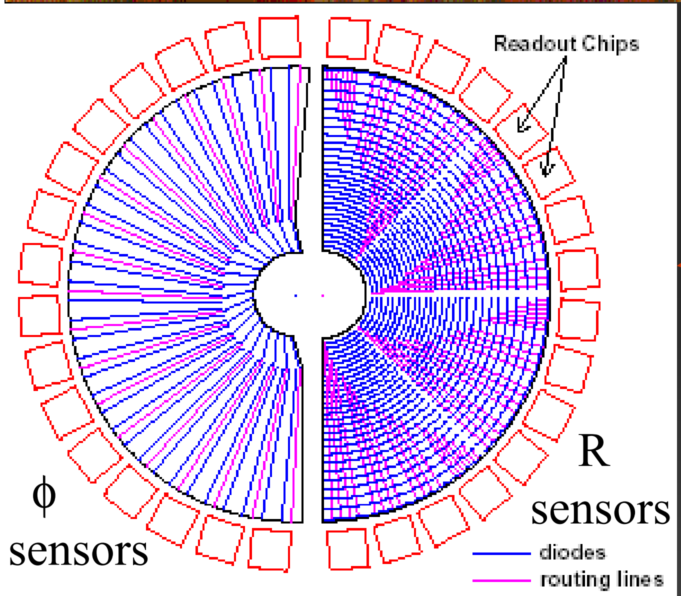




The LHCb Detector

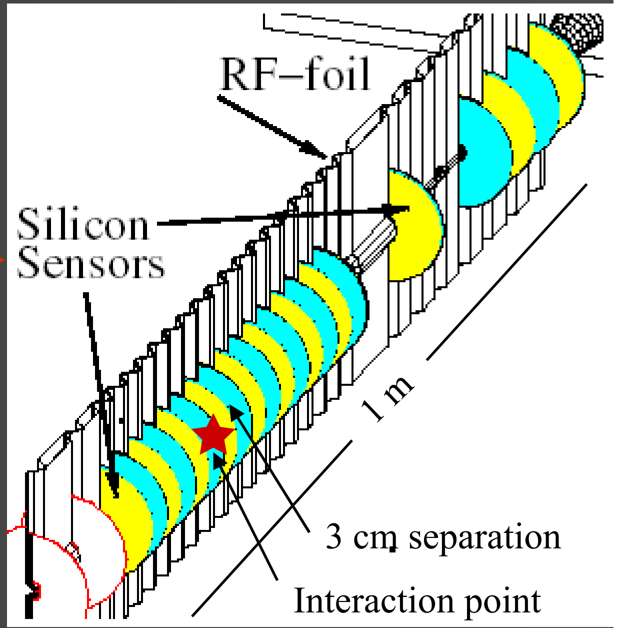


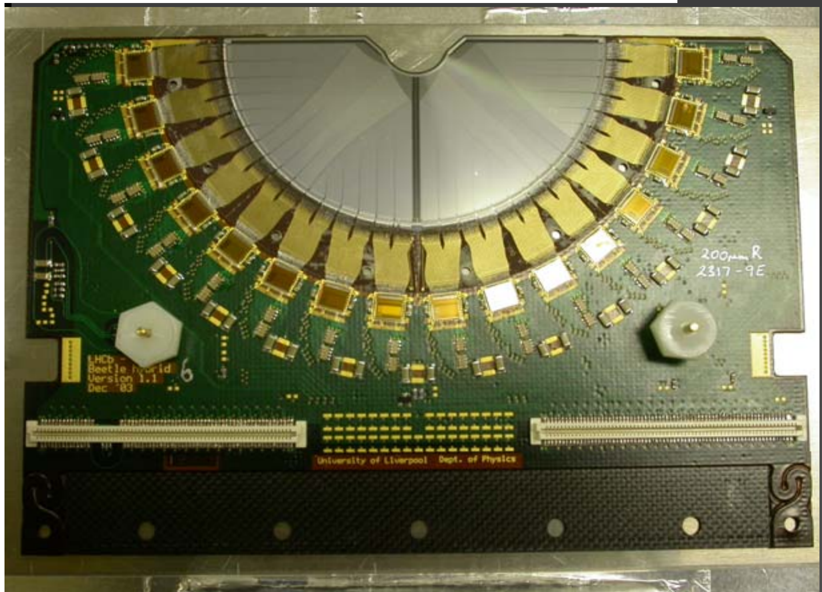
The VELO

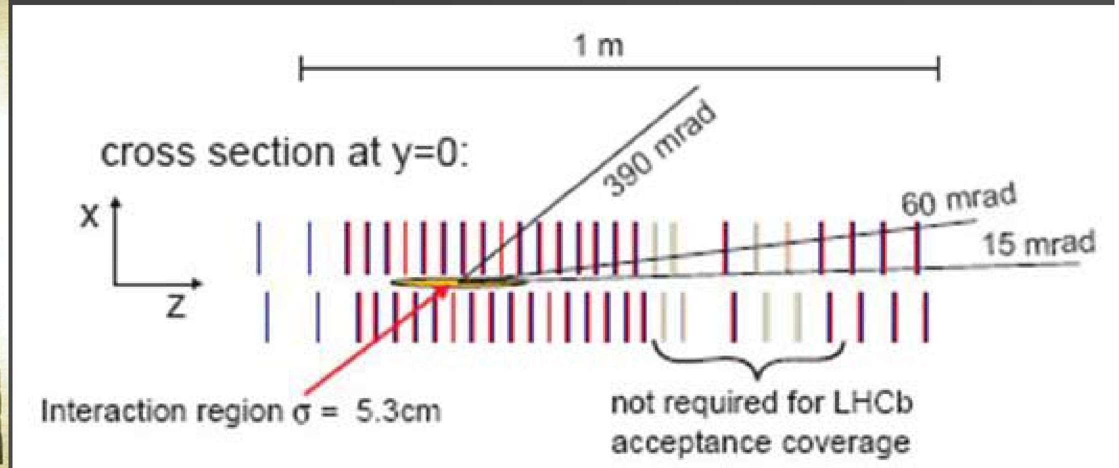


Geometry

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







Triggering

- Necessary because b fraction is only ~1% of inelastic cross-section
- 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
  - 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

Software Triggers

- Second Level: All detector information available. Basic strategy is to use VELO information to find tracks from b decays that miss the main production vertex; also events with two good muons are accepted & single muon with $p_T > 2.1$ GeV/c. Strategies are constantly being improved.
- Higher Level Triggers: Here more sophisticated algorithms are applied. Both inclusive selections and exclusive selections tuned to specific final states done after full event reconstruction has finished. Output rate is ~2 kHz

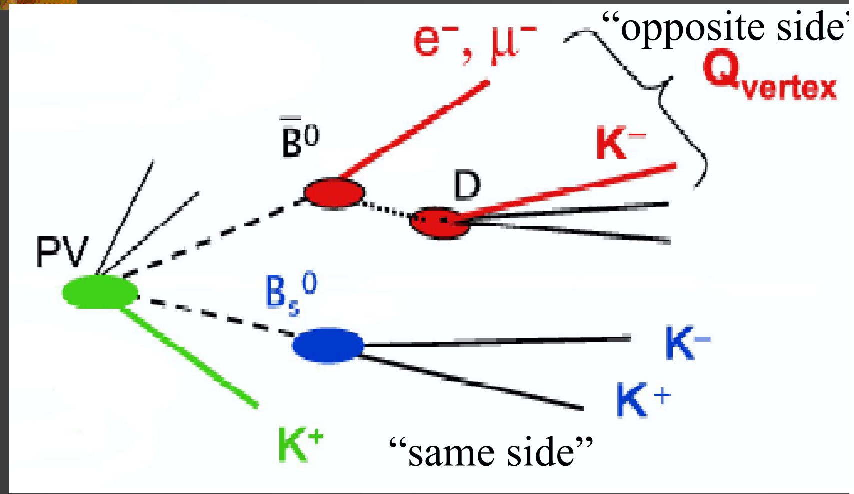
Trigger Output

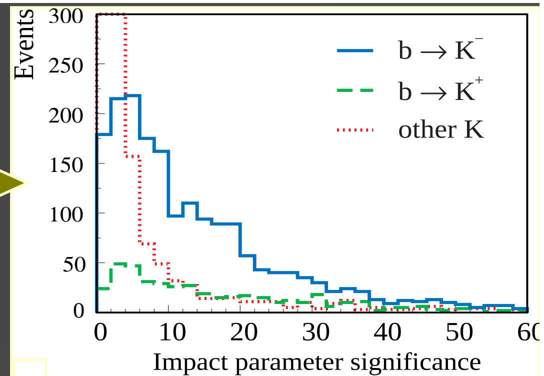
Output rate	Trigger Type	Physics Use
200 Hz	Exclusive B candidates	Specific final states
600 Hz	High Mass di-muons	J/ψ, $b \rightarrow J/\psi X$
300 Hz	D* Candidates	Charm, calibrations
900 Hz	Inclusive b (e.g. $b \rightarrow \mu$)	B data mining

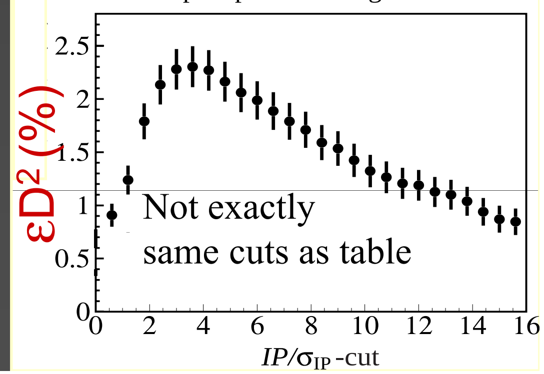
- Rough guess at present (split between streams still to be determined)
- Large inclusive streams to be used to control calibration and systematics (trigger, tracking, PID, tagging)

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 $K^\pm$ (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





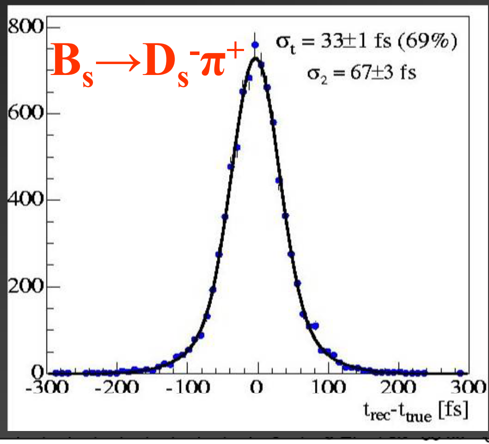


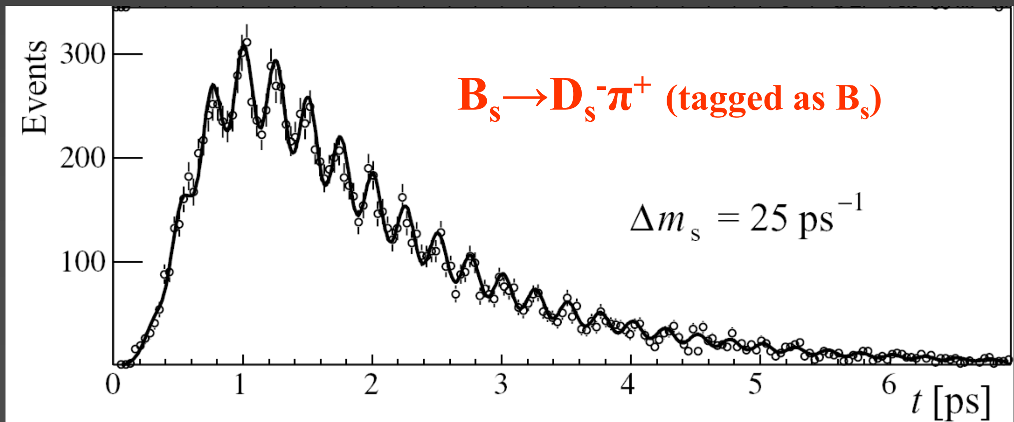
Method (For B_S)	$\mu^\pm$	$e^\pm$	$K^\pm$ same	$K^\pm$ opp	Jet charge
εD^2(%)	1.5	0.7	3.1	2.5	0.8

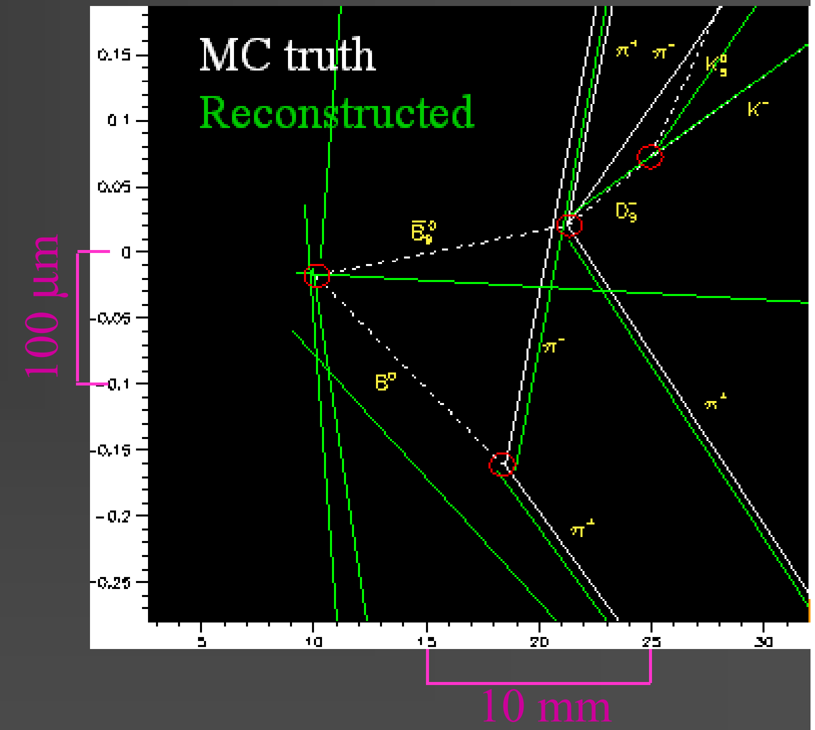
Expect εD^2 ~ 7.5% for B_S & 4.3% for B_d

Background Reduction Using σ_t

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

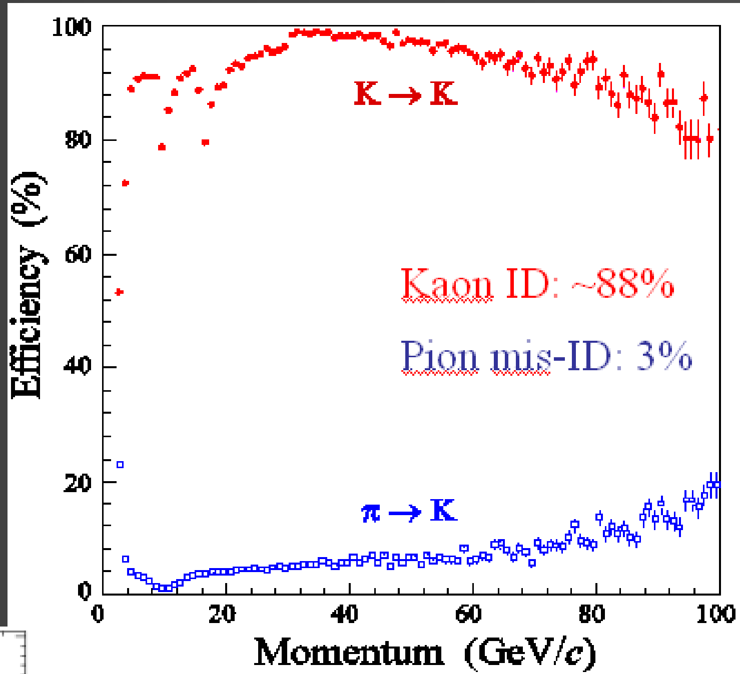


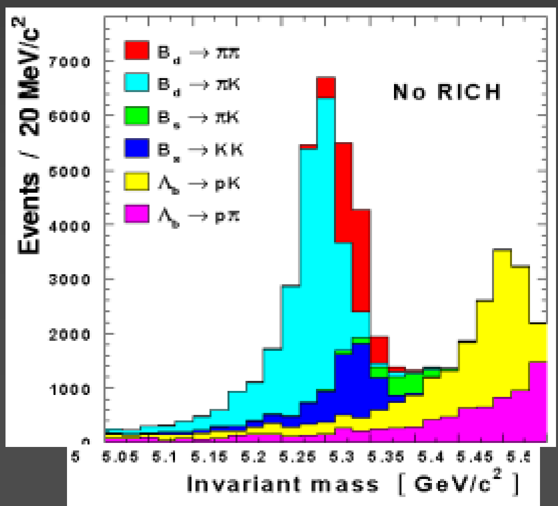


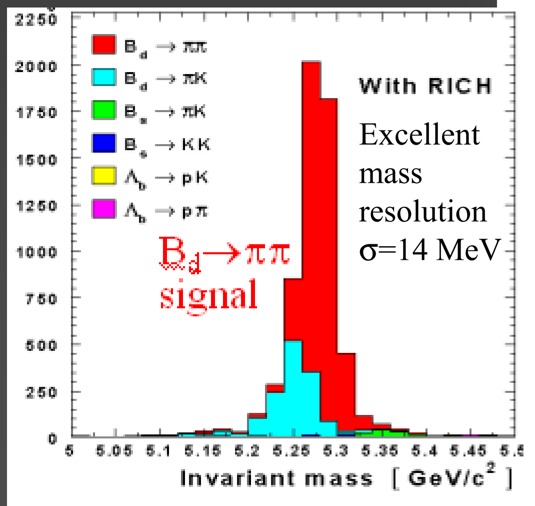


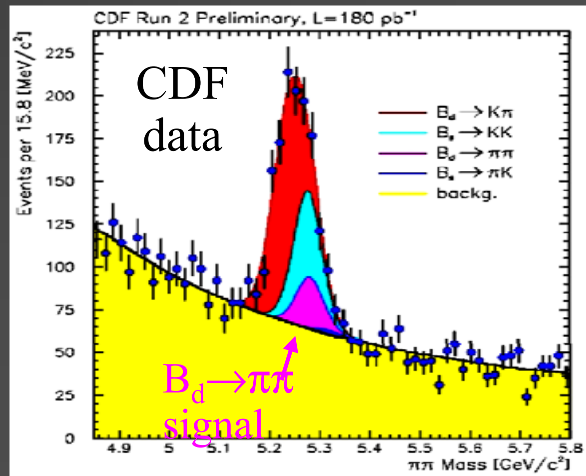
Background Reduction from Particle ID

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







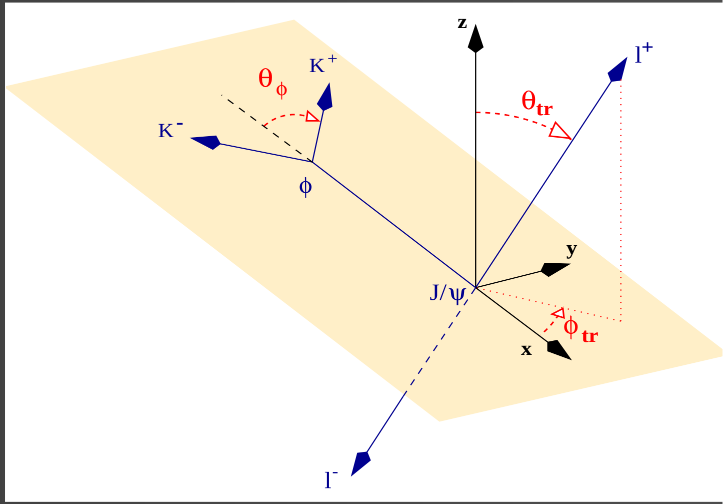


Particle Identification

- 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

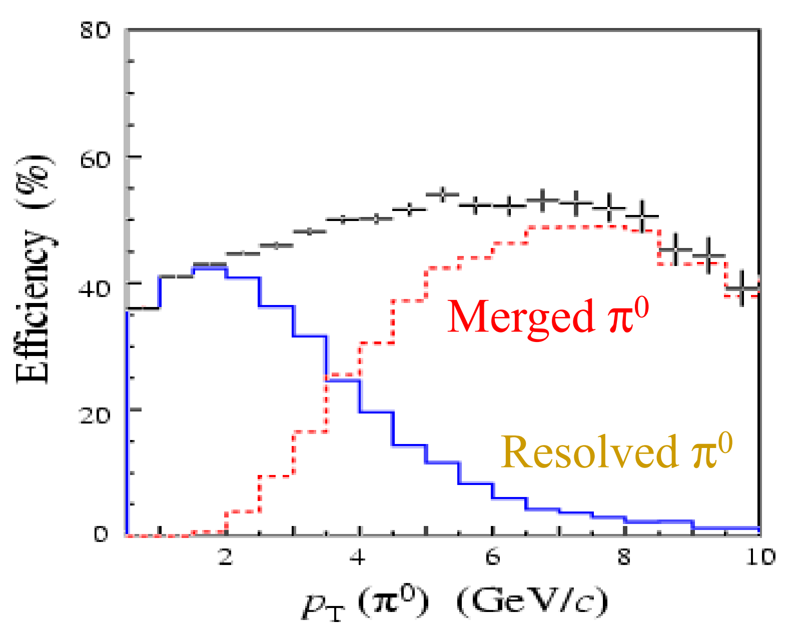
CP Asymmetry in $B_S \to J/\psi\ \phi$

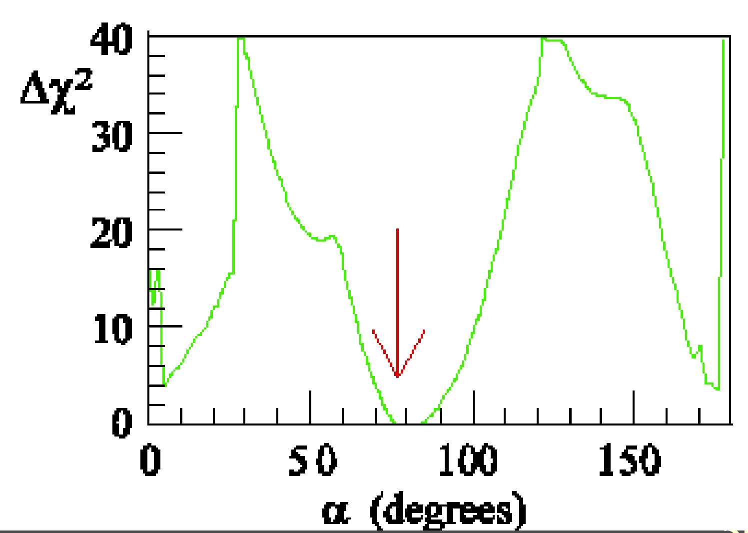
- Just as $B^o \to J/\psi\ K_S$ measures CPV phase β $B_S \to J/\psi\ \phi$ measures CPV B_S mixing phase ϕ_S
- Since this is a Vector-Vector final state, must do an angular (transversity) analysis
- The width difference $\Delta\Gamma_S/\Gamma_S$ also enters in the fit
- LHCb will get 131,000 such events in 2 fb^{-1}. Projected errors are ±0.023 in ϕ_S & ±0.011 in $\Delta\Gamma_S/\Gamma_S$
- With 100 fb^{-1} (LHCb upgrade) error in ϕ_S decreases to ±0.003 (only $\mathcal{L}$ improvement), useful to distinguish among Supersymmetry models (see slide 12)



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

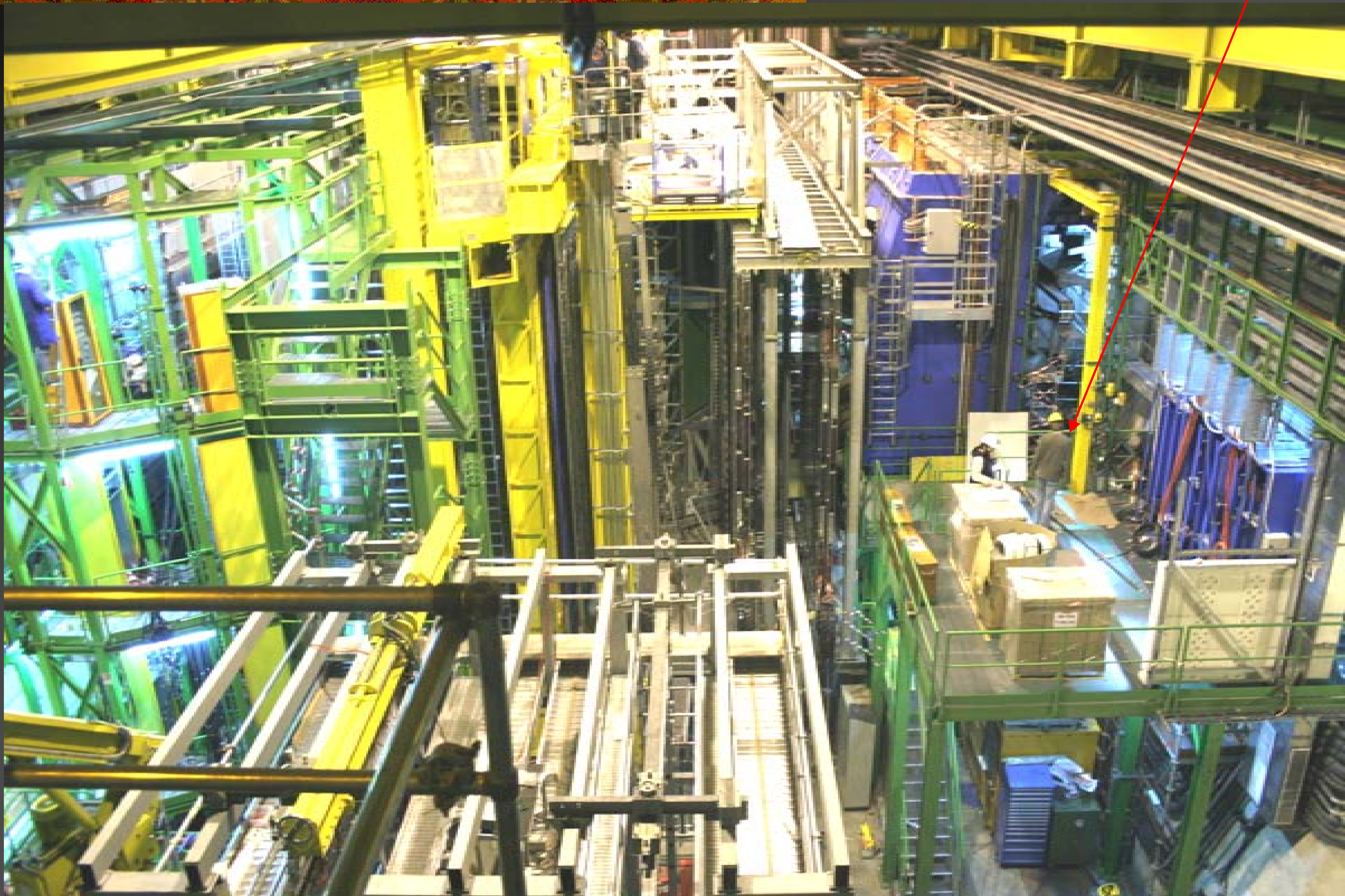
	Channel	Yield	B/S	Precision
γ	$B_s \to D_s^{-+} K^{+-}$	5.4k	< 1.0	$\sigma(\gamma) \sim 14^o$
	$B_d \to \pi^+ \pi^-$	36k	0.46	$\sigma(\gamma) \sim 4^o$
	$B_s \to K^+ K^-$	36k	< 0.06	
	$B_d \to D^0 (K\pi, KK) K^{*0}$	3.4 k, 0.5 k, 0.6 k	<0.3, <1.7, < 1.4	$\sigma(\gamma) \sim 7^o - 10^o$
	$B^- \to D^0 (K^-\pi^+, K^+\pi^-) K^-$	28k, 0.5k	0.6, 1.5	$\sigma(\gamma) \sim 5^o - 15^o$
	$B^- \to D^0 (K^+K^-, \pi^+\pi^-) K^-$	4.3 k	1.0	
	$B^- \to D^0 (K_S\pi^+\pi^-) K^-$	1.5 - 5k	< 0.7	$\sigma(\gamma) \sim 8^o - 16^o$
α	$B_d \to \pi^+ \pi^- \pi^0$	14k	< 0.8	$\sigma(\alpha) \sim 10^o$
	$B \to \rho^+\rho^0, \rho^+\rho^-, \rho^0\rho^0$	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	$\sigma(\Delta m_s) \sim 0.01\ ps^{-1}$
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 ±0.3 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}

Status

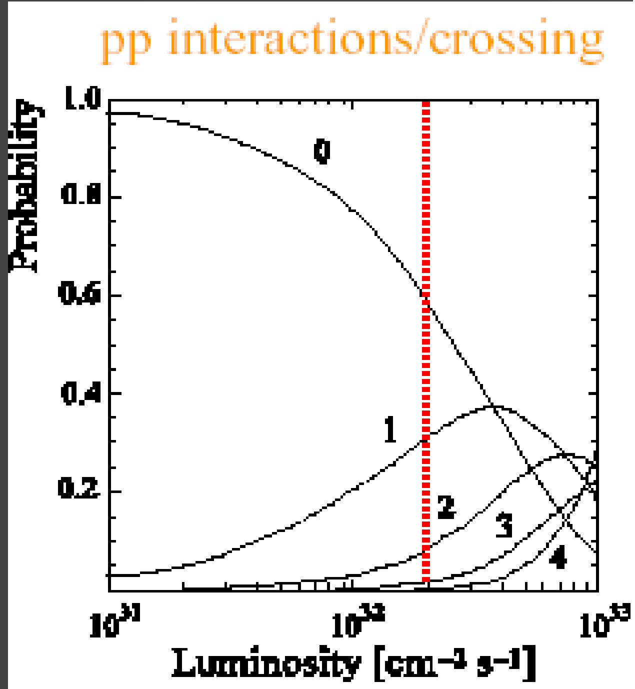
- Magnet installed
& mapped
- ECAL, HCAL, RICH II
  & Muon Filter Installed
- VELO modules have all been mounted
- Construction on all
other items proceeding
- Software is progressing
- Detector should be complete and installed for Engineering Run

View of the Pit



How to Improve Sensitivity

- Must show greatly improved reach for upgrade
  1. Increase luminosity
  2. Allow triggers on multiple int/xing. (Currently limit hadronic modes by insisting on only 1)
  3. Improve trigger efficiency by using detached vertex trigger in 1st trigger level
  4. Improve vertex resolution & ∴ selection ε
  5. Improve EM calorimeter (segmentation in center)



Example $B^+ \rightarrow D(K\pi)K^+$

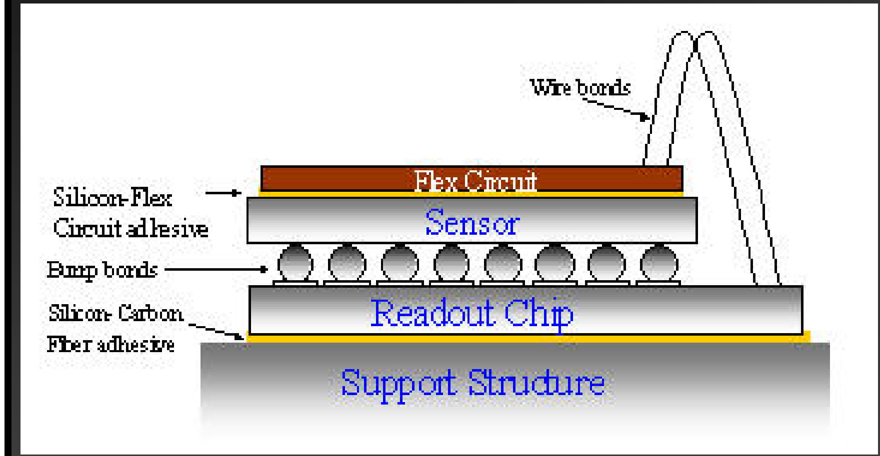
- Signal Yield = $\mathcal{L} * \sigma_{B+} * \mathcal{B} * \varepsilon_{TOT}$, with ε_{TOT}=0.5%, the signal efficiency
- ε_{TOT} = 8.2% (geometry) × 87.8% (reconstruction) × 28.4% (selection) × 25.0% (trigger)
- Improve $\mathcal{L}$x10, selectionx2? (from better vertex resolution) , triggerx3? Total=x60
- Also Ecal improvement for neutral and e^- modes

Possible Upgrade Path

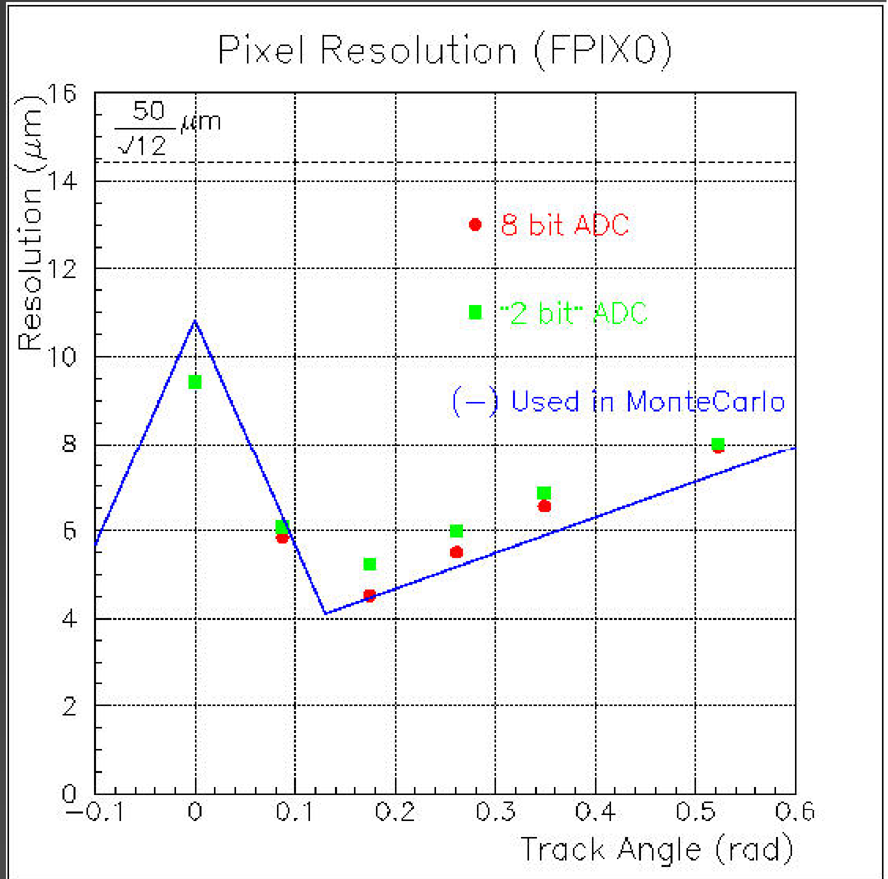
- VELO needs to be replaced after ~6-10 fb^{-1} due to radiation damage, ∴ need rad hard technology
  - Are considering hybrid Silicon pixels as a replacement since they are much more rad hard than current VELO, we could move closer to the beam getting better vertex σ and run at higher luminosity
  - Investigating the possibility that VELO be embedded in a ~1 T field to help vertex triggering
- EM calorimeter upgrades such as having better segmentation in the central region
- Major modifications to readout including long digital pipelines running at 40 MHz that would enable extensive 1st level vertex triggering and allow higher luminosity running

Pixels

Pixel Module Construction



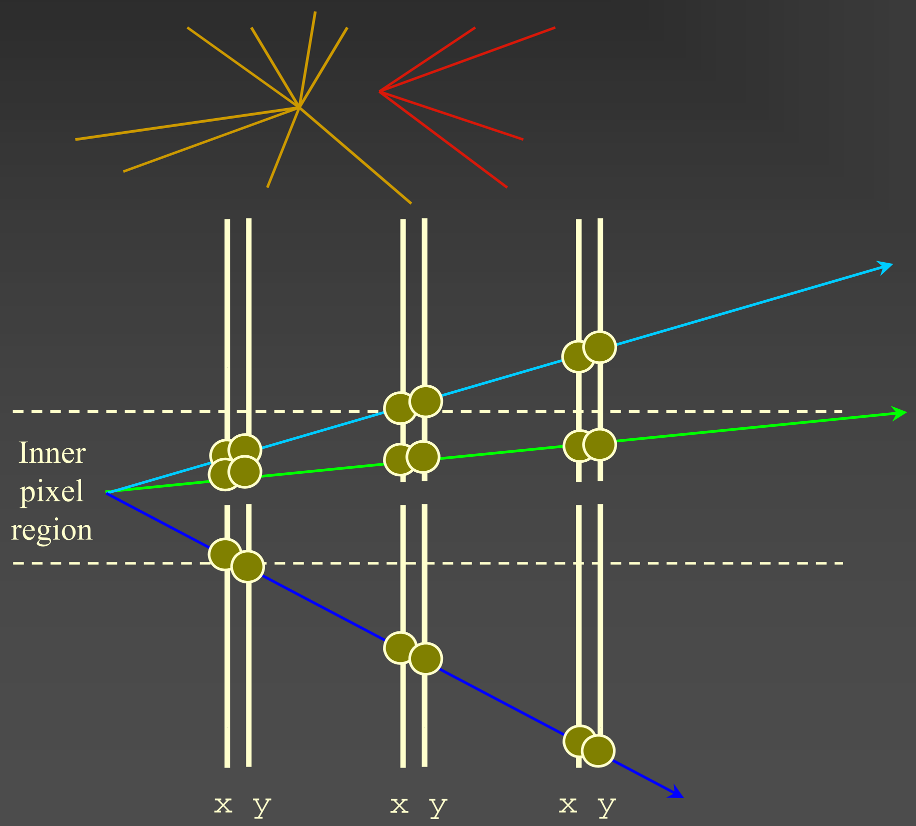
- Analog pixel's – working systems studied in beams, including "almost" final electronics



FNAL, Iowa, Milano, Syracuse
J. Appel et al., NIM **A485, 411 (2002)**
[hep-ex/0108014]

Possible Vertex Triggering

◆ Idea: find primary vertices & detached tracks from b or c decays



- Pixel hits from 3 stations are sent to an FPGA tracker that matches "interior" and "exterior track hits
- Interior and exterior triplets are sent to a CPU farm to complete the pattern recognition:
  - interior/exterior triplet matcher
  - fake-track removal
- *See E. Gottschalk, Nucl.Phys.Proc.Suppl. 156, 252 (2006).*

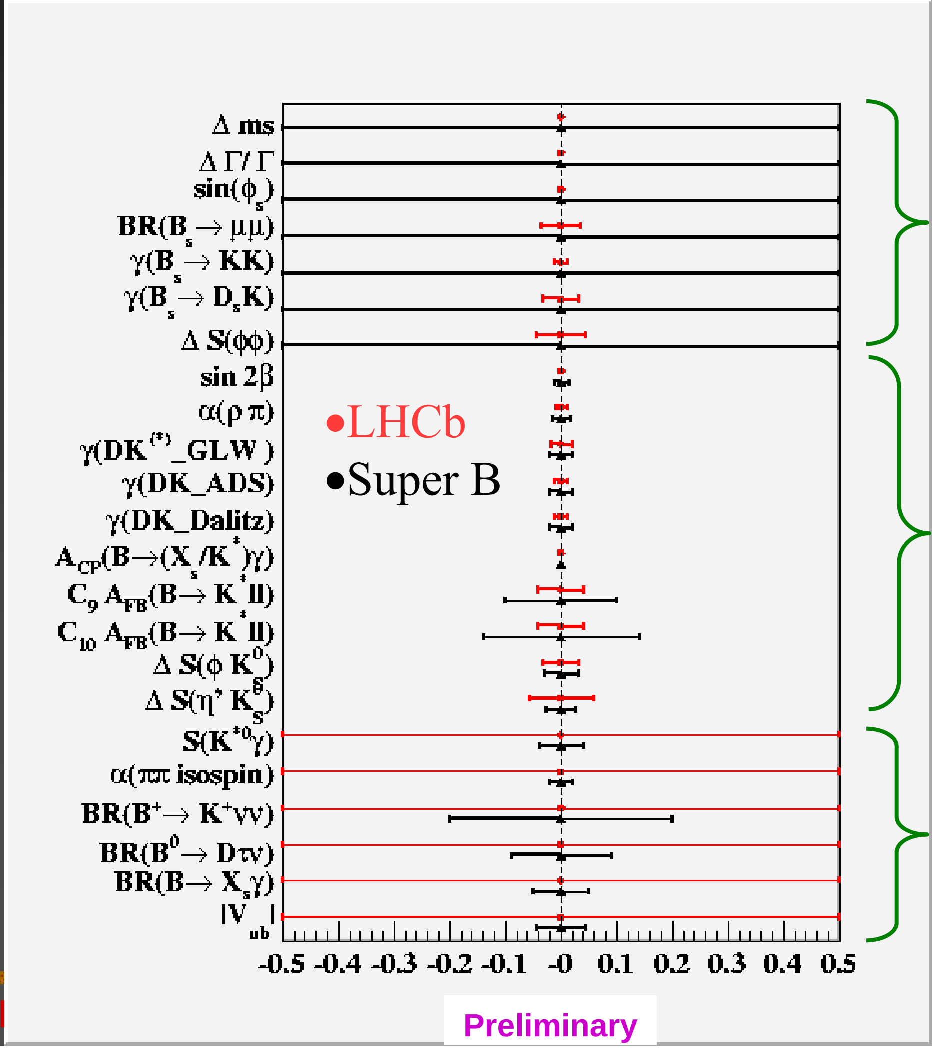
Upgrade Plans

- LHCb upgrade group has been established
- Simulations required
- R & D including beam tests are being planned
- Data, of course, would be useful to test these concepts

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$_s$ only accessible at LHCb

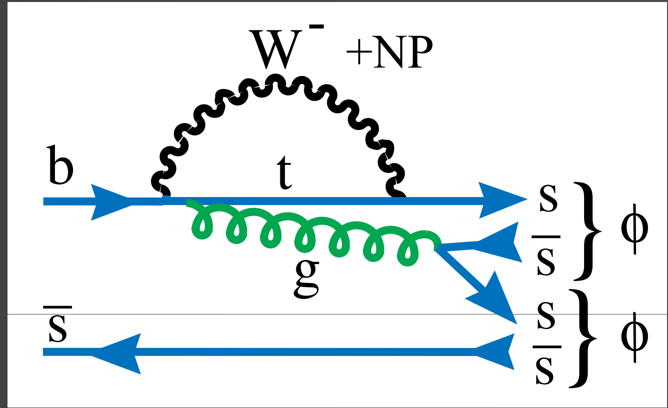
Common

No IP

Neutrals, ν

One Comparison

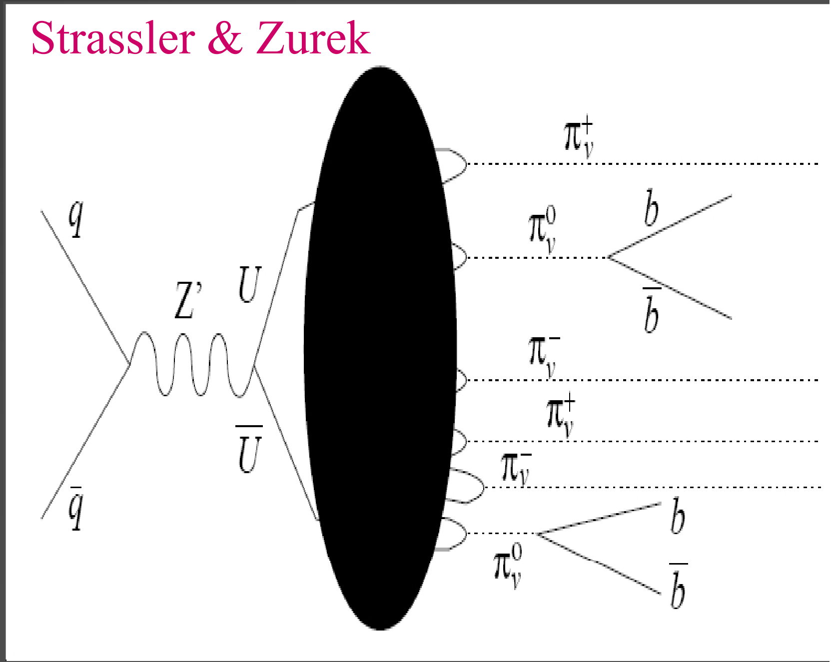
- $B_S \to \phi\phi$, versus $B^o \to \phi K_S$
- Purpose: measure difference in CP violation between Color Suppressed Tree + Penguin and CST ≡ A (recall slide 22)



- Might think that Vector-Vector state is much worse due to angular analysis, but this method automatically ensures that any K^+K^- S-wave is taken care of
- Super B $B^o \to \phi K_S$, estimated error in A for 50 ab^{-1} is ±0.03
- LHCb $B_S \to \phi K_S$, estimated error for 100 fb^{-1} is ±0.019-0.045
- LHCb $B_S \to \phi\phi$, estimated error for 100 fb^{-1} is ±0.006-0.014,
- where larger error is due to $\mathcal{L}$ increase only

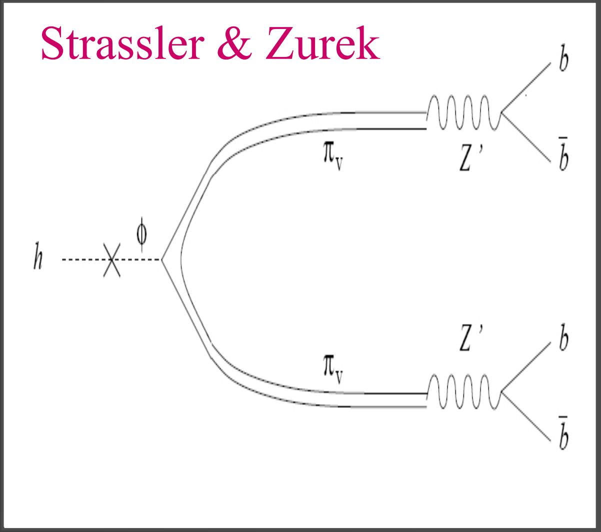
Other Possibilities: "Hidden" Gauge Sectors

- 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 $Z' \rightarrow U\,\overline{U}$, fragmentation causes lots of particle production, with some particles containing new U_1 & U_2 with v=0. These scalar particles $\pi_v{}^o \rightarrow b\overline{b}$ preferentially due to helicity conservation if $2m_B < m(\pi_v) < m_{WW}$

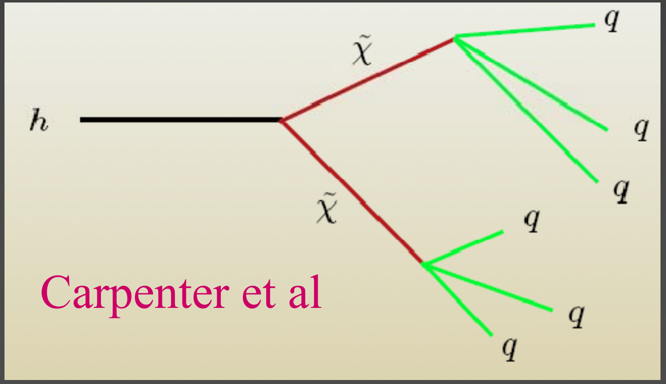


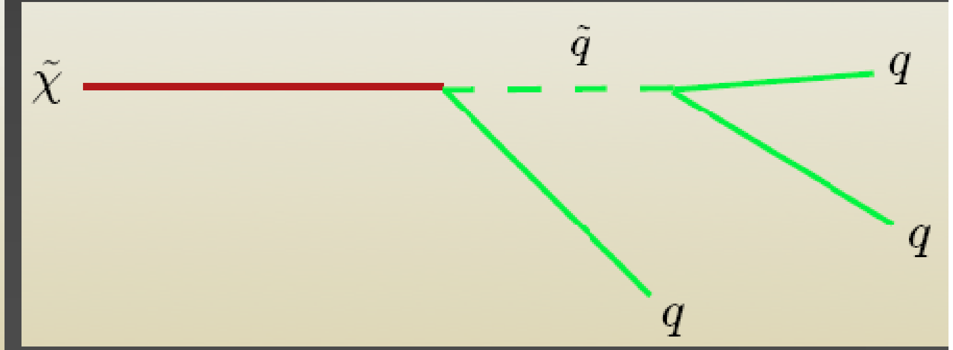
Higgs decays

- π_v lifetime can be large or small
- Can also have
  Higgs$\rightarrow \pi_v\, \pi_v \rightarrow b\bar{b}\; b\bar{b}$



  - Or





  - Again lifetime (decay length) is unknown

Generalized Search

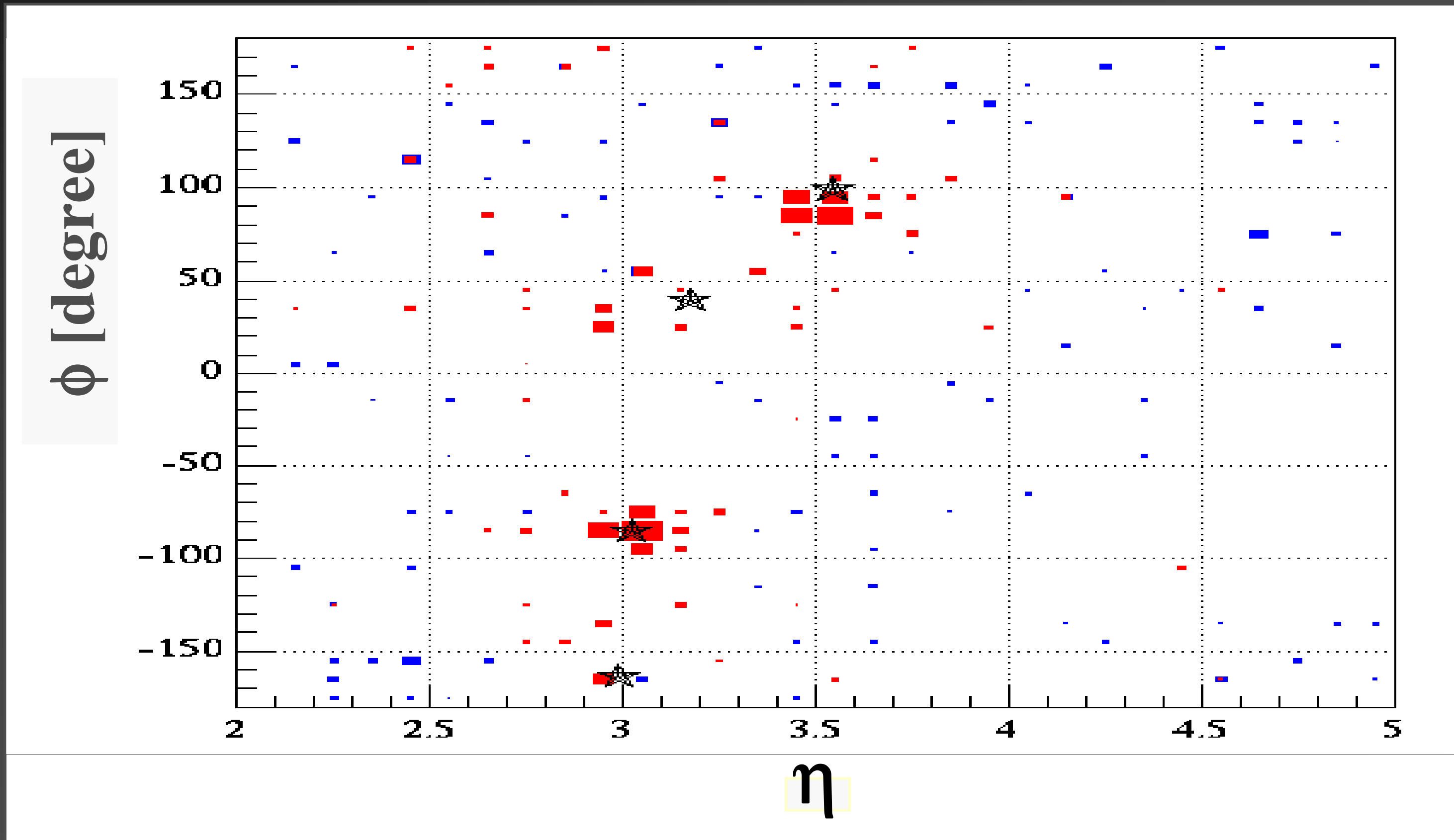
- Many models, many possibilities
- We need to search for anything new that decays to $b\bar{b}$
  - Need to do this as a function of lifetime and mass
  - We don't know branching ratio for Higgs decay or production cross-section for hidden valleys so we start with a few model dependent cases
- Disclaimer: All of these simulations are extremely preliminary first looks

Adapt Strassler – Zurek Models

- Start with the simple parameter sets, recommended by M. Strassler, taking into account some LHCb features
- Unstable v-pions decay to $b\bar{b}$-pairs
  - Strong interaction parameter Λ_v in the interval 35-120 GeV
- τ_v in the interval 0.1ps-100ps & infinity
- Require at least 3 b-quarks in LHCb acceptance

E_t Flow Example for Higgs

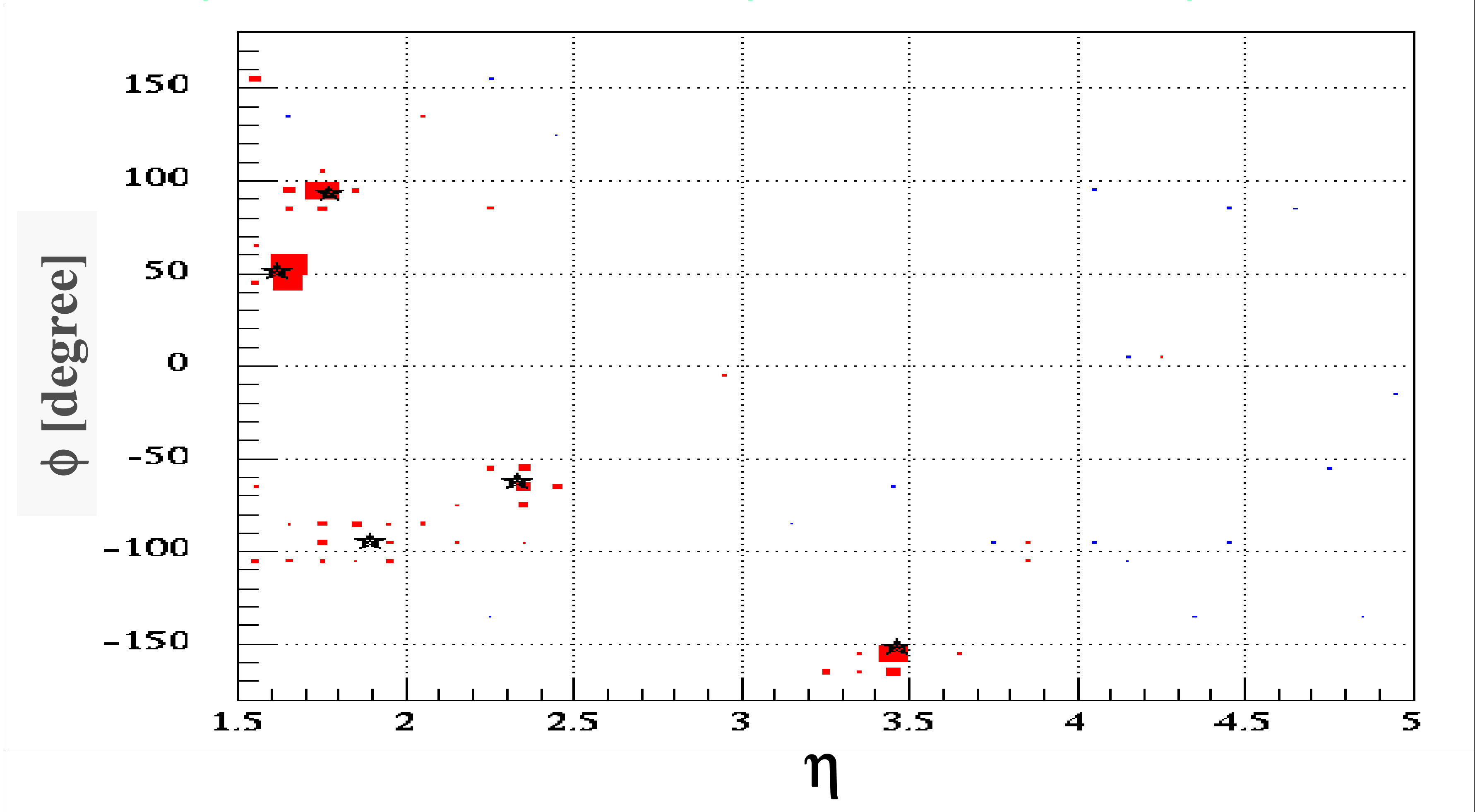
$M(H^0)$=120 GeV, $m(\pi_v^o)$=35 GeV, $\tau(\pi_v^o)$=1 ps



Calorimeter energies much larger than underlying event

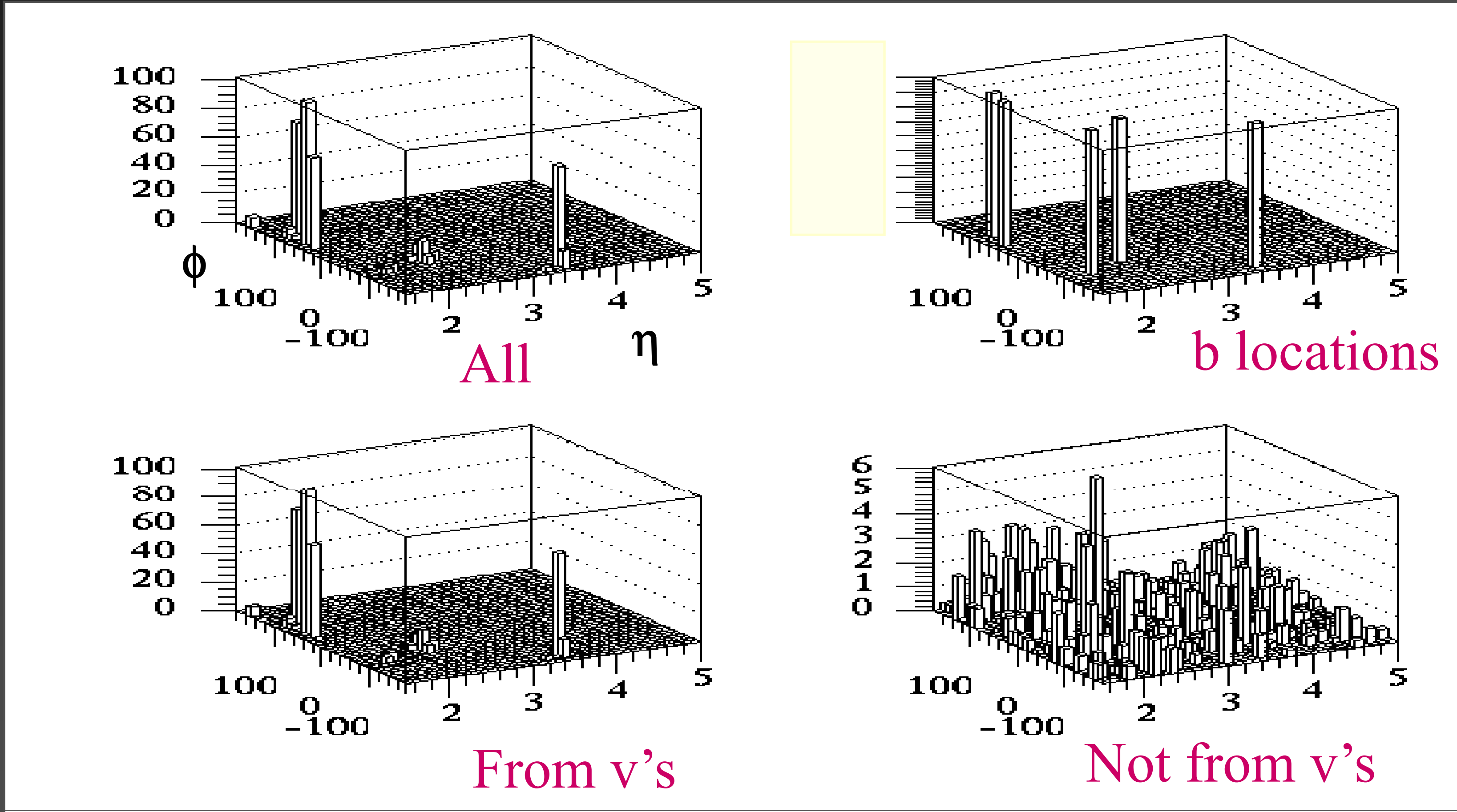
E_t Flow Example for Hidden Valley

$m(\pi_v^o)$= 120 GeV, $\tau(\pi_v^o)$=0.1 ps, $\tau(\pi_v^+)$=10 ps



E_t versus ϕ & η

- Most of E_t in event is in b jets

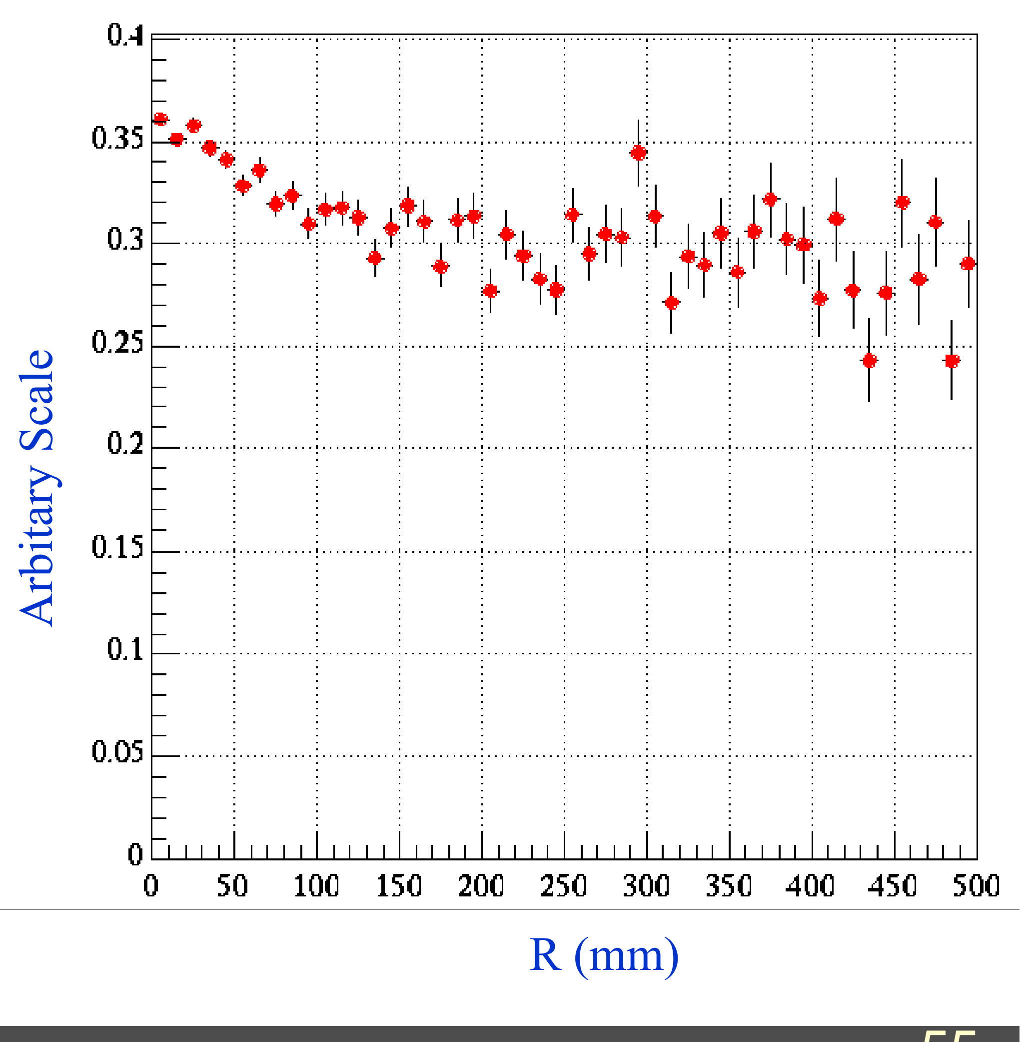


- Must do background simulations

Efficiencies

- 1st level trigger (L0) efficiency is very high >80% for 3 or more jets in 8.2% geometrical acceptance
- Efficiency to reconstruct jets decreases slowly as a function of the ν decay length once L0 is satisfied
- Higher trigger levels can be adjusted in order to accept these events

Jet Efficiency vs ν Flight Distance



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*


LHCb Ski Outing
March 2007
Photo credit: Tomasz Skwarnicki
The End
A Hidden Valley?

16th International Workshop on Vertex Detectors

Vertex 2007

September 23 - 28, Lake Placid, NY

To review progress on Silicon based Vertex detectors with emphasis on existing & future detectors, new materials, software, alignment, electronics, triggering, 3D devices, monolithic structures, new developments, applications to medical & other fields

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