First studies in the detector geometry working group

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Achille Stocchi - LAL, Orsay
for the Detector Geometry working group

SuperB meeting, Orsay, Feb. 2009

detector geometry working group

The group was formed to examine critically the open questions listed below and provide quantitative information to help taking decisions on the final SuperB detector design.

- A forward PID detector compared to a longer DCH
  - momentum coverage range?
  - tradeoff between X0 in front of EMC and gain from forw. PID
- backward EMC vs. no backward EMC
  - What angular acceptance and energy resolution?
- In addition:
  - SVT internal geometry and SVT-DCH transition radius
  - quality and angular coverage of forw. EMC
  - Amount and distribution of absorber in IFR
  - physics case for backward PID?

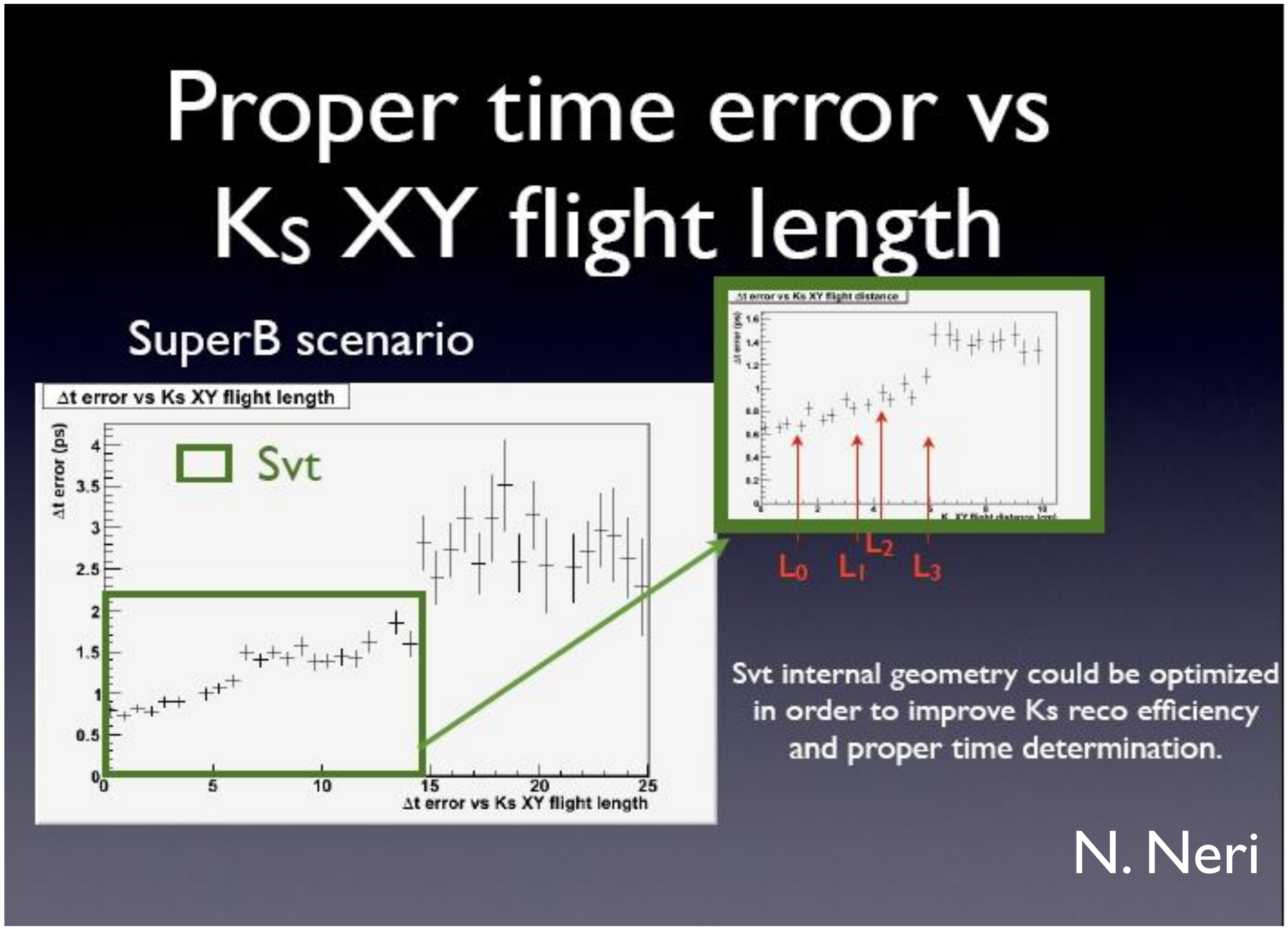
DGWG session yesterday

16:00->*18:30* **Parallel V - detector geometry group** (Convener: Achille Stocchi (*LAL*) , Matteo Rama (*LNF*))
Description:
Location: Salle 166 - Bldg 200

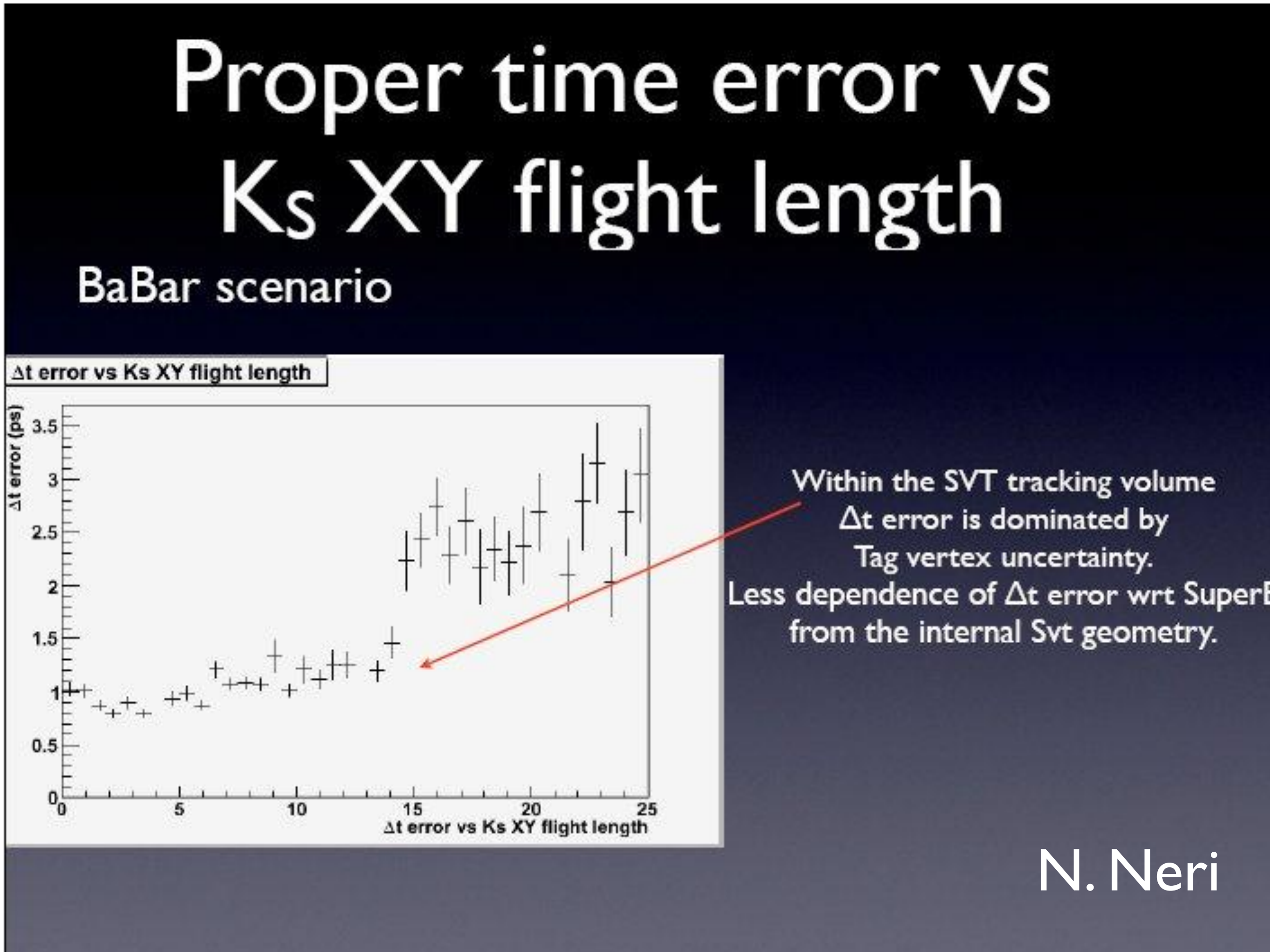
16:00	SVT studies (10') (Slides)	Nicola Neri (*Universita' di Pisa & INFN*)
16:10	study of deltaT in B->Kspi0 (10') (Slides)	Gabriele Simi (*UMD College Park, MD*)
16:20	study of B and D vertexing (10') (Slides)	Aritoki Suzuki (*Lawrence Berkeley National Laboratory*)
16:30	mu/pi separation using TOF in DIRC (10') (Slides)	Brian Meadows (*University of Cincinnati*)
16:40	physics case of forw. PID (20')	Achille Stocchi, Leonid Burmistrov (*LAL*)
17:00	Breco in FastSim. Impact of PID (15') (Slides)	Elisa Manoni (*PG*)
17:15	endcap EMC - plans (20') (Slides)	Chih-hsiang Cheng (*Caltech*) , Elisa Manoni (*PG*)
17:35	IFR optimization strategy (10') (Slides)	Gianluigi Cibinetto (*FE*) , marcello rotondo (*INFN Padova*)
17:45	AFit (15') (Minutes; Slides)	Adrian Bevan (*Queen Mary, U. London*)

Δt error vs. Ks f.l. of B→KsKs

- Results on impact of L0 on vertex done with PravdaMC validated with FastSim



Δt error vs. Ks f.l. of B→KsKs

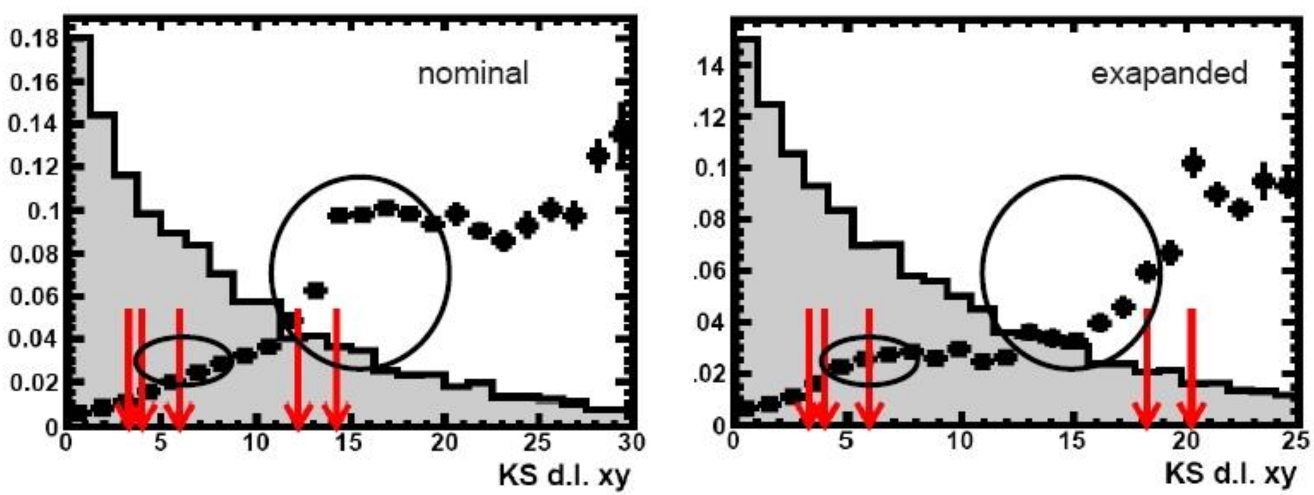


B→Ksπ^0 : Ks f.l. resolution vs. SVT geometry

G. Simi

Filling the gap between SVT and DCH

- Expand L4 and L5 up to maximum allowed:
  - Layer 4: 12.2->17.4
  - Layer 5: 14.2->20.2 (DCH S.T. is at 21.3cm)



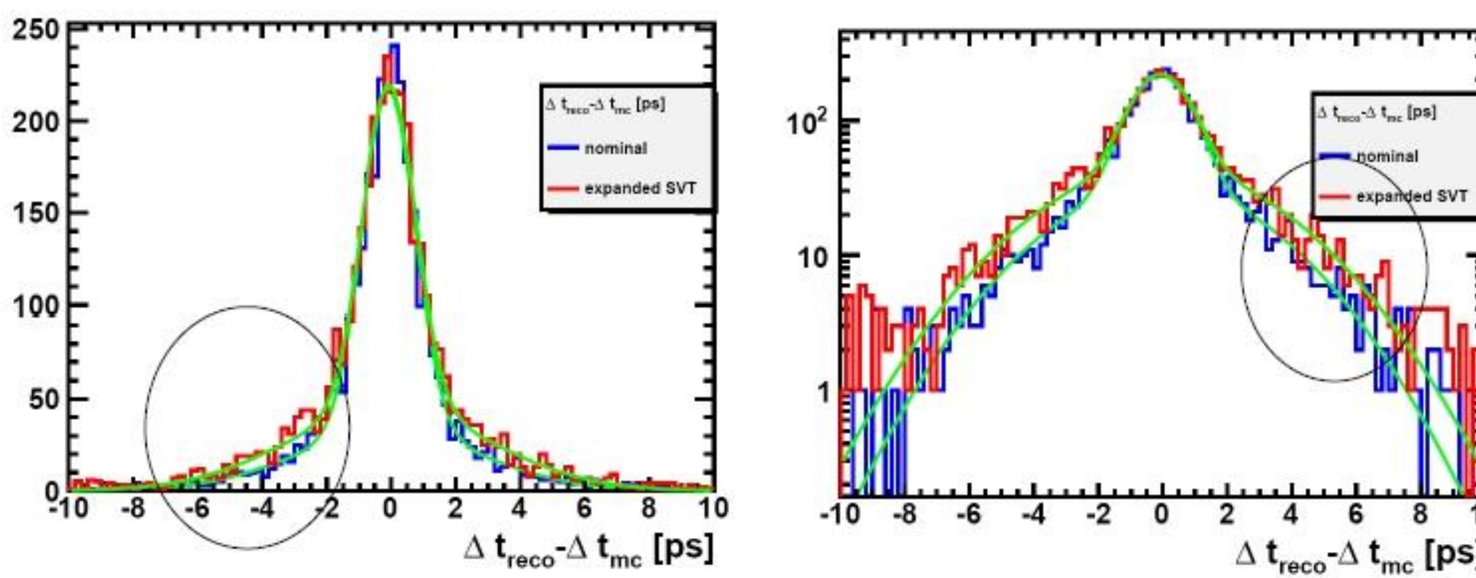
how the Ks decay length changes by 'expanding' the external SVT layers?

B→Ksπ⁰ : comparison of Δt resolutions

G. Simi

Events where the tracks from Ks satisfy a quality cut on # SVT hits

Δt resolution



- most of the additional events are populating mainly the tails of the resolution

Optimizing the design for B→Ks Ks/π^0

- Optimization depends on many factors, not just the FastSim output
  - redundancy for the innermost and outermost layers: obtained with two nearby layers
  - length of Phi strips: set a limit to the largest radius
  - slow track reconstruction efficiency
  - etc.
- We should come up with a list with all 'constraints' we can think of and start from it to find a good detector design

Vertex study with $B^0 \rightarrow D^*K$

$B^0 \rightarrow D^{*-}K^+$, $D^{*-} \rightarrow D^0\pi^-$, $D^0 \rightarrow K^-\pi^+$

Summary of Vertex Resolution with Babar / Super-B Configuration

- Reconstructed vertex resolution from FastSim shows agreement with FullSim.
  - Centers around 0
  - Resolutions agree between 10% ~ 20%
- Improvement on vertex resolution
  - B° 0.008 → 0.004
  - D° 0.012 → 0.004

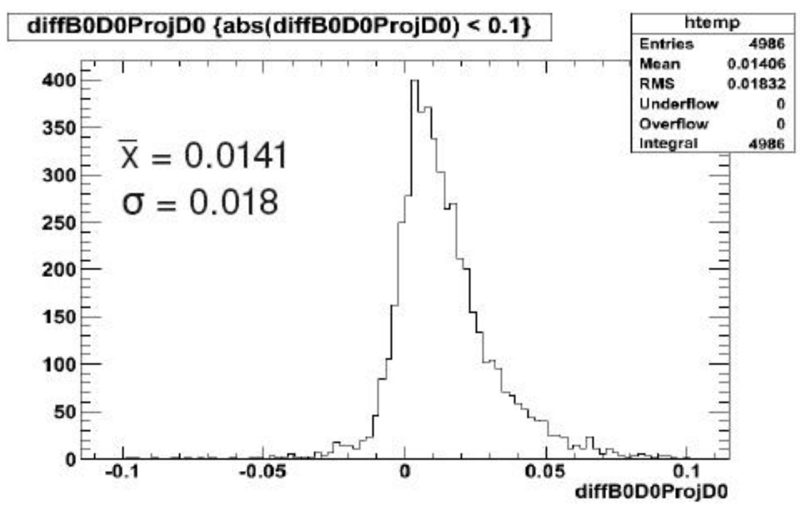
A. Suzuki/D. Brown

Vertex study with $B^0 \rightarrow D^*K$

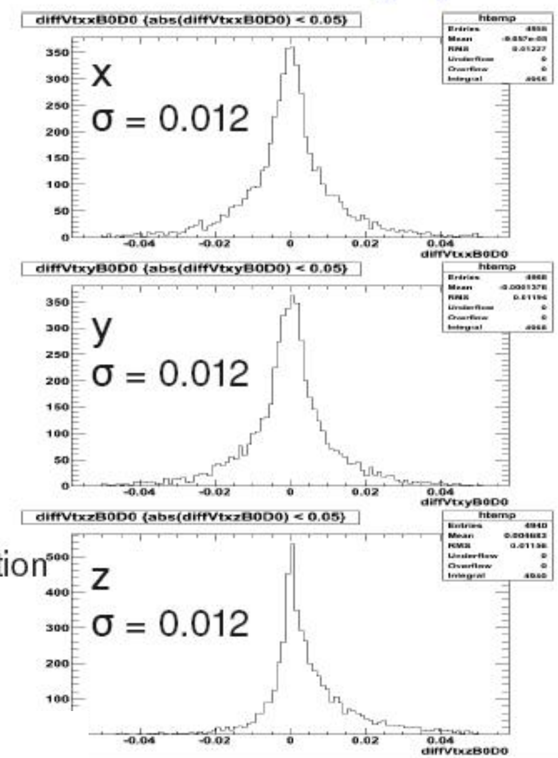
(D° - B°) Vertex Separation

- Study if its possible to distinguish B° and D° vertex
  → Plot vertex position difference in direction of momentum of D°

Vertex difference along D0 momentum



Vertex difference along x-y-z



- Separation along momentum is bigger than resolution
- Average 3.5σ away
- Vertices are separable

Future plans:

Look at generic decaying side for vertex separation
Use more generic vertex algorithm for tagging side

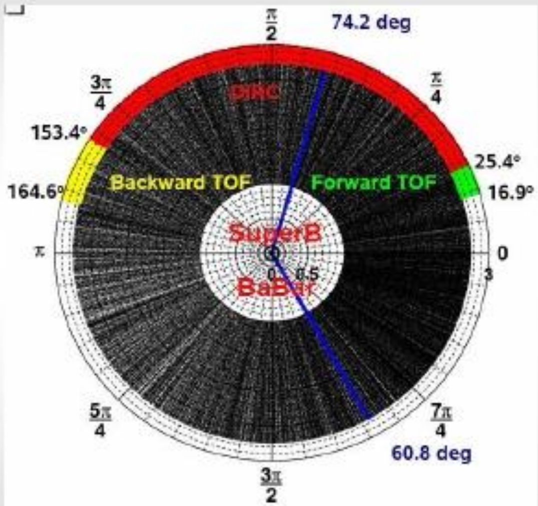
A. Suzuki/D. Brown

first studies of Breco vs. PID

PID devices geometry (I)

E. Manoni/F.Renga

* different PID device coverage (by Leonid)



* Study the impact of the three devices by selecting Breco candidates with all tracks crossing:
  - DIRC
  - DIRC + FW TOF
  - DIRC + FW TOF + BW TOF

implemented by cutting in θ_{Lab}

* "geometric" gain wrt DIRC-only by adding:
  - FW TOF : 6.1%
  - BW TOF : 0.6%

Breco modes

SL Breco	HAD Breco
$B \rightarrow D^{(*)} l \nu$	$B \rightarrow D^{(*)} n_1 \pi\, n_2 K\, n_3\, K_s\, n_4\, \pi^0$

reconstruction efficiency $O(10^{-3})$

'toy' PID

* Study effects of the kaon and pion PID by using MC-truth information
  - choose a K and a π selector assuming the BaBar performancies

selector	efficiency	misID
Kaon: KLHTight	85%	1% (with pion)
Pion: piLHVeryLoose	99%	20% (with kaon)

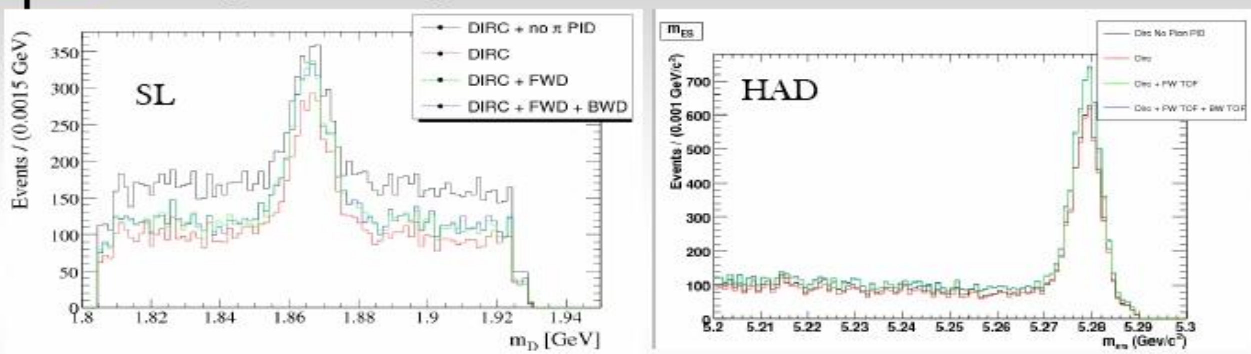
first studies of BReco vs. PID

E. Manoni/F.Renga

SuperB workshop Orsay

PID devices geometry (II)

* π VeryLoose, K Tight



HAD RECONSTRUCTION	signal region $m_{ES}>5.27 GeV/c^2$	sideband: $m_{ES}<5.26 GeV/c^2$
K PID + Dirc	5140	5514
K PID + π PID + Dirc	5023	5005
K PID + π PID + Dirc + Fw TOF	5969	6273
K PID + π PID + Dirc + Fw TOF + BW TOF	6045	6386

elisa manoni

8

Next steps

Use PID selectors when available

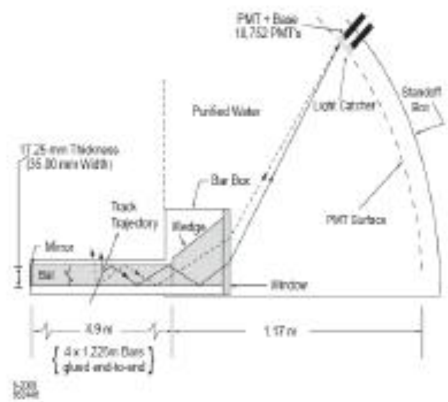
Reconstruct signal side, as B→K*n n and related quantities (Eextra, etc.)

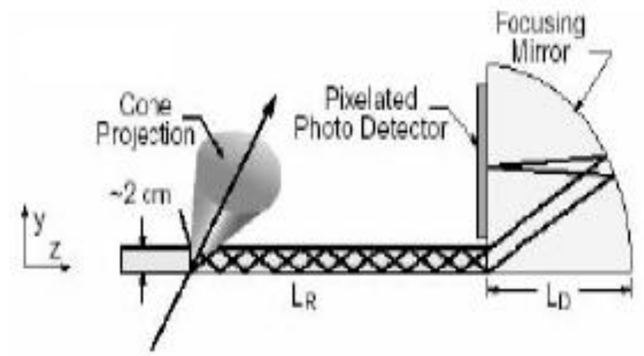
fDIRC

B. Meadows

use time information to separate pions/muons in DIRC

Rudiments of the fDirc





it may be feasible with a new focusing system

- Conventional PMT's
  - τ resolution ~1.6 ns
- Water stand-off box
- No focussing
  - Size of PMT window and cross-section of bar introduce uncertainties in photon direction

- PMT array (Hamamatsu H-8500 Flat-panel MaPMT
  - τ resolution ~ 140 ps
- Oil (or quartz ??) SOB
- Focussing mirror (f~0.5 m) maps a direction onto a "point" in the detector plane.

Brian Meadows,
Feb 16, 2009

University of Cincinnati

fDIRC

B. Meadows

Conclusions

- It appears that the fDirc should bring good improvements to all PID, especially in μID in the low momentum region.
- Forward PID will increase efficiency for low momentum muons that typically miss the barrel Dirc.
  - A TOF measurement in this momentum range is quite effective.
- A simulation, within the FastSim framework, is needed to make a quantitative evaluation of any gains there may be from fDirc and forward TOF.

  (See also Nicolas Arnaud's talk this morning:

  http://agenda.infn.it/getFile.py/access?contribId=99&sessionId=17&resId=0&materialId=slides&confId=959)

Brian Meadows,
Feb 16, 2009

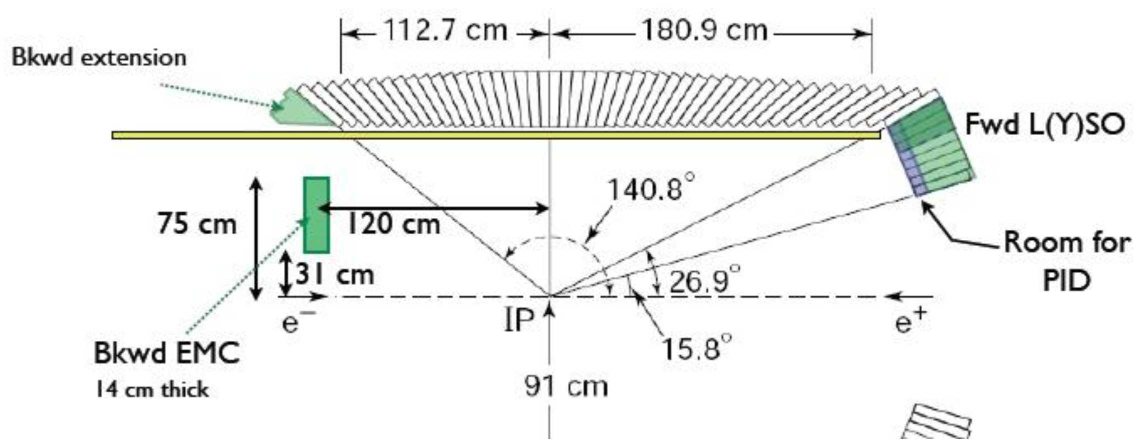
University of Cincinnati

EMC options

C. Cheng

Scenarios

1. Barrel (CsI(Tl)) only
2. Barrel + Forward Endcap (3 CsI(Tl) rings, 12 LYSO rings)
3. Barrel + Forward Endcap (~20 LYSO rings)
   1. with/without forward PID
4. Barrel + Forward Endcap (LYSO) + Backward Endcap
   1. with/without forward PID



Plans of EMC (CalTech)

C. Cheng

- Optimization:
  - phot. energy/ang. resolution
  - π^0 mass resolution, efficiency
  - E/p
  - study effect from backgrounds

- Approach from both on detector resolution effects (use single particles, interplay with Geant4 simulation), and from on sensitivities to physics channels.
- Personally I will continue working on EMC fastsim (naturally, study the detector effects), and will start physics study with $B \to X_s\gamma$, and/or $B \to \tau\nu$.
  - There may be 1 postdoc and 1 gradstudent from Caltech joining the efforts.

IFR baseline and optimization

- *A first SuperB IFR configuration is available in PacSim*
- *According to CDR:*
  - *Reduced number of active layers to 8*
  - *More # of Interaction lenghts (6.5-7.5 instead of 5-6 we have now in BaBar)*

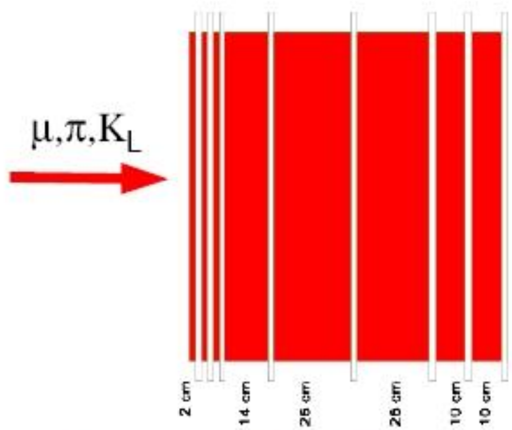


Figure 4-41. *Sketch of the longitudinal segmentation of the iron absorber (gray Active detector positions are shown in white from the innermost (left) to the outermo (right) layers*

IFR: parameters to be optimize

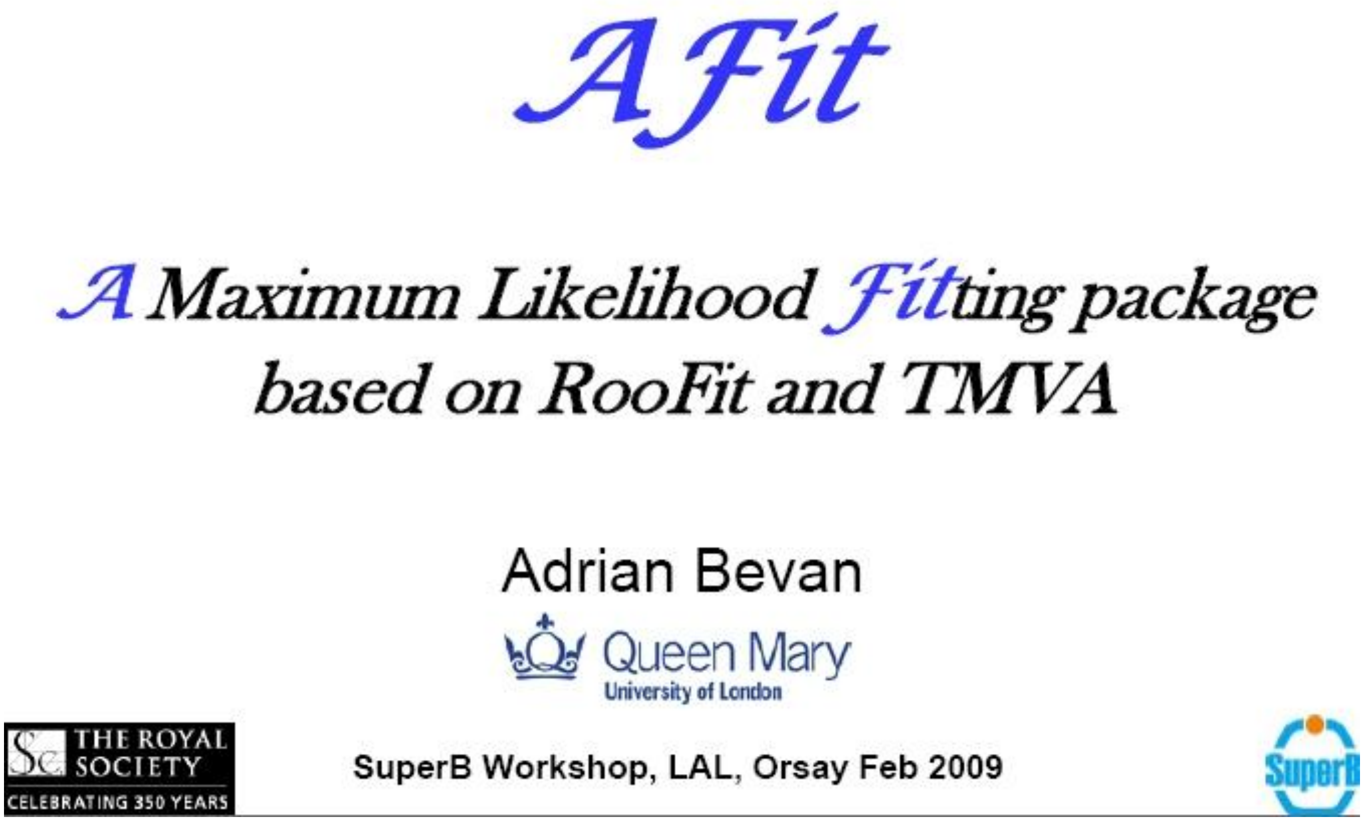
- Detector, parameters that need to be optimized:
  - # of interaction lenghts
  - Spatial resolution, baseline is 4cm x 20cm
  - Transverse segmentation: better identify the neutral hadrons
  - Esplore the possibility to have a cylindrical active layer outside the EMC
  - Background studies: require the full sim, can affect the Geometry of the scintillator slab (spatial resolution)

Plans

IFR: Detector Optimization

- *Use the Full Sim. geometry only to study the shape of he hadronic shower in a sampling detector*
  - *Parameterize the shower with a functional form in the Fast Sim.*
  - *This is crucial for the Fast Sim itself, but could be used to optimize the detector geometry*
- *Integrate the output of the Full Sim in the Fast Sim? GHits hadrons in the IFR active layers can be treated as PacSimHits?*
  - *Is it possible this kind of integration, how can be implemented in short time Scale?*
- ***Any better idea or suggestion?***
- *This kind of studies require to involve the Full Sim. WG*

AFit



Afit is available from http://pprc.qmul.ac.uk/~bevan/afit/

Some considerations

- Finding the optimal design of a detector involves many factors, not limited to those coming from a fast simulation. Finding and evaluating all relevant factors is part of the DGWG job.
- Optimizations of a given detector is usually correlated to the other systems.
  - Example: to evaluate the impact of a forward PID device we need to combine all available PID info, such as dE/dx.
- We urgently need those tools necessary to perform a physics analysis. Tagging, PID selectors, etc. This kind of development will proceed in parallel, but people involved in DGWG are asked to contribute to this development (it's already happening in a few cases)

To follow the DGWG activity:

- DGWG mailing list: https://lists.infn.it/sympa/info/superb-dgwg
- Wiki page (still empty): http://mailman.fe.infn.it/superbwiki/index.php/DGWG/Home
- We meet on Tuesday @17:30 CET every two weeks

Conclusion

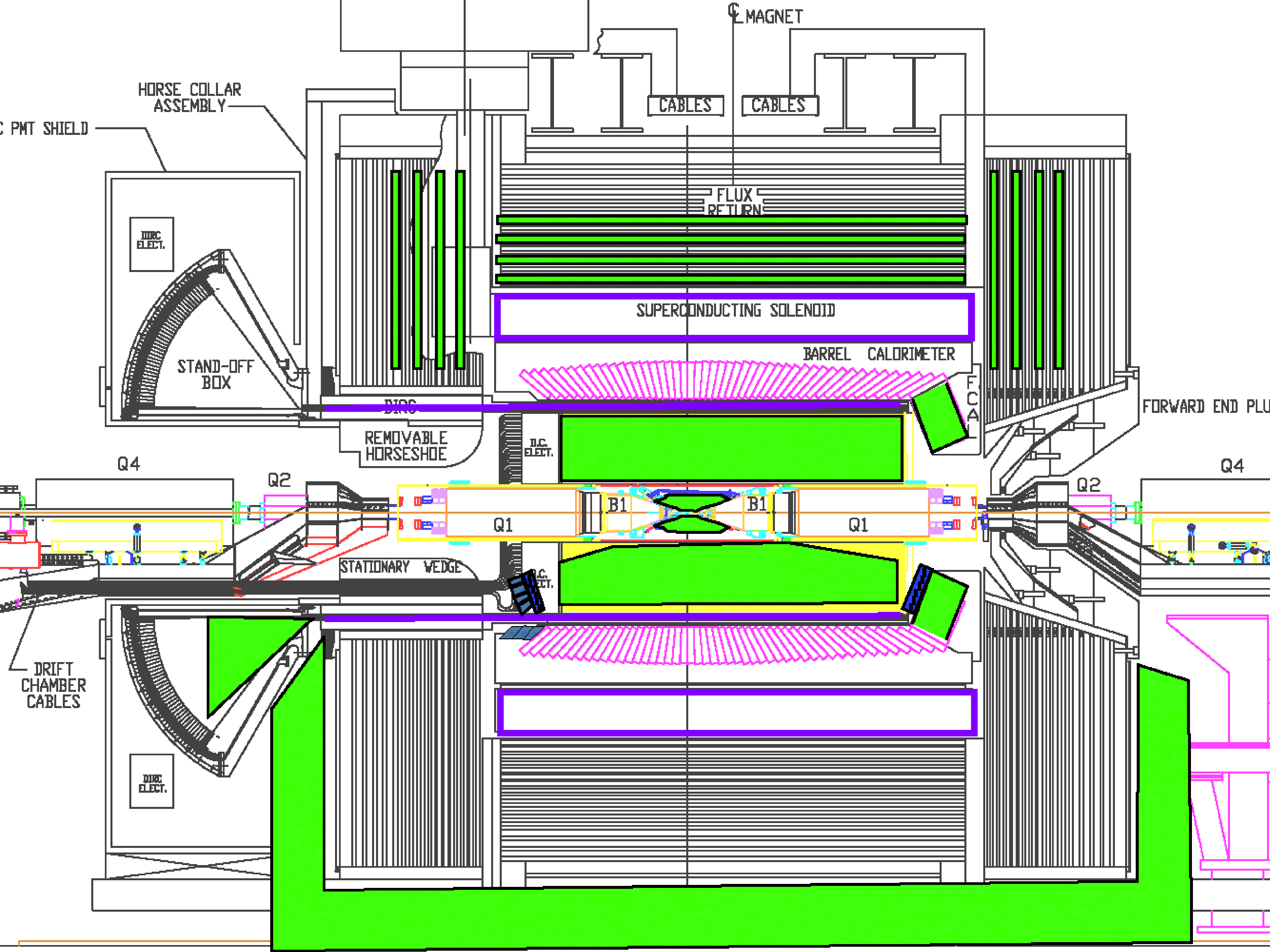
Not really much to add…

- DGWG activity started 1 month ago.
- First preliminary results were discussed at the DGWG session yesterday. Good discussions.
- We've a lot of work ahead.

current activity

	People (22/jan/09)	Detector options	Optimization studies	Physics benchmarks	Items needing development
SVT	D. Brown, N. Neri, D. Roberts, G. Simi		internal geometry, radius of outer layer	B→Ksπ^0/Ks$\pi^0\gamma$, beta, Recoil, (tagging)	▪ dE/dx ▪ endcap PID response ▪ PID selectors ▪ tuning of EMC response ▪ hadron shower sim. ▪ Flavour tagging ▪ Tag vertex
DCH	M. Rama, G. Finocchiaro		longer DCH replacing forw. PID, inner radius	tracking performance, dE/dx	
PID	A. Stocchi, L. Burmistrov, N. Arnaud, A. Perez, A. Berdyugin, B. Meadows, F. Renga	forward PID yes/no, backward PID yes/no	angular and momentum coverage range, needed PID performance, #rad. length (impact on endcap EMC performance)	B→(d,s) l^+l^-, Recoil, tagging, B→Knunubar, B→tau nu	
EMC	C. Cheng, E. Manoni, A. Rossi	backward EMC yes/no	angular coverage of forw/back endcaps, needed performance, degradation due to endcap PID	B→Ksπ^0/Ks$\pi^0\gamma$, B→tau nu, b→sγ, B→K nu nubar Recoil, tagging	
IFR	G. Cibinetto, M. Rotondo		amount and distribution of absorber	beta, Recoil, tagging	
			Other: position of IR vertex		

BACKUP



℄ MAGNET
HORSE COLLAR ASSEMBLY
C PMT SHIELD
CABLES
CABLES
FLUX RETURN
DIRC ELECT.
SUPERCONDUCTING SOLENOID
BARREL CALORIMETER
STAND-OFF BOX
F C A
FORWARD END PLU
DIRC
REMOVABLE HORSESHOE
D.C. ELECT.
Q4
Q2
Q1
B1
B1
Q1
Q2
Q4
STATIONARY WEDGE
D.C. ELECT.
DRIFT CHAMBER CABLES
DIRC ELECT.

our current strategy

- Start from a *restricted* number of channels which cover a wide spectrum both in terms of physics potential and of detector requirements

selection of golden modes in different NP scenarios (Valencia proc., arxiv 0810.1312)

	H^+ high $\tan\beta$	Minimal FV	Non-Minimal FV (1-3)	Non-Minimal FV (2-3)	NP Z-penguins	Right-Handed currents
$\mathcal{B}(B \to X_s\gamma)$		X		O		O
$A_{CP}(B \to X_s\gamma)$				X		O
$\mathcal{B}(B \to \tau\nu)$	X-CKM					
$\mathcal{B}(B \to X_s l^+ l^-)$				O	O	O
$\mathcal{B}(B \to K\nu\overline{\nu})$				O	X	
$S(K_S\pi^0\gamma)$						X
β			X-CKM			X

X The GOLDEN channel for the given scenario

O Not the GOLDEN channel for the given scenario but can show experimentally measurable deviations from SM.

…plus $\tau \to \mu\gamma$

our current strategy

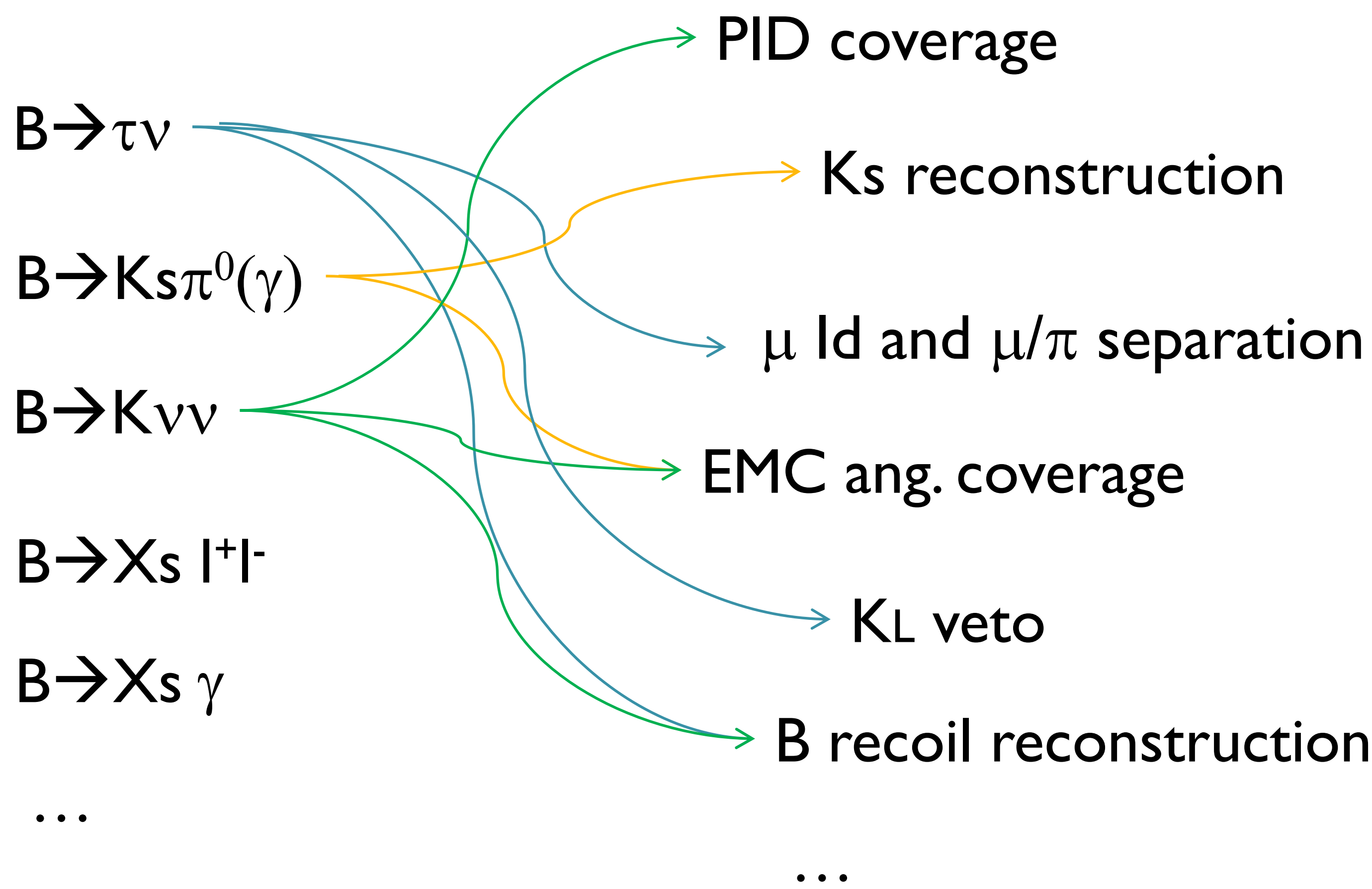
estimated sensitivity

Mode	Sensitivity			
	Current	10 ab^{-1}	75 ab^{-1}	
$\mathcal{B}(B \to X_s \gamma)$	7%	5%	3%	(*)
$A_{CP}(B \to X_s \gamma)$	0.037	0.01	0.004–0.005	(+)
$\mathcal{B}(B^+ \to \tau^+ \nu)$	30%	10%	3–4%	(+)
$\mathcal{B}(B^+ \to \mu^+ \nu)$	X	20%	5–6%	
$\mathcal{B}(B \to X_s l^+ l^-)$	23%	15%	4–6%	
$A_{\rm FB}(B \to X_s l^+ l^-)_{s_0}$	X	30%	4–6%	
$\mathcal{B}(B \to K \nu \overline{\nu})$	X	X	16–20%	
$S(K_S^0 \pi^0 \gamma)$	0.24	0.08	0.02–0.03	(*)

(*) theoretically limited (+) systematics limited

Process	Expected 90%CL upper limited	4σ Discovery Reach
$\mathcal{B}(\tau \to \mu \gamma)$	2×10^{-9}	5×10^{-9}

detector optimization



recoil

- The recoil technique (hadronic and semileptonic) is crucial in many SuperB measurements
  - The physics reach of many key channels is improved by optimizing B recoil efficiency and purity
- In this sense the recoil can be considered as a benchmark ‘channel’ of its own for the detector geometry optimization
- Recoil reconstruction improvement mostly depends on PID and EMC coverage/resolution

$B^+ \rightarrow K^+ \nu \nu$

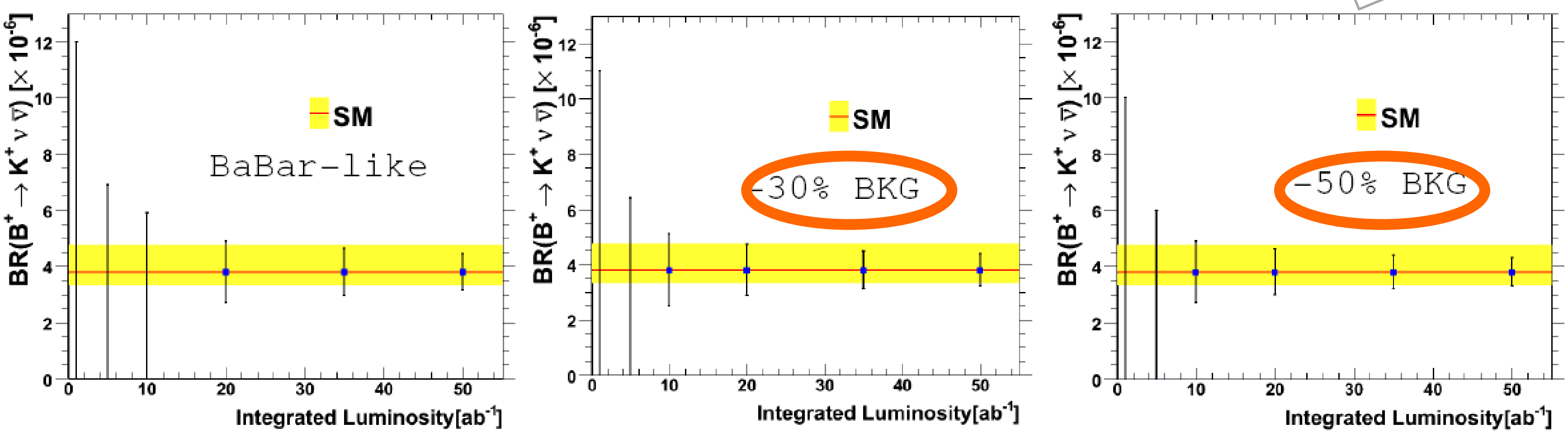
from Francesco Renga

- Recoil Technique (both HAD and SL);
- Kinematics: cut on the K CM momentum;
- Cut-and-count technique;

EXPECTED YIELDS PER ab^{-1}

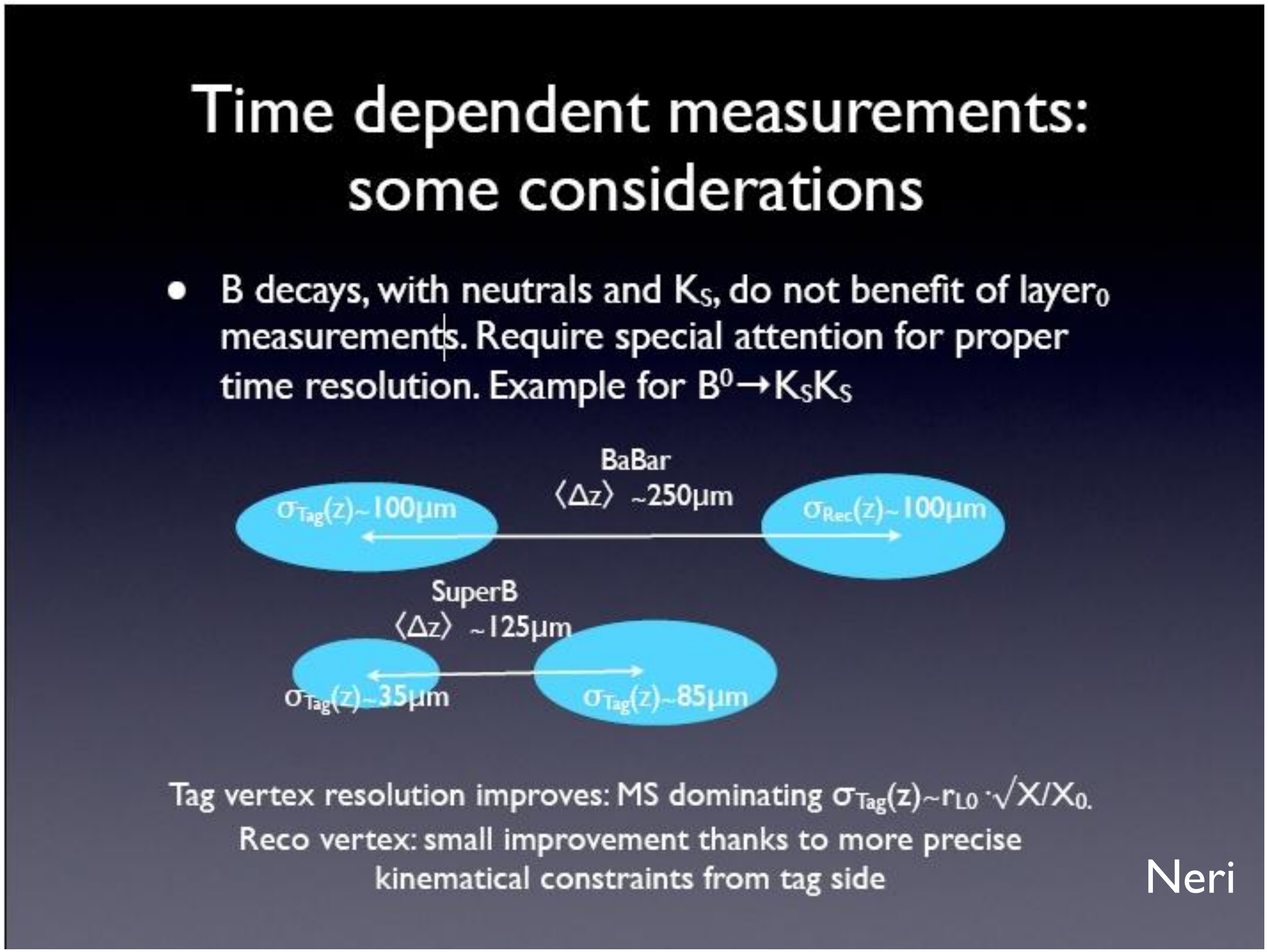
SL RECOIL	HAD RECOIL
$N_{sig} = 6.4 \quad (\varepsilon = 0.00164)$	$N_{sig} = 2.6 \quad (\varepsilon = 0.000678)$
$N_{bkg} = 84$	$N_{bkg} = 60$

toy MC



Reduction of the background → make the observation possible with $10ab^{-1}$ instead of $20ab^{-1}$..

Contributions to the Δz resolution in B→KsKs



B physics @ U(4S)

Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\sin(2\beta)$ $(J/\psi\, K^0)$	0.018	0.005 (†)
$\cos(2\beta)$ $(J/\psi\, K^{*0})$	0.30	0.05
$\sin(2\beta)$ (Dh^0)	0.10	0.02
$\cos(2\beta)$ (Dh^0)	0.20	0.04
$S(J/\psi\, \pi^0)$	0.10	0.02
$S(D^+D^-)$	0.20	0.03
α $(B \to \pi\pi)$	$\sim 16°$	3°
α $(B \to \rho\rho)$	$\sim 7°$	1–2° (∗)
α $(B \to \rho\pi)$	$\sim 12°$	2°
α (combined)	$\sim 6°$	1–2° (∗)
γ $(B \to DK$, $D \to CP$ eigenstates)	$\sim 15°$	2.5°
γ $(B \to DK$, $D \to$ suppressed states)	$\sim 12°$	2.0°
γ $(B \to DK$, $D \to$ multibody states)	$\sim 9°$	1.5°
γ $(B \to DK$, combined)	$\sim 6°$	1–2°
$2\beta + \gamma$ $(D^{(*)\pm}\pi^\mp,\ D^\pm K^0_S\pi^\mp)$	20°	5°
$S(\phi K^0)$	0.13	0.02 (∗)
$S(\eta' K^0)$	0.05	0.01 (∗)
$S(K^0_S K^0_S K^0_S)$	0.15	0.02 (∗)
$S(K^0_S \pi^0)$	0.15	0.02 (∗)
$S(\omega K^0_S)$	0.17	0.03 (∗)
$S(f_0 K^0_S)$	0.12	0.02 (∗)
$\lvert V_{cb}\rvert$ (exclusive)	4% (∗)	1.0% (∗)
$\lvert V_{cb}\rvert$ (inclusive)	1% (∗)	0.5% (∗)
$\lvert V_{ub}\rvert$ (exclusive)	8% (∗)	3.0% (∗)
$\lvert V_{ub}\rvert$ (inclusive)	8% (∗)	2.0% (∗)

Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab
$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	visible	5%
$\mathcal{B}(B \to D\tau\nu)$	10%	2%
$\mathcal{B}(B \to \rho\gamma)$	15%	3% (†)
$\mathcal{B}(B \to \omega\gamma)$	30%	5%
$A_{CP}(B \to K^*\gamma)$	0.007 (†)	0.004 († ∗)
$A_{CP}(B \to \rho\gamma)$	~ 0.20	0.05
$A_{CP}(b \to s\gamma)$	0.012 (†)	0.004 (†)
$A_{CP}(b \to (s+d)\gamma)$	0.03	0.006 (†)
$S(K^0_S\pi^0\gamma)$	0.15	0.02 (∗)
$S(\rho^0\gamma)$	possible	0.10
$A_{CP}(B \to K^*\ell\ell)$	7%	1%
$A^{FB}(B \to K^*\ell\ell)s_0$	25%	9%
$A^{FB}(B \to X_s\ell\ell)s_0$	35%	5%
$\mathcal{B}(B \to K\nu\bar{\nu})$	visible	20%
$\mathcal{B}(B \to \pi\nu\bar{\nu})$	–	possible

A. Stocchi

Possible also at LHCb

Similar precision at LHCb

τ physics

Process	Sensitivity
$\mathcal{B}(\tau \to \mu\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to e\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to \mu\mu\mu)$	2×10^{-10}
$\mathcal{B}(\tau \to eee)$	2×10^{-10}
$\mathcal{B}(\tau \to \mu\eta)$	4×10^{-10}
$\mathcal{B}(\tau \to e\eta)$	6×10^{-10}
$\mathcal{B}(\tau \to \ell K^0_S)$	2×10^{-10}

Charm at U(4S) and threshold

Mode	Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$D^0 \to K^+K^-$	y_{CP}	2–3×10^{-3}	5×10^{-4}
$D^0 \to K^+\pi^-$	y'_D	2–3×10^{-3}	7×10^{-4}
	x'^2_D	1–2×10^{-4}	3×10^{-5}
$D^0 \to K^0_S\pi^+\pi^-$	y_D	2–3×10^{-3}	5×10^{-4}
	x_D	2–3×10^{-3}	5×10^{-4}
Average	y_D	1–2×10^{-3}	3×10^{-4}
	x_D	2–3×10^{-3}	5×10^{-4}
$D^0 \to K^+\pi^-$	x'^2	To be evaluated at LHCb	3×10^{-5}
	y'		7×10^{-4}
$D^0 \to K^+K^-$	y_{CP}		5×10^{-4}
$D^0 \to K^0_S\pi^+\pi^-$	x		4.9×10^{-4}
	y		3.5×10^{-4}
	$\lvert q/p \rvert$		3×10^{-2}
	ϕ		2°

Channel	Sensitivity
$D^0 \to e^+e^-$, $D^0 \to \mu^+\mu^-$	1×10^{-8}
$D^0 \to \pi^0 e^+e^-$, $D^0 \to \pi^0\mu^+\mu^-$	2×10^{-8}
$D^0 \to \eta e^+e^-$, $D^0 \to \eta\mu^+\mu^-$	3×10^{-8}
$D^0 \to K^0_S e^+e^-$, $D^0 \to K^0_S\mu^+\mu^-$	3×10^{-8}
$D^+ \to \pi^+ e^+e^-$, $D^+ \to \pi^+\mu^+\mu^-$	1×10^{-8}
$D^0 \to e^\pm\mu^\mp$	1×10^{-8}
$D^+ \to \pi^+ e^\pm\mu^\mp$	1×10^{-8}
$D^0 \to \pi^0 e^\pm\mu^\mp$	2×10^{-8}
$D^0 \to \eta e^\pm\mu^\mp$	3×10^{-8}
$D^0 \to K^0_S e^\pm\mu^\mp$	3×10^{-8}
$D^+ \to \pi^- e^+e^+$, $D^+ \to K^- e^+e^+$	1×10^{-8}
$D^+ \to \pi^-\mu^+\mu^+$, $D^+ \to K^-\mu^+\mu^+$	1×10^{-8}
$D^+ \to \pi^- e^\pm\mu^\mp$, $D^+ \to K^- e^\pm\mu^\mp$	1×10^{-8}

B_s at U(5S)

Observable	Error with 1 ab^{-1}	Error with 30 ab^{-1}
$\Delta\Gamma$	0.16 ps^{-1}	0.03 ps^{-1}
Γ	0.07 ps^{-1}	0.01 ps^{-1}
β_s from angular analysis	20°	8°
$A^s_{\rm SL}$	0.006	0.004
$A_{\rm CH}$	0.004	0.004
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	$< 8 \times 10^{-9}$
$\lvert V_{td}/V_{ts} \rvert$	0.08	0.017
$\mathcal{B}(B_s \to \gamma\gamma)$	38%	7%
β_s from $J/\psi\phi$	16°	6°
β_s from $B_s \to K^0\bar{K}^0$	24°	11°

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