B Physics in LHC Era

The 17'th Nordic Particle Physics Meeting

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Spåtind, Norway

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and
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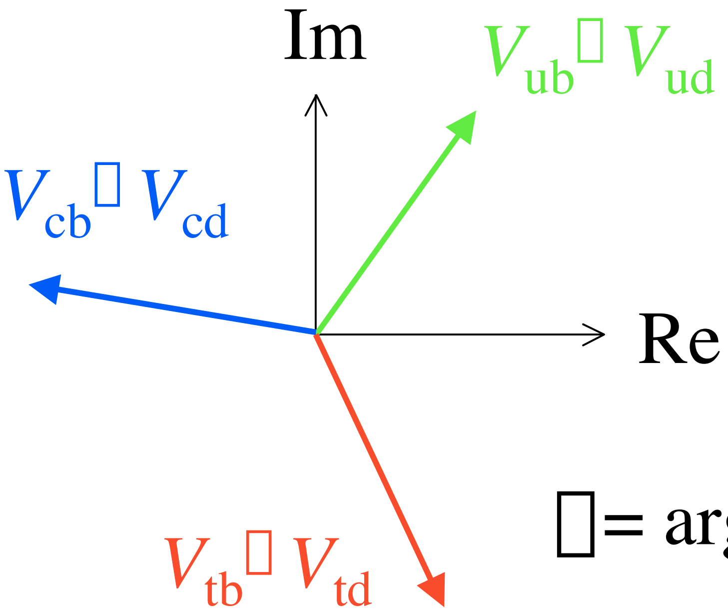
1) CKM picture

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

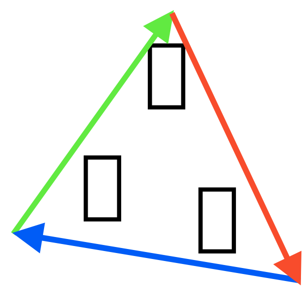
Unitarity: $\boldsymbol{V^\dagger V = 1}$

1) $V_{ub}{}^{\square} V_{ud} + V_{cb}{}^{\square} V_{cd} + V_{tb}{}^{\square} V_{td} = 0$



Unitarity means ⟹

$$\square = \arg \frac{\square V_{tb}{}^{\square} V_{td}}{V_{ub}{}^{\square} V_{ud}}$$



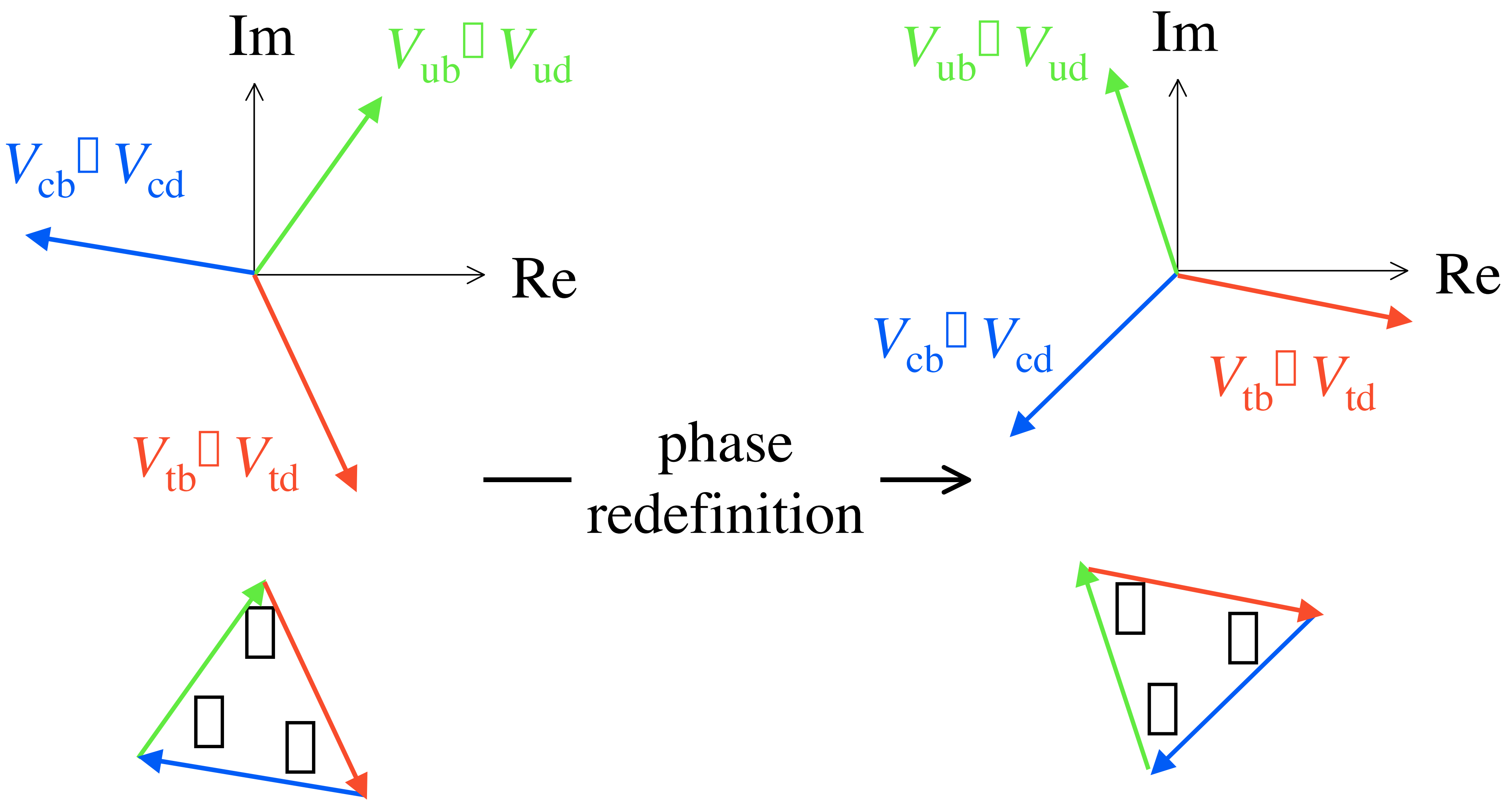
$$\square = \arg \frac{\square V_{ub}{}^{\square} V_{ud}}{V_{cb}{}^{\square} V_{cd}}$$

$$\square = \square \square \arg \frac{V_{tb}{}^{\square} V_{td}}{V_{cb}{}^{\square} V_{cd}}$$

$$\square + \square + \square = \square$$

$$\square = \arg \frac{\square V_{tb}^{\square} V_{td}}{V_{ub}^{\square} V_{ud}} \qquad \square = \square \square \arg \frac{V_{tb}^{\square} V_{td}}{V_{cb}^{\square} V_{cd}} \qquad \square = \arg \frac{\square V_{ub}^{\square} V_{ud}}{V_{cb}^{\square} V_{cd}}$$

- invariant under quark phase redefinition -

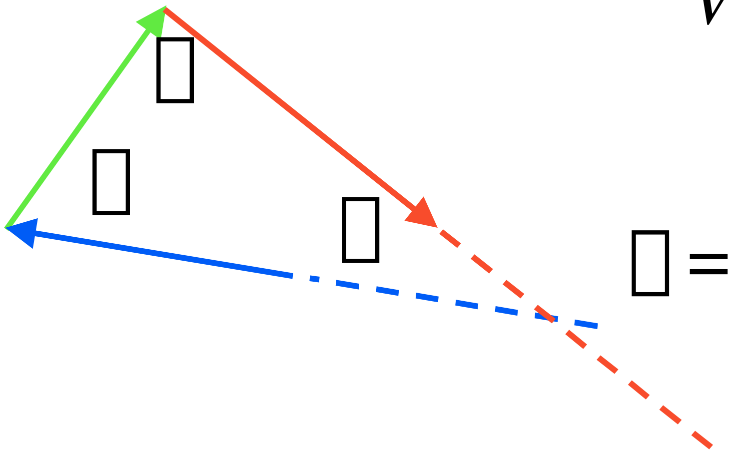


英和辞典

West Cost				Far East
	□	□	$\square_2$	
	□	□	$\square_1$	
	□	□	$\square_3$	

If CKM is not unitary…

$$\square = \arg \frac{\square V_{tb}{}^{\square} V_{td}}{V_{ub}{}^{\square} V_{ud}}$$



$$\square = \arg \frac{\square V_{ub}{}^{\square} V_{ud}}{V_{cb}{}^{\square} V_{cd}}$$

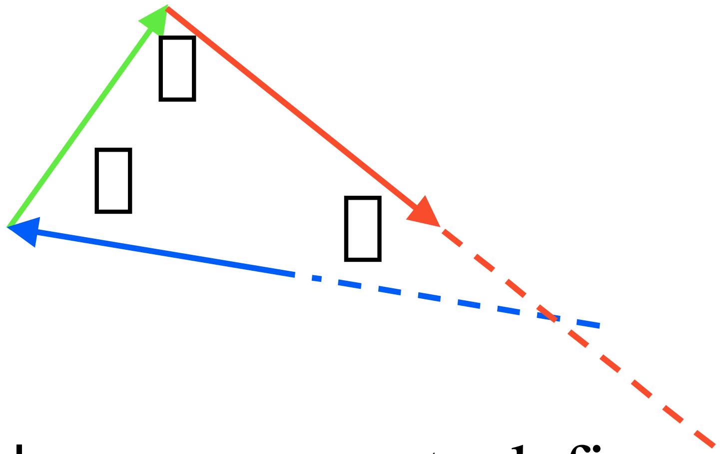
$$\square = \square \square \arg \frac{V_{tb}{}^{\square} V_{td}}{V_{cb}{}^{\square} V_{cd}}$$

$\square + \square + \square = \square$ is still valid!!

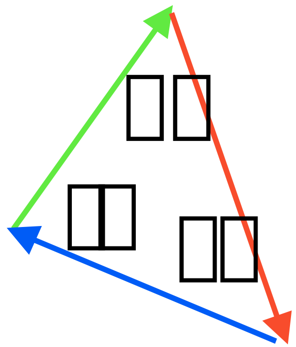
□ This is not a test of unitarity.

CP violation measurements

measure the angles (□ and □):

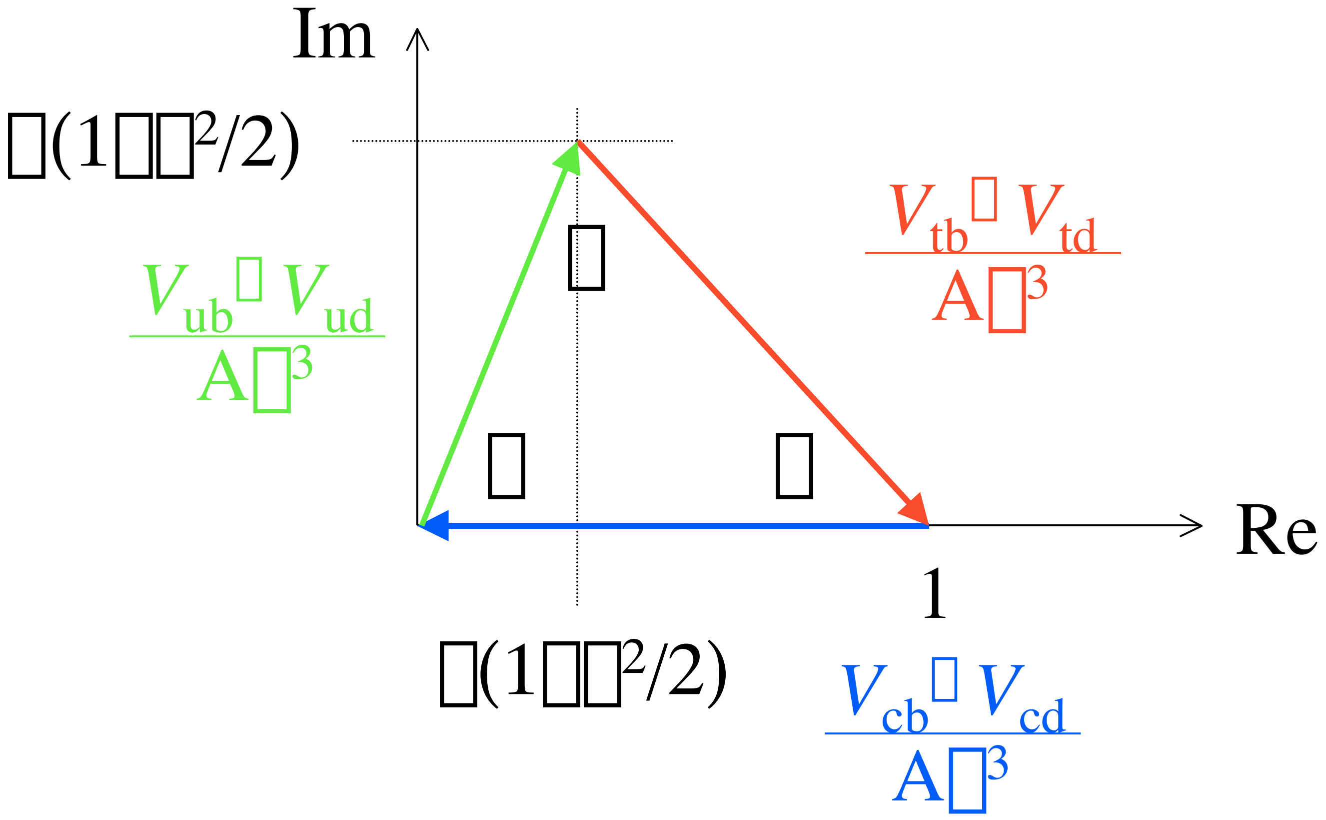


$|V_{cb}|$, $|V_{ub}|$ and $|V_{td}|$ measurements define a triangle:

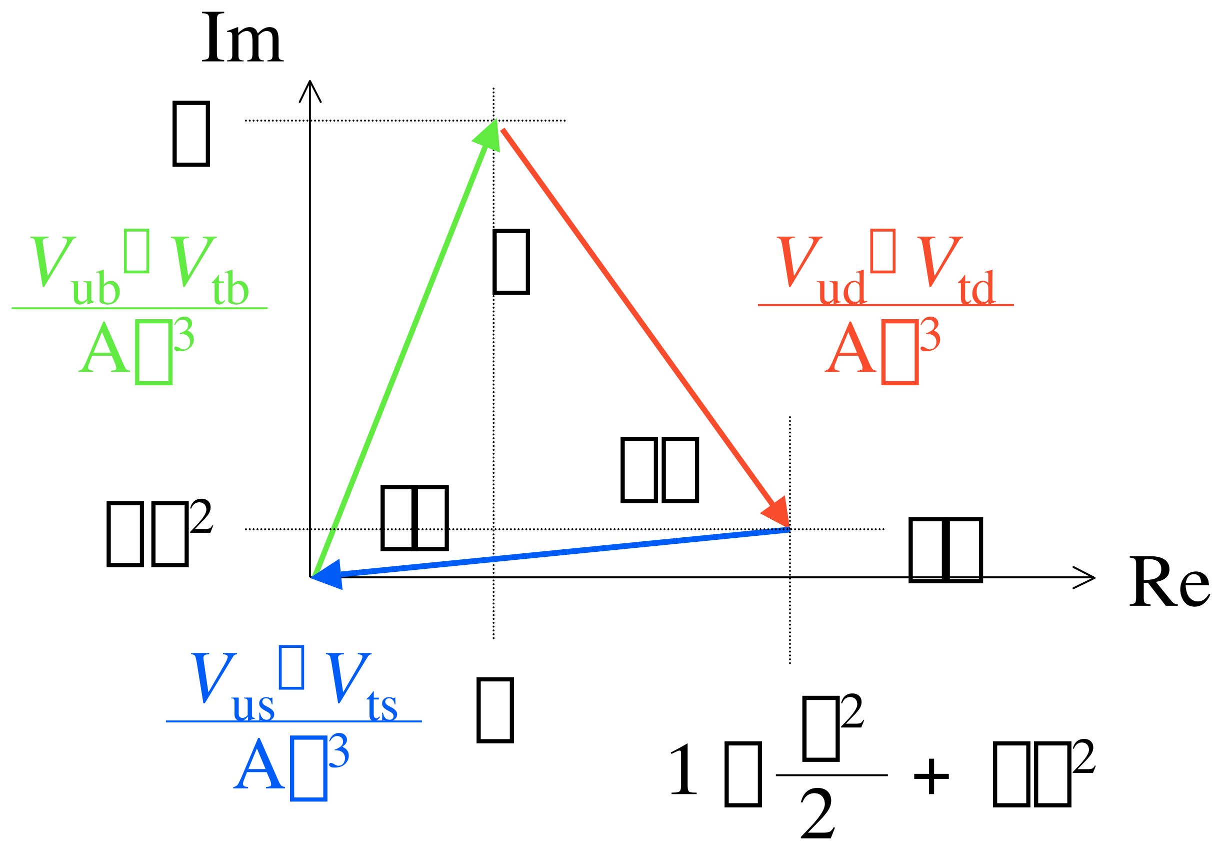


□ ≠ □□, □ ≠ □□

Using the Wolfenstein's parametrization (□, A, □, □)



$$2)\ V_{ud}\square V_{td} + V_{us}\square V_{ts} + V_{ub}\square V_{tb} = 0$$



□□+ □□= □

□□□ □□= □

Important conclusions:

$$\arg V_{td} = \square\square$$
$$\arg V_{ub} = \square\square$$
$$\arg V_{ts} = \square\square + \square$$

$$\square = \tan^{\square 1} \frac{\square}{1 \square \square} \left(1 \square \frac{\square^2}{2(1 \square \square)} \right)$$

$$\square = \tan^{\square 1} \frac{\square}{\square}$$

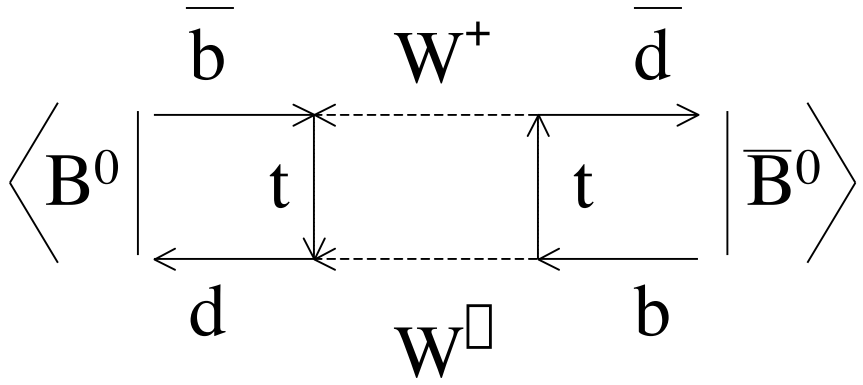
$$\square\square = \square\square^2$$

If we ignore the $\square^2$ correction, 1) and 2) are degenerate.

A must for the next generation experiments!

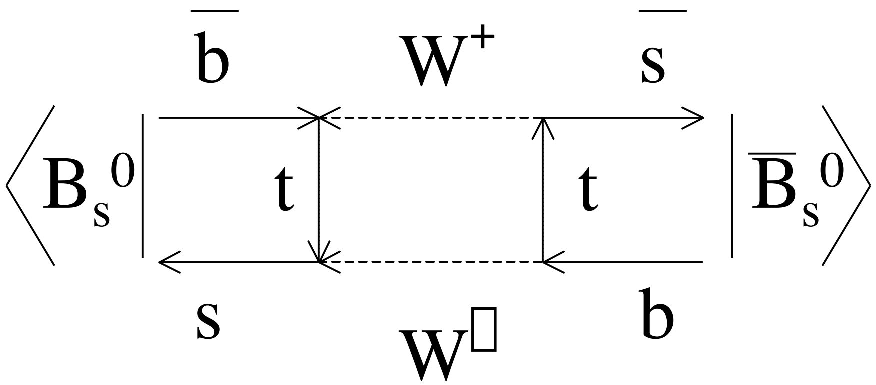
2) □, □, and □□ measurements

B-$\overline{\text{B}}$ oscillation dispersive part: M_{12}



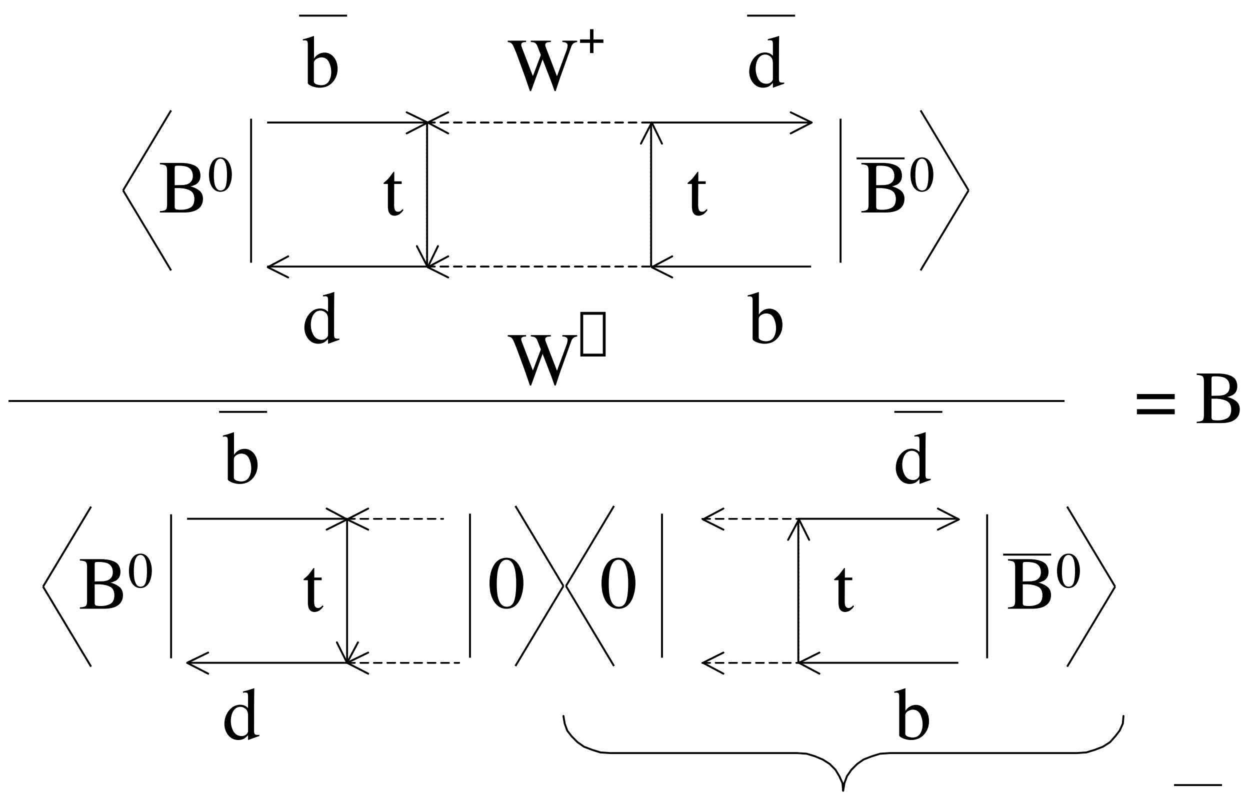
$$\square m = 2|M_{12}| \mu\ B_d f_d^2 |V_{td}|^2 |V_{tb}|^2$$

$$\arg M_{12} = \arg (V_{td}{}^{\square} V_{tb})^2 + \square$$
$$= 2\square + \square$$

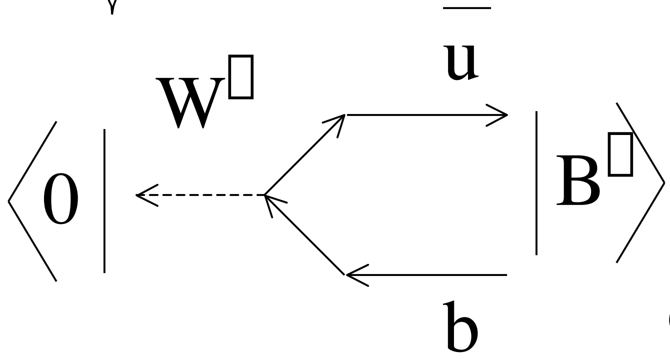


$$\square m_s = 2|M_{12}| \mu\ B_s f_s^2 |V_{ts}|^2 |V_{tb}|^2$$

$$\arg M_{12} = \arg (V_{ts}{}^{\square} V_{tb})^2 + \square$$
$$= \square 2 \square\square + \square$$



vacuum saturation approximation



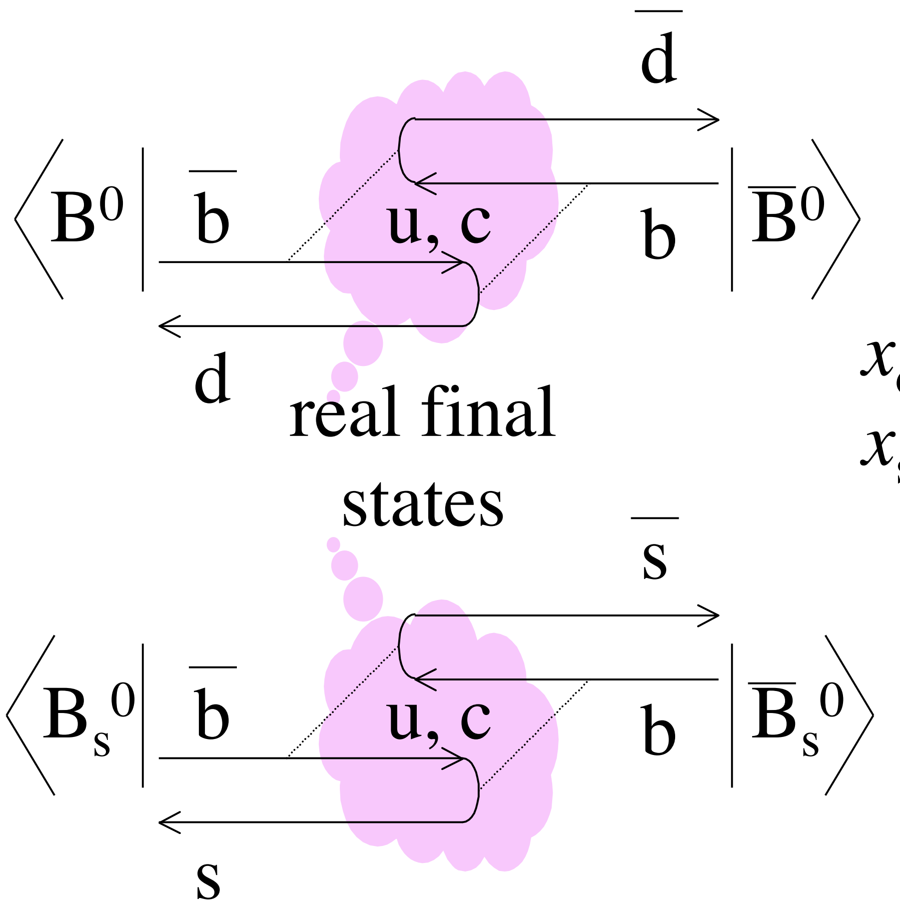
$\propto f_B |V_{ub}|$

decay constant

leptonic decay

$\Gamma_{B \to \ell \nu} \propto f_B^2 |V_{ub}|^2$

B-$\overline{\mathrm{B}}$ oscillation absorptive part: Γ_{12}



$$\Delta\Gamma = 2\,|\Gamma_{12}|$$

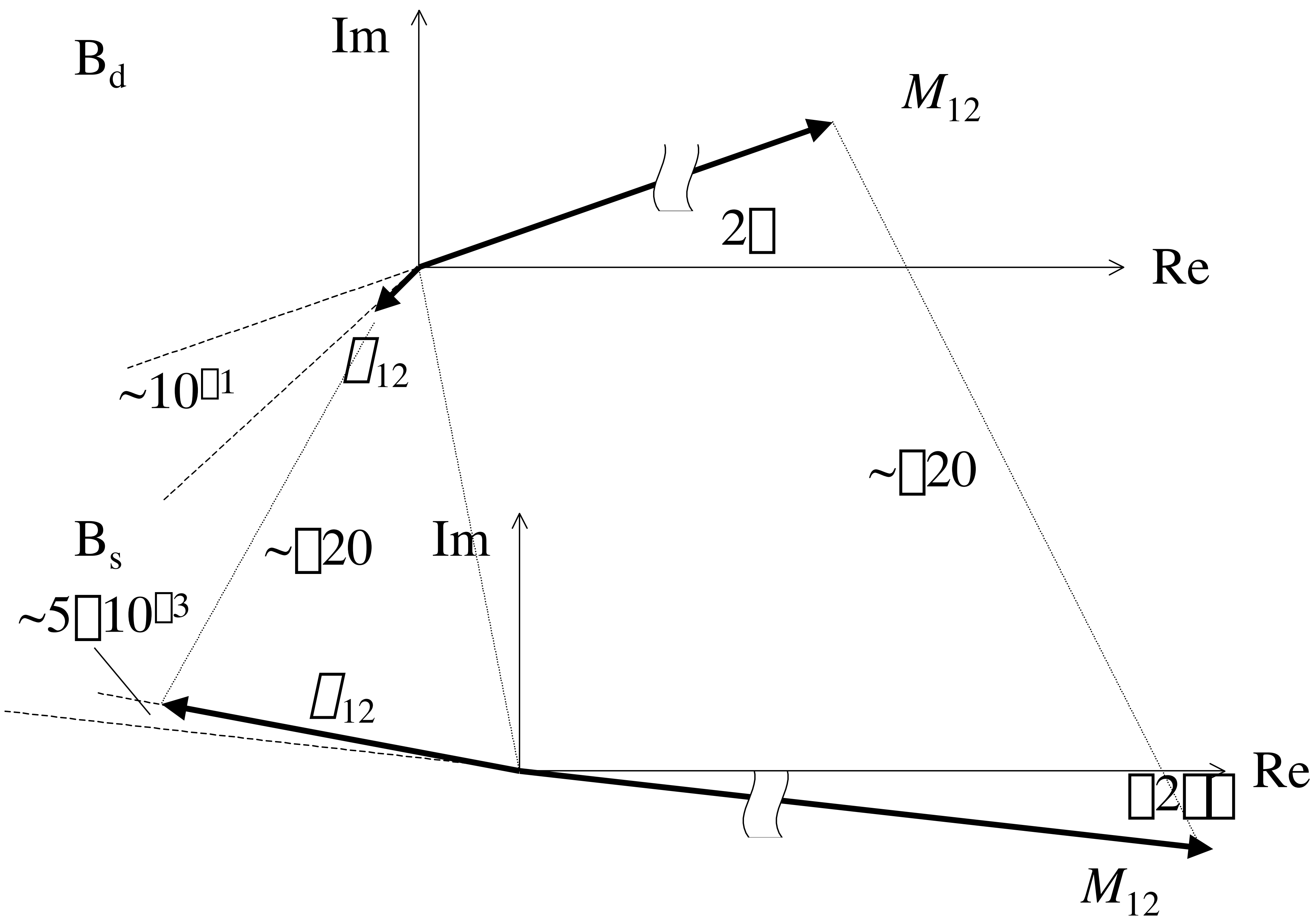
$$\frac{\Delta\Gamma}{\Delta m} = \frac{3\pi m_b^2}{2 m_W^2 S(x_t)} \sim 5\times 10^{-3}$$

$x_d = \Delta m/\Gamma \approx 0.73$ (measurements)

$x_s = 20$ (SM) > 16 (measurements)

$$\frac{\Delta\Gamma}{\Gamma} = \begin{cases} \sim 10^{-3}: B_d \\ \sim 10^{-1}: B_s \end{cases}$$

$$\arg\frac{M_{12}}{\Gamma_{12}} = \pi + \frac{8m_c^2}{3m_b^2}\,\square\square \begin{cases} \dfrac{\square 1}{(1\square\square\square)^2 + \square^2} : B_d & \approx \square\ \square\ 10^{-1} \\ \square^2 : B_s & \approx \pi + 5\times 10^{-3} \end{cases}$$



Im
B_d
M_12
Re
~10
12
~20
B_s
Im
~20
12
Re
M_12

To be more precise…

The mass and decay width differences:

$$m_{\text{heavy}} - m_{\text{light}} \equiv \Delta m = \square 2|M_{12}| \,\square\, \cos\left(\arg M_{12}/\Gamma_{12}\right)$$

$$\Gamma_{\text{heavy}} - \Gamma_{\text{light}} \equiv \Delta\Gamma = 2|\Gamma_{12}| \,\square\, \cos\left(\arg M_{12}/\Gamma_{12}\right)$$

$\sim\square 1$

CP violation in the oscillation:

$$d \equiv \operatorname{Im} \frac{\Gamma_{12}}{M_{12}} = \square \frac{\Delta\Gamma}{\Delta m} \sin\left(\arg M_{12}/\Gamma_{12}\right)$$

5×10^{-3}

$\sim 10^{-1}$ (B_d)

$\sim 5\times 10^{-3}$ (B_s)

$$\frac{\overline{B}_{t=0} \rightarrow B_t - B_{t=0} \rightarrow \overline{B}_t}{\overline{B}_{t=0} \rightarrow B_t + B_{t=0} \rightarrow \overline{B}_t} = 2d < 10^{-3}$$

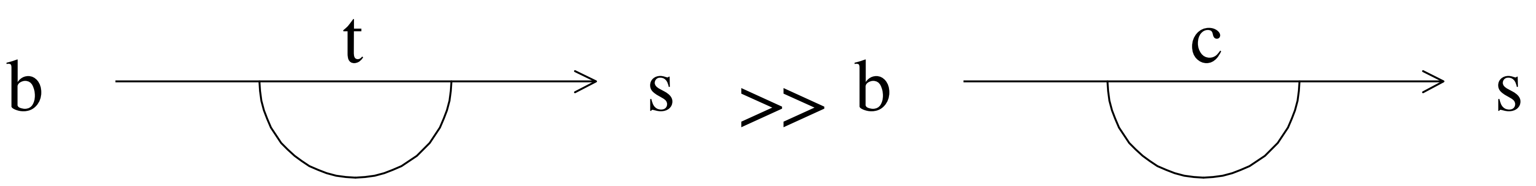
$\overline{B}^0 \longrightarrow \overline{B}^0$ $b \to c + \bar{c}s$: $V_{cb}V_{cs}^* \propto e^{i0}$

$\searrow$ $J/\psi\, K_S$

$M_{12} \propto e^{2i\beta}$ B^0 $\bar{b} \to \bar{c} + c\bar{s}$: $V_{cb}^* V_{cs} \propto e^{i0}$

$\sin 2\beta \times \sin \Delta m t$

NB: penguin contribution



$V_{bt}V_{ts}^* \propto e^{\square i \square\square}$ $V_{bc}V_{cs}^* \propto e^{i0}$

$\frac{\Delta A}{A} \sim \lambda^2 = 0.05 \longrightarrow$ effect should be less than a few %

Theoretically clean.

$\overline{B}^0 \longrightarrow \overline{B}^0$ — $b \to c + \bar{u}d$: $V_{cb}V_{cd}^* \propto e^{i0}$

$\longrightarrow D^{*+}\pi^-$

$\overline{B}^0 \longrightarrow B^0$, $M_{12} \propto e^{2i\beta}$ — $\bar{b} \to \bar{u} + c\bar{d}$: $V_{ub}^* V_{cd} \propto e^{i\gamma}$

$\sin(2\beta+\gamma)\sin\Delta mt$

No other diagram contribute to the process.

NB: strong phase

$b \to c + \bar{u}d$ and $b \to u + \bar{c}d$

may have a strong phase difference δ!

$\overline{B}^0 \to D^{*+}\pi^-$ and $\overline{B}^0 \to D^{*-}\pi^+$

$2\beta+\gamma+\delta$ and $2\beta+\gamma-\delta$

Strong phase difference can be measured.

Theoretically VERY clean measurement.

$\overline{B}_s^0 \longrightarrow \overline{B}_s^0$ $b □ c + \bar{c}s$: $V_{cb}V_{cs}^{□} \mu\; e^{i0}$

$\overline{B}_s^0 \longrightarrow B_s^0$ $\longrightarrow$ J/□ □(□)

$M_{12}\ \mu\ e^{□2i□□}$ $\bar{b} □ \bar{c} + c\bar{s}$: $V_{cb}^{□}V_{cs}\ \mu\ e^{i0}$

$\sin 2□□ □ \sin □mt$

CP(J/□) = +1, CP(□) = +1

CP(J/□ □) = $(□1)^{L_{J/□\text{-}□}}$

$S = S_{J/□} + S_{□}$: 0, 1, 2, $J = S + L = 0$

$L_{J/□\text{-}□} = 0, 1$ or 2

□ fraction of $L_{J/□\text{-}□} = 1$ needed: angular analysis

CP(J/□) = +1, CP(□) = □1

CP(J/□ □) = $□(□1)^{L_{J/□\text{-}□0}} = +1$

$\overline{B}_s^0$ $\overline{B}_s^0$ b □ $c+\bar{u}s$: $V_{cb}V_{us}^{□}$ μ e^{i0}

$D_S^+ K^{□}$

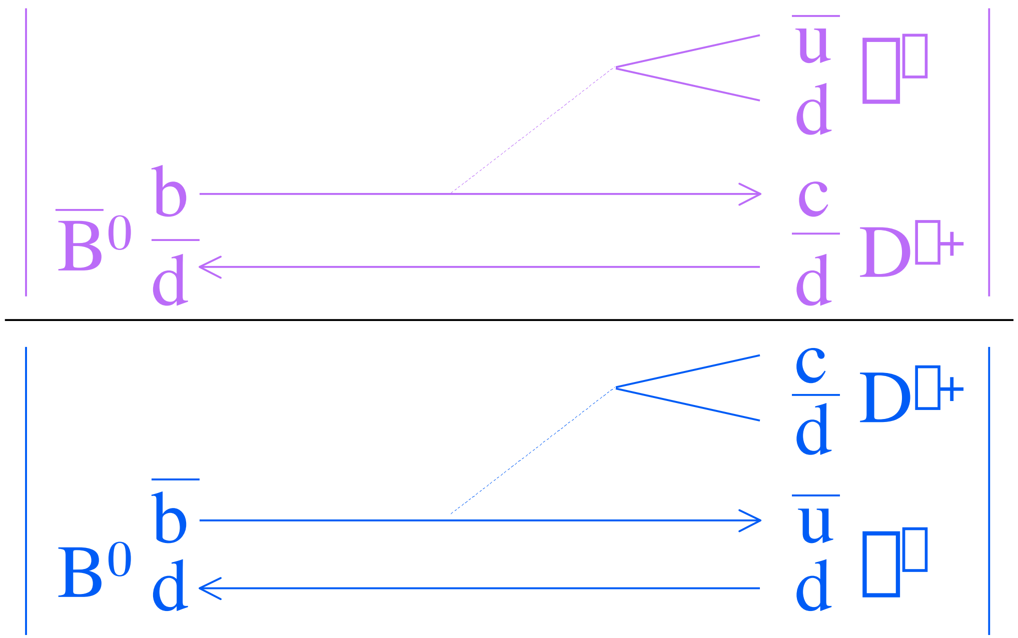
M_{12} μ $e^{□2i□□}$ B_s^0 $\bar{b}$ □ $\bar{u}+c\bar{s}$: $V_{ub}^{□}V_{cs}$ μ $e^{i□}$

sin 2□□□□ □ sin □*mt*

Strong phase: same as the B_d □ D□□ case,
i.e. measurable!

☺ □□/□ □0.1 □ cos 2□□□□ □ sinh □□*t* measurable.

Theoretically VERY clean measurement.

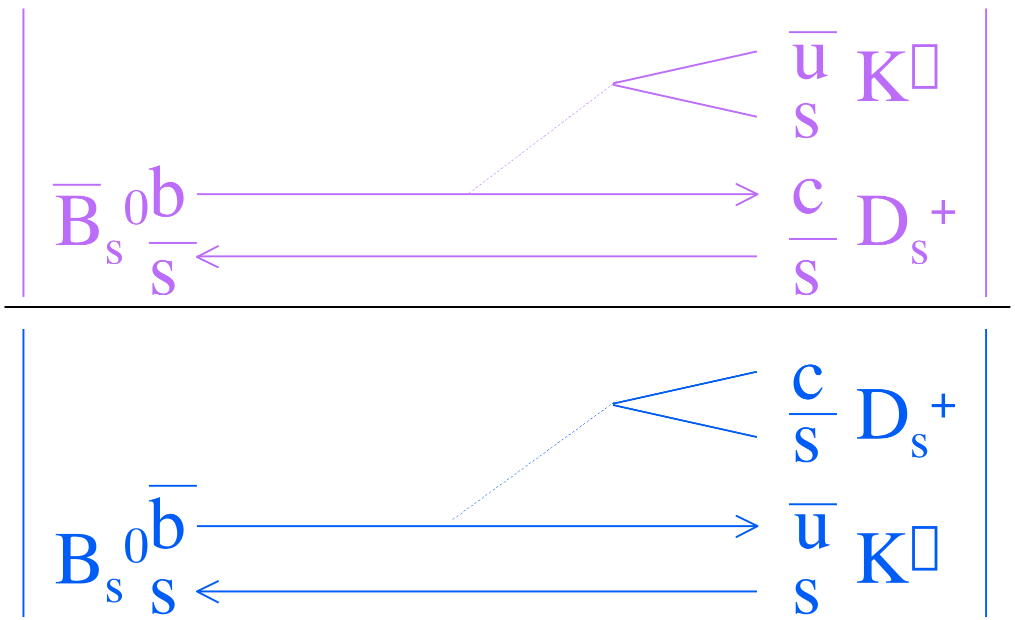


$B_d \to D^{\mp}\pi^{\pm}$

$\sim \dfrac{A\lambda^2}{A\lambda^4\sqrt{\rho^2+\eta^2}} \sim 1/0.02$

small interference term ☹

$\dfrac{\Delta m}{\Gamma} \sim 1$ ☺



$B_s \to D_s K$

$\sim \dfrac{A\lambda^3}{A\lambda^3\sqrt{\rho^2+\eta^2}} \sim 0.4$

large interference term ☺

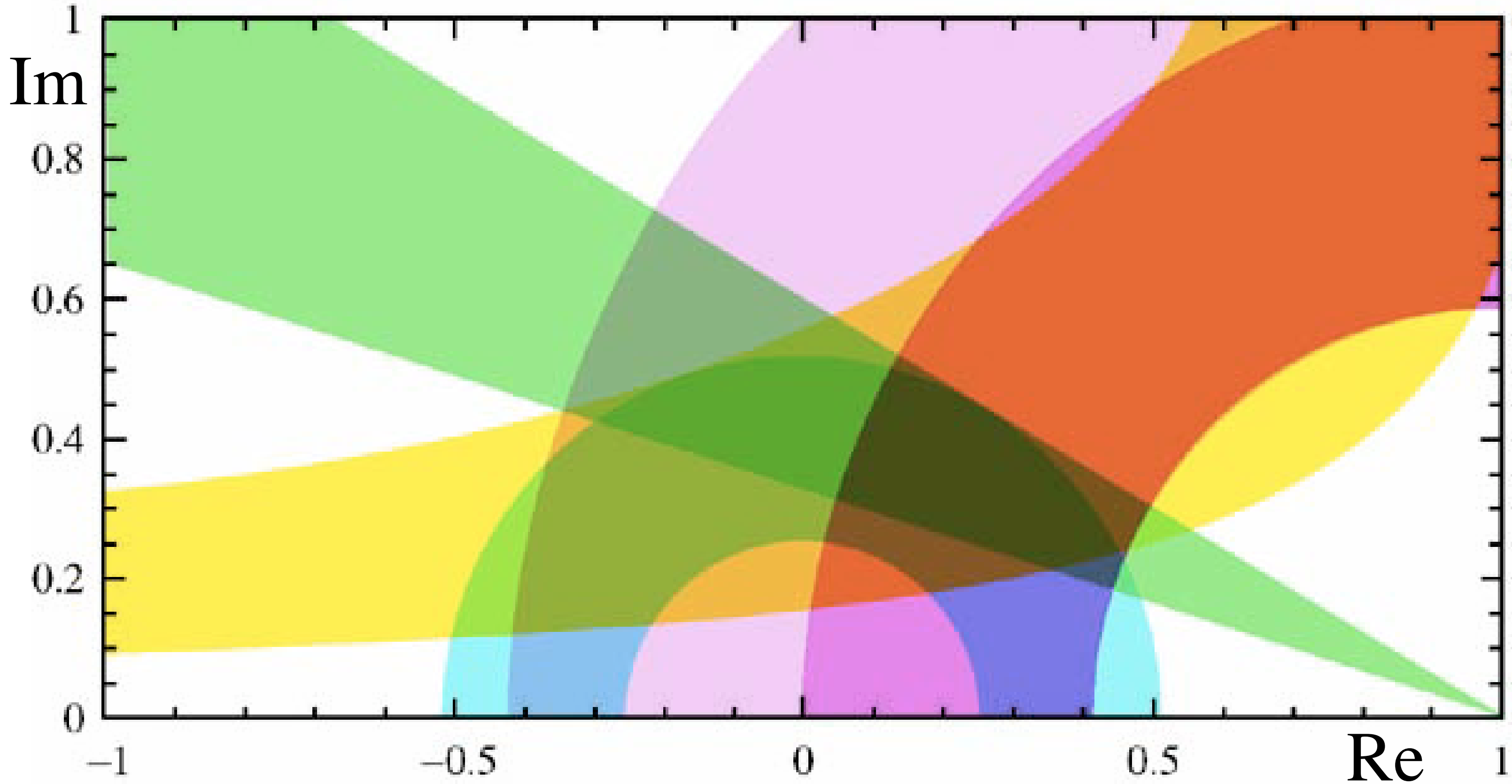
$\dfrac{\Delta m}{\Gamma} \sim 20$ ☹

3) CP landscape

CKM constraints now

+ limit on

$|V_{ub}/V_{cb}|$ □$m(B_d)$ □$m(B_s)$ □(K) sin 2□



Perfectly consistent within the statistics!

CKM fit without sin 2β measurements

$\rho=0.23\pm0.?$, $\eta=0.33\pm0.?$ "?" is somewhat "theological"

$\sin 2\beta =$	$0.50 - 0.86$ CL > 32%	A.Höcker et al.
	0.698 ± 0.066	A.Stocchi et al.

$\beta = 23.2°$ without λ^2 correction, $22.5°$ with λ^2 correction

sin 2β differs by 0.02

Kaon system:

$|\varepsilon| = (2.271 \pm 0.017) 10^{-3}$

known to better than 1%

theoretical uncertainties ~10%

$\mathrm{Re}(\varepsilon'/\varepsilon) = (17.3 \pm 2.3) \times 10^{-4}$

known to 13%

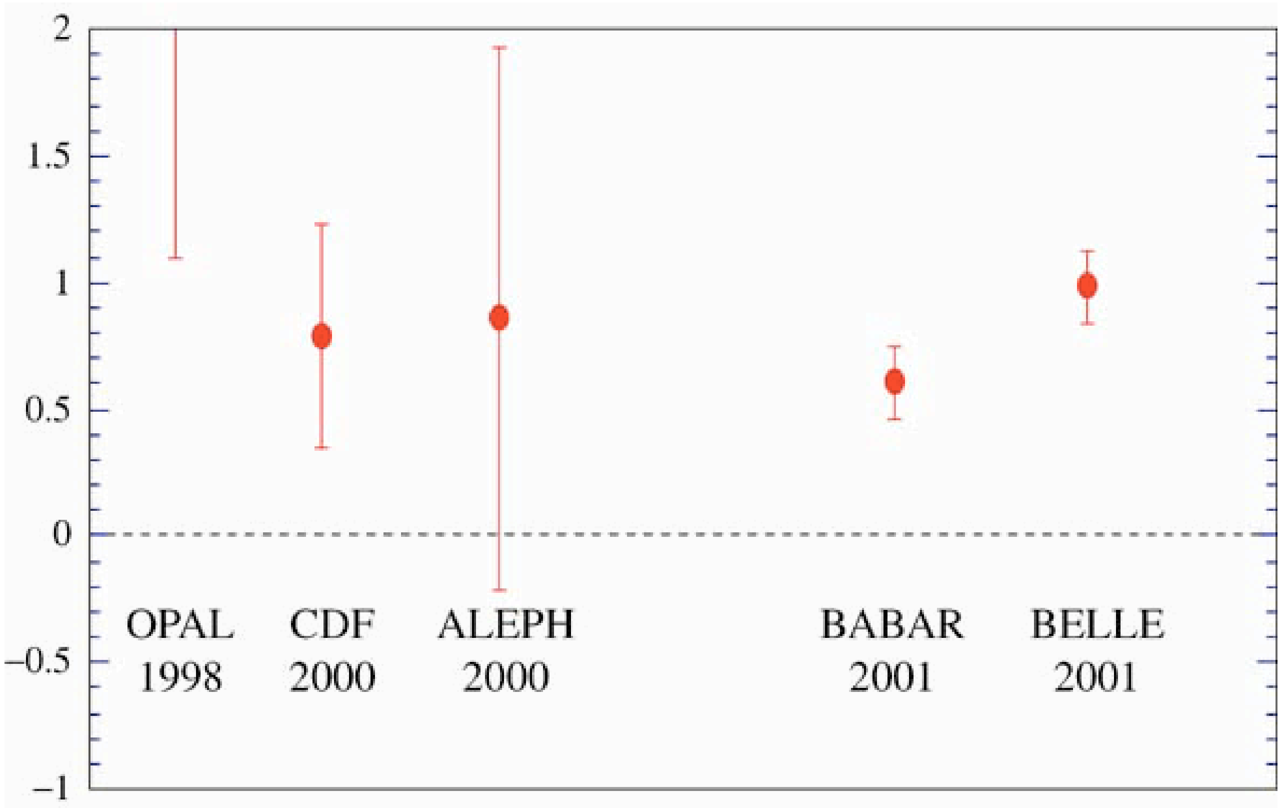
theoretical uncertainties >100%

$\Rightarrow$ No precision test is possible

B-meson system: sin 2β

OPAL (1998)	$= 3.2^{+1.9}_{-2.1}$
CDF (2000)	$= 0.79^{+0.41}_{-0.44}$
ALEPH (2000)	$= 0.84^{+0.84}_{-1.05}$
BABAR (2001)	$= 0.59 \pm 0.15$
BELLE (2001)	$= 0.99 \pm 0.15$

BABAR and BELLE combined: 0.79 ± 0.17: $\chi^2 = 3.56$ (error scaled)



Major improvements expected…

Theory:

A better understanding of $Bf_B^{2} \propto |V_{td}/V_{cb}|^2$ from $\Delta m(B_d)$

$$\sqrt{(1-\rho)^2+\eta^2}$$

Theory and more data

A better understanding of $b \to u, c + \ell\nu$ decays: $|V_{ub}/V_{cb}|$

$$\sqrt{\rho^2+\eta^2}$$

More data

An order of magnitude smaller error on sin 2β:

before hitting the penguin pollution

$\sqrt{(1-\rho)^2+\eta^2}$ from the $\Delta m(B_d)/\Delta m(B_s)$ measurement

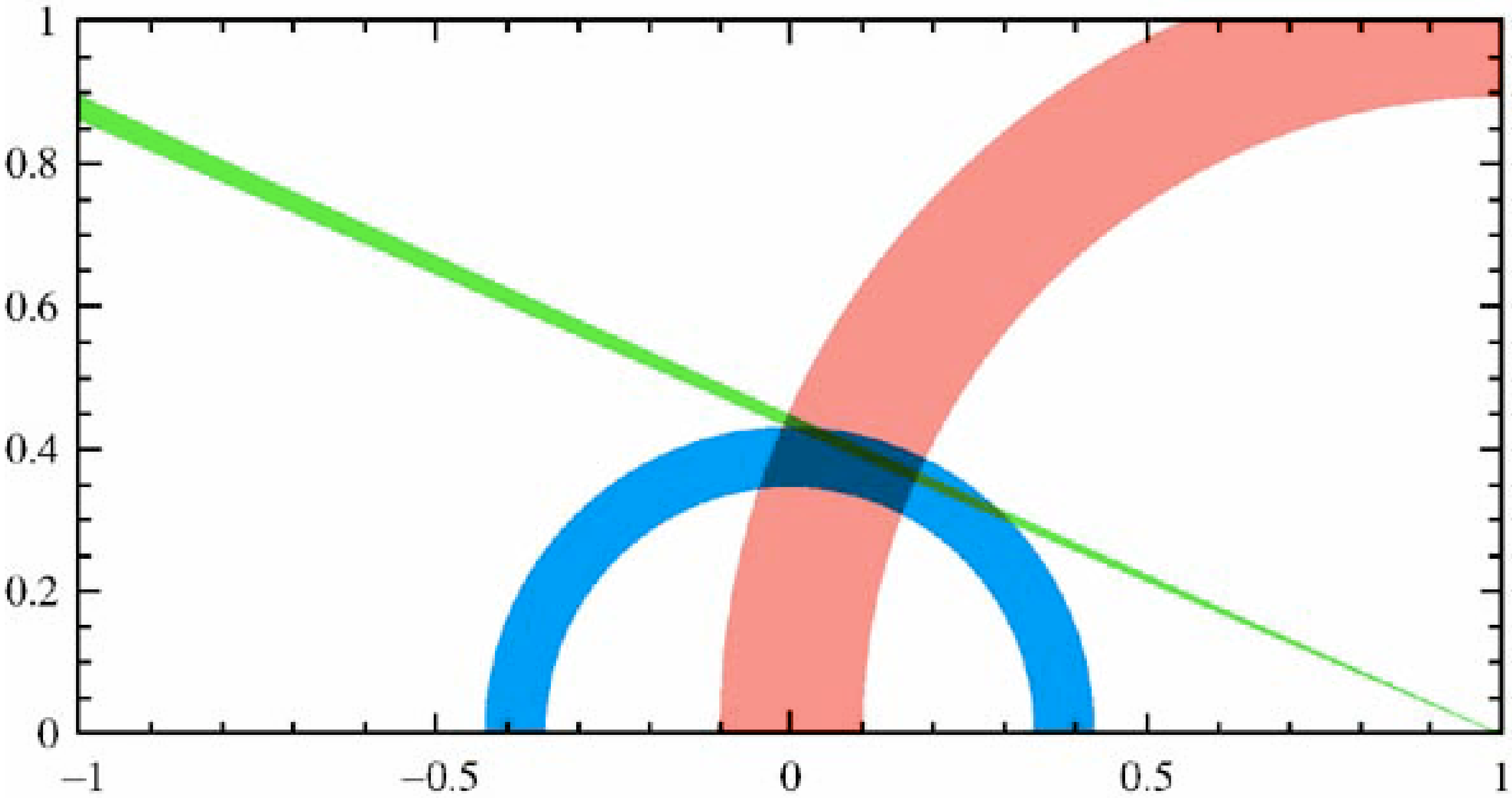
2001

~2007

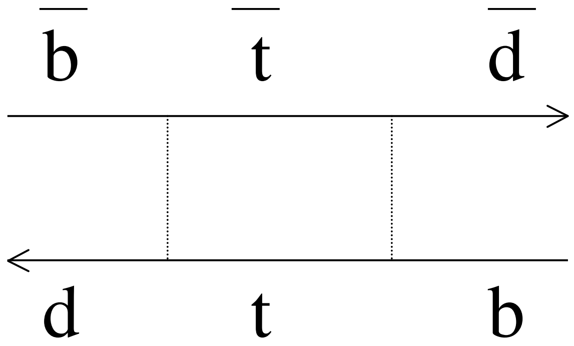
$\sqrt{□^2 + □^2}$: improved by a factor of 3

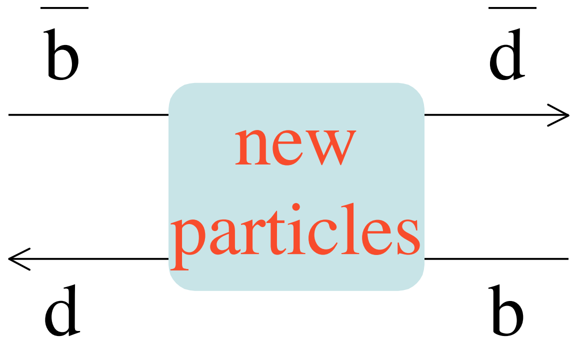
$\sqrt{(1\ □\ □)^2 + □^2}$: improved by a factor of 4

sin 2□: ±0.01



4) Possible effect of new physics





$$M_{12} = M_{12}^{SM} + M_{12}^{NP}$$

$$\Delta m \not\Leftrightarrow |V_{td}|^2$$

$$\arg M_{12} = 2\beta + \phi_{bd}^{NP}$$

CP asymmetry in $B_d \to J/\psi\, K_S \not\Leftrightarrow \sin 2\beta$

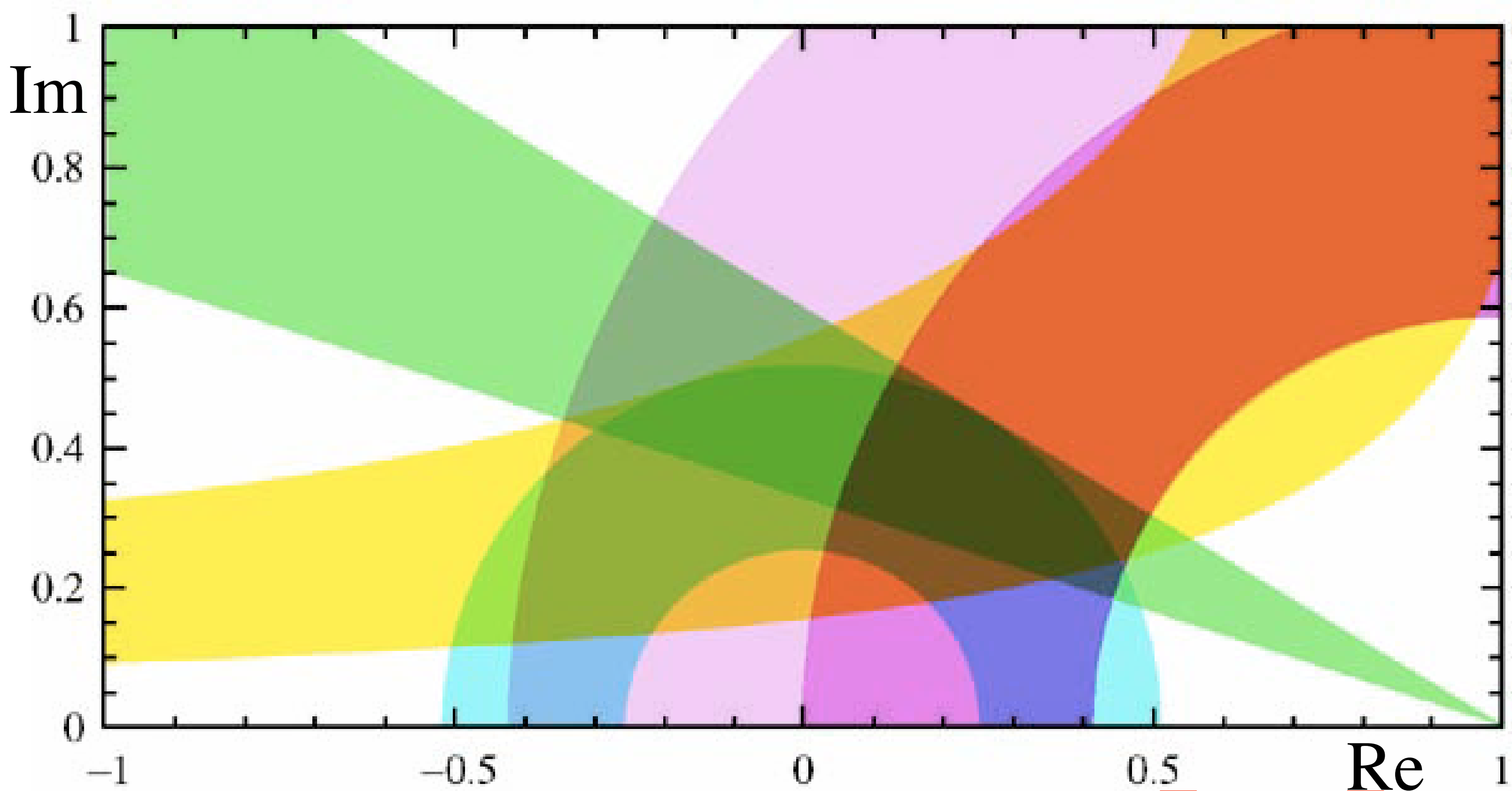
CP asymmetry in B_d □ J/□ K_S ↔ (crossed out) sin 2□

New physics in K-$\bar{K}$ oscillation

□m ↔ (crossed out) $|V_{td}|^2$

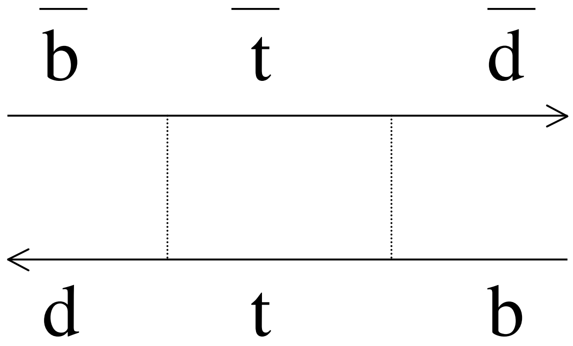
+ limit on

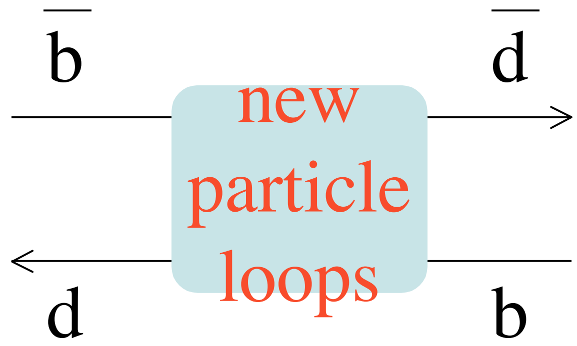
$|V_{ub}/V_{cb}|$ □$m(B_d)$ □$m(B_s)$ □(K) sin 2□



Not enough constraint to determine □ and □.

B_d





$$\arg M_{12} = 2\square + \square_{bd}^{NP}$$

CP asymmetry in B_d □ $J/\square\ K_S$ ⟺ $\sin(2\square + \square_{bd}^{NP})$

CP asymmetry in B_d □ $D^{\square}\ \square$ ⟺ $\sin(2\square + \square + \square_{bd}^{NP})$

B_s

$$\arg M_{12} = 2\square\square + \square_{bs}^{NP}$$

CP asymmetry in B_s □ $J/\square\ \square$ ⟺ $\sin(2\square\square + \square_{bs}^{NP})$

CP asymmetry in B_s □ $D_s\ K$ ⟺ $\sin(2\square\square + \square + \square_{bs}^{NP})$

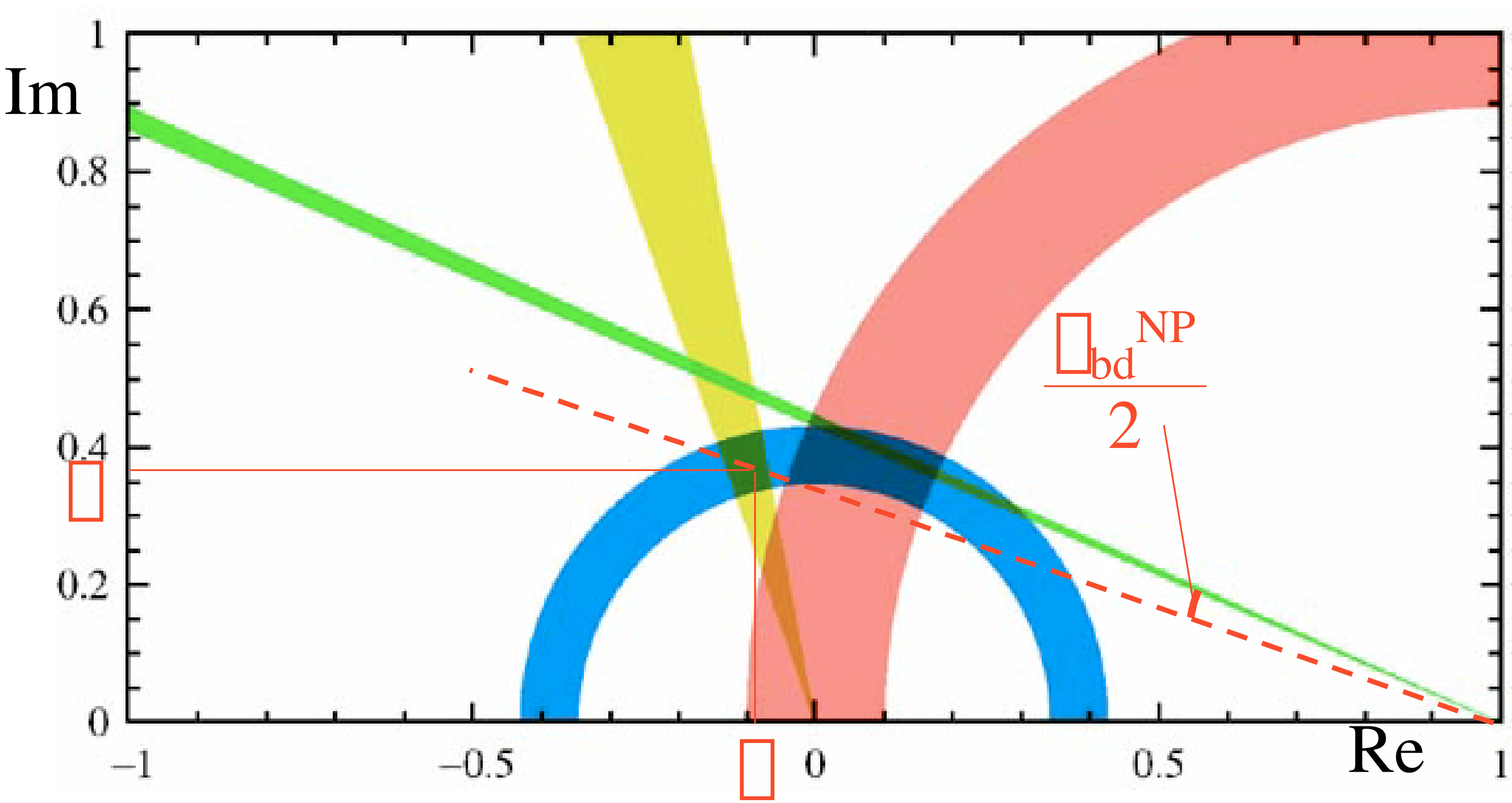
□ □ can be determined!

~2007 clean measurements

BABAR, BELLE: $|V_{cb}|$, $|V_{ub}|$, Δm_d, sin 2β,

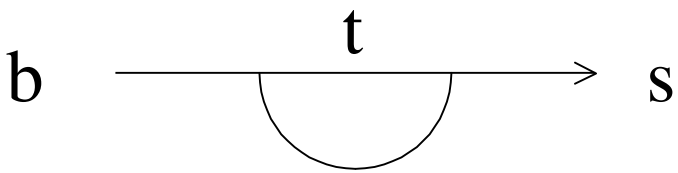
CDF (D0): Δm_s, sin 2β,

Clean measurements of γ: ±5°

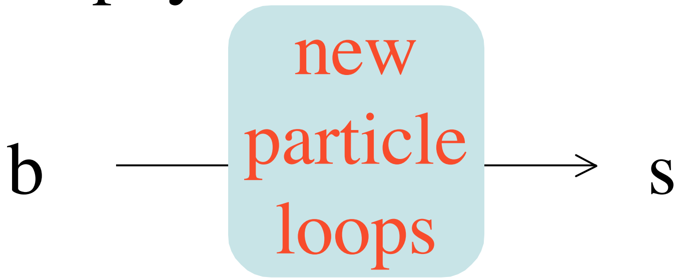


Dedicated B experiments at LHC (and Tevatron)!!!

Penguin could be affected by new physics?

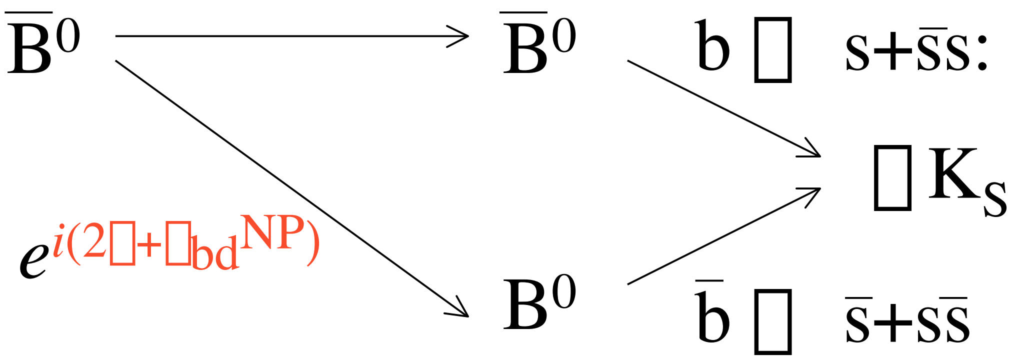


$V_{bt}V_{ts}^{\square}$ μ $e^{\square i \square\square}$



A_{bs}^{NP} μ $e^{\square i \square_{pbs}^{NP}}$

$B_d \square \; \square K_s$



M_{12} μ $e^{i(2\square+\square_{bd}^{NP})}$

sin ? □ sin □*mt*

$B_s \square \; \square\square$ as well

Future experiments need to have:

High statistics B_d and B_s.

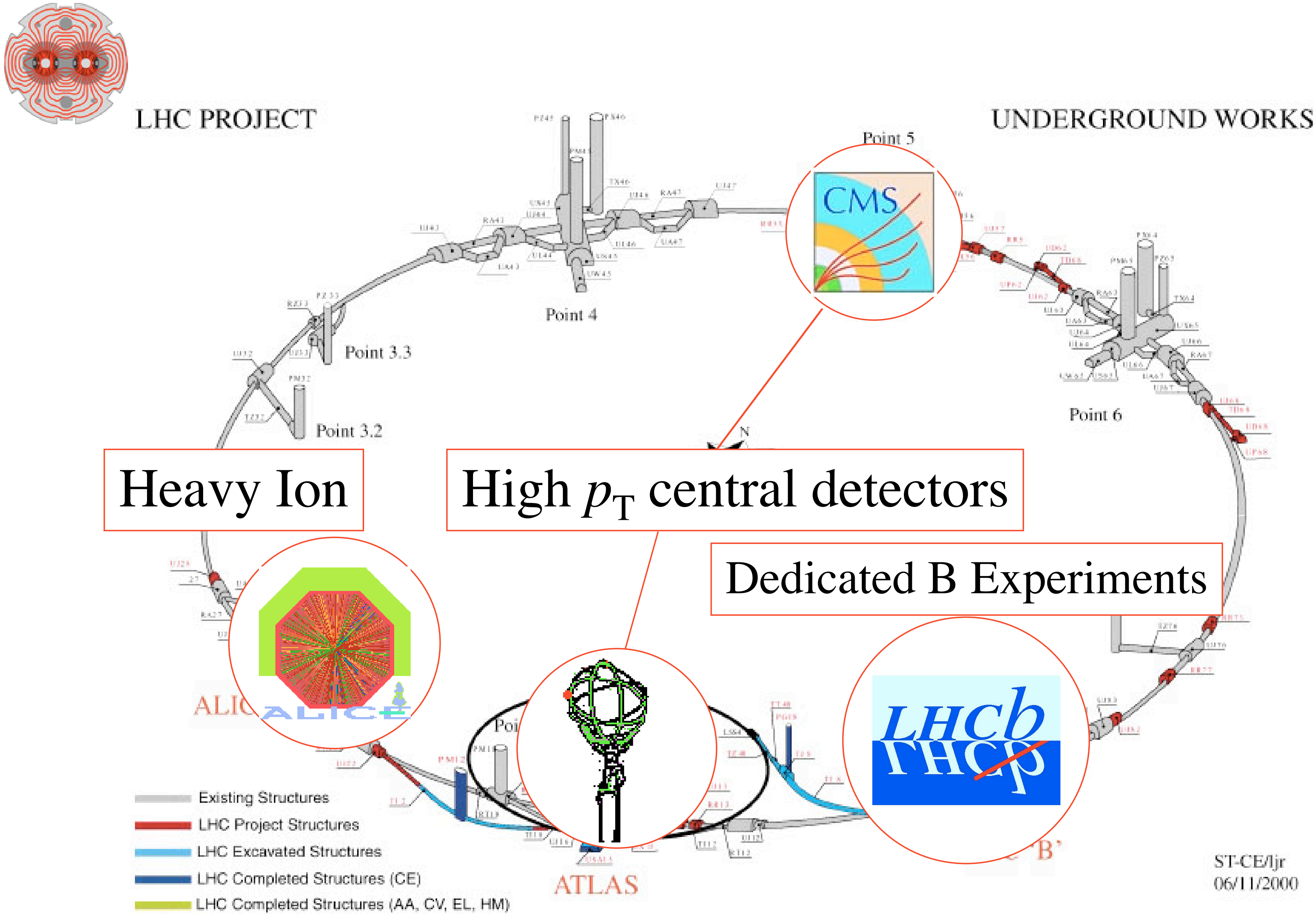
Trigger sensitive to the final state with leptons
and with only hadrons.

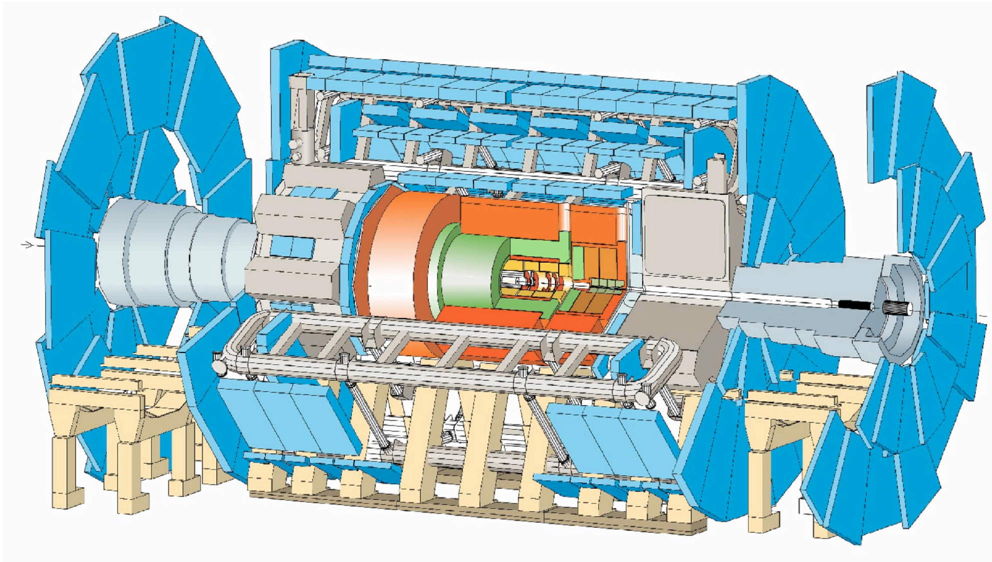
Good proper time resolution for measuring the CP violating
oscillation amplitudes of the B_s meson.

Good □/K/□/e separation to reduce the background from
both combinatorics and other B meson decays.
-kaon identification also useful for the flavour tag-

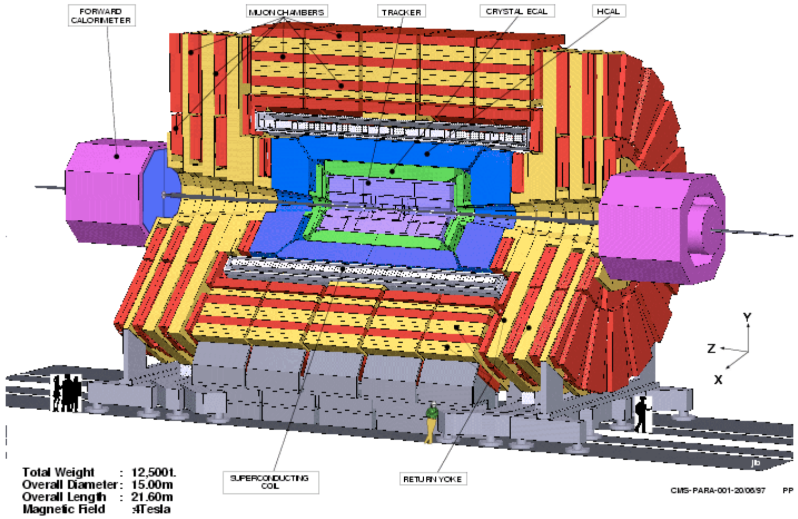
Good momentum and vertex resolutions
to reduce background.

5) LHC experimental conditions

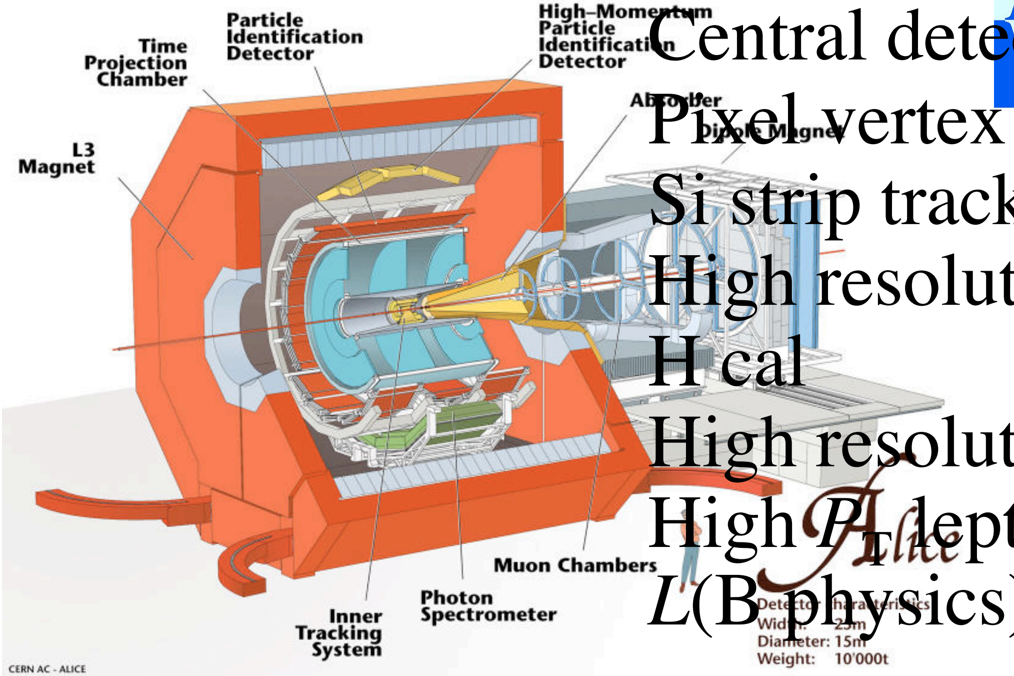

LHC PROJECT
UNDERGROUND WORKS
Point 5
CMS
Point 4
Point 3.3
Point 3.2
Point 6
Heavy Ion
High p_T central detectors
Dedicated B Experiments
ALICE
ATLAS
LHCb
Existing Structures
LHC Project Structures
LHC Excavated Structures
LHC Completed Structures (CE)
LHC Completed Structures (AA, CV, EL, HM)
ST-CE/ljr
06/11/2000

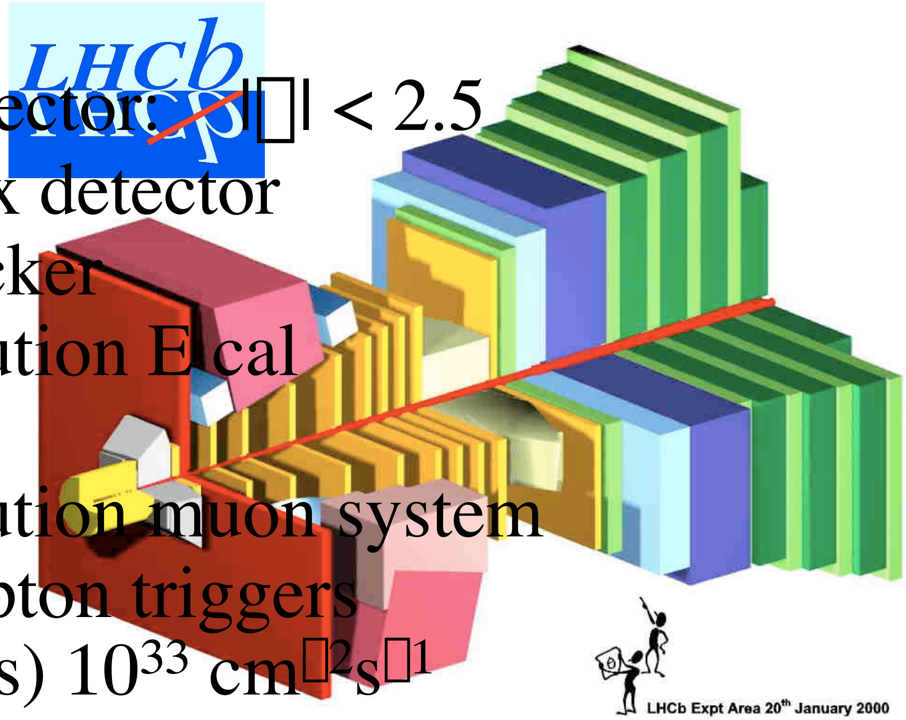


ATLAS



CMS





- Central detector: $|\eta| < 2.5$
- Pixel vertex detector
- Si strip tracker
- High resolution E cal
- H cal
- High resolution muon system
- High P_T lepton triggers
- L(B physics) 10^{33} cm^{-2}s^{-1}

LHC will become operational in ~2006

with a starting luminosity of 10^{32} to 10^{33} $cm^{-2}s^{-1}$

(design luminosity > 10^{34} $cm^{-2}s^{-1}$)

$\sigma_{b\bar{b}}$ expected in pp collisions at $\sqrt{s}$ = 14 TeV: 500 μb

5×10^{11} to 5×10^{12} $b\bar{b}$ pairs in 1 year (10^7 s)

$\Rightarrow$ powerful source of b quarks!

cf.

Υ(4S) B factories: 10^7 B-$\bar{B}$/year @ $L = 10^{33}$ $cm^{-2}s^{-1}$

LHC could have a big potential for B physics.

However not too easy experimental environment…

$$\frac{\sigma_{b\bar{b}}}{\sigma_{inelastic}} = 5\times10^{-3}$$

cf

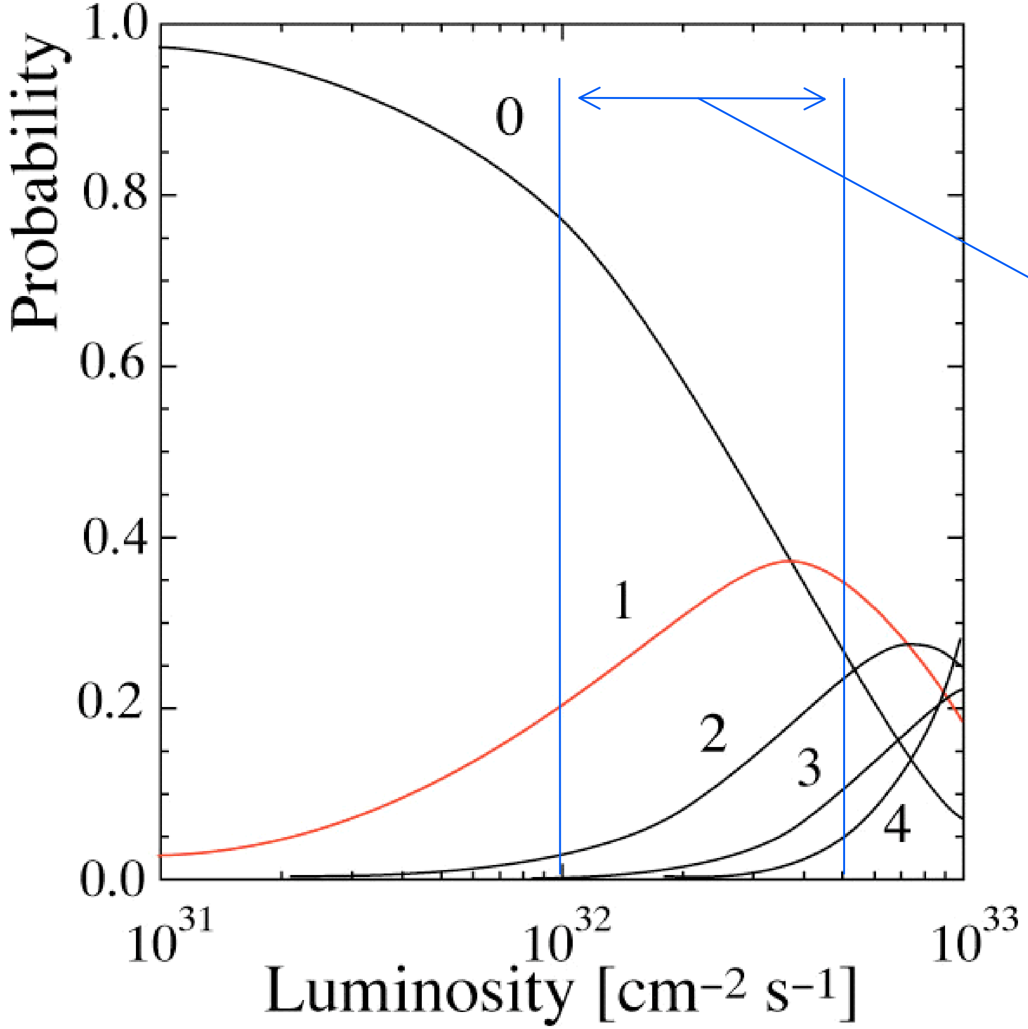
Υ(4S) B factories: 0.2

HERA-B 10^{-6}

Fixed target charm experiments $\frac{\sigma_{c\bar{c}}}{\sigma_{inelastic}} \approx 10^{-3}$

Bunch crossing frequency: f_{pp} = 40 MHz, i.e. every 25 nsec

Number of $p\bar{p}$ inelastic interactions in one bunch crossing ($\sigma_{inelastic}$ = 80 mb), 0, 1, 2 …

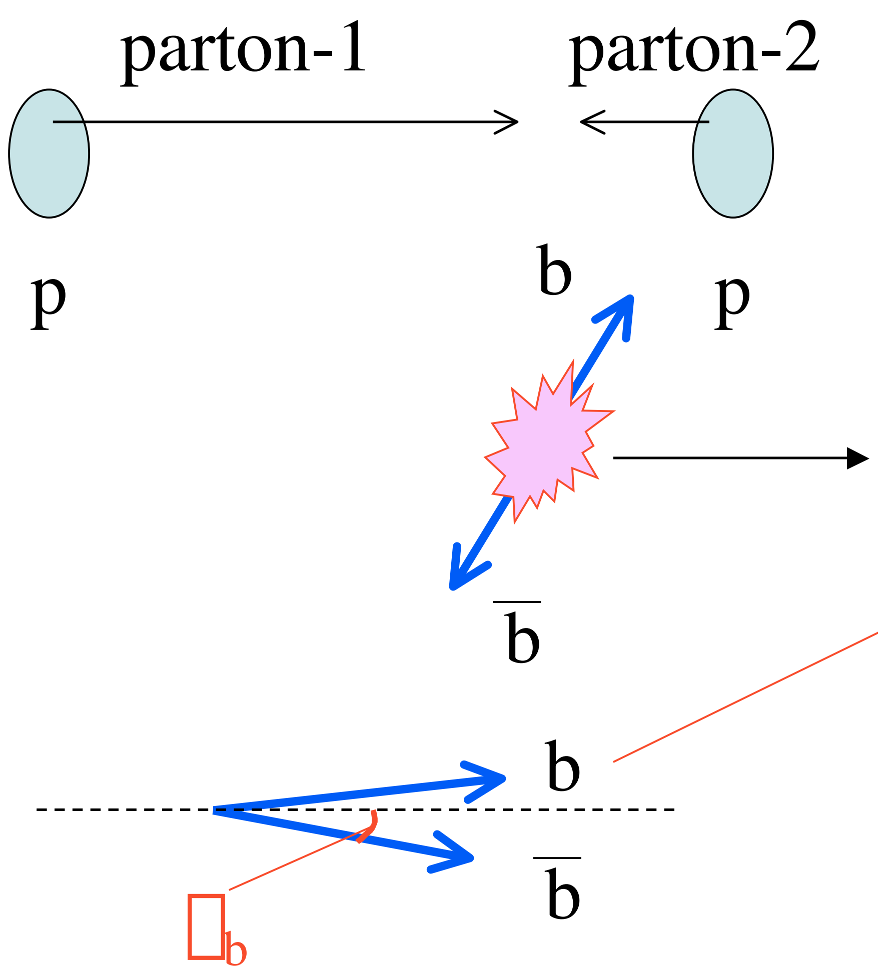


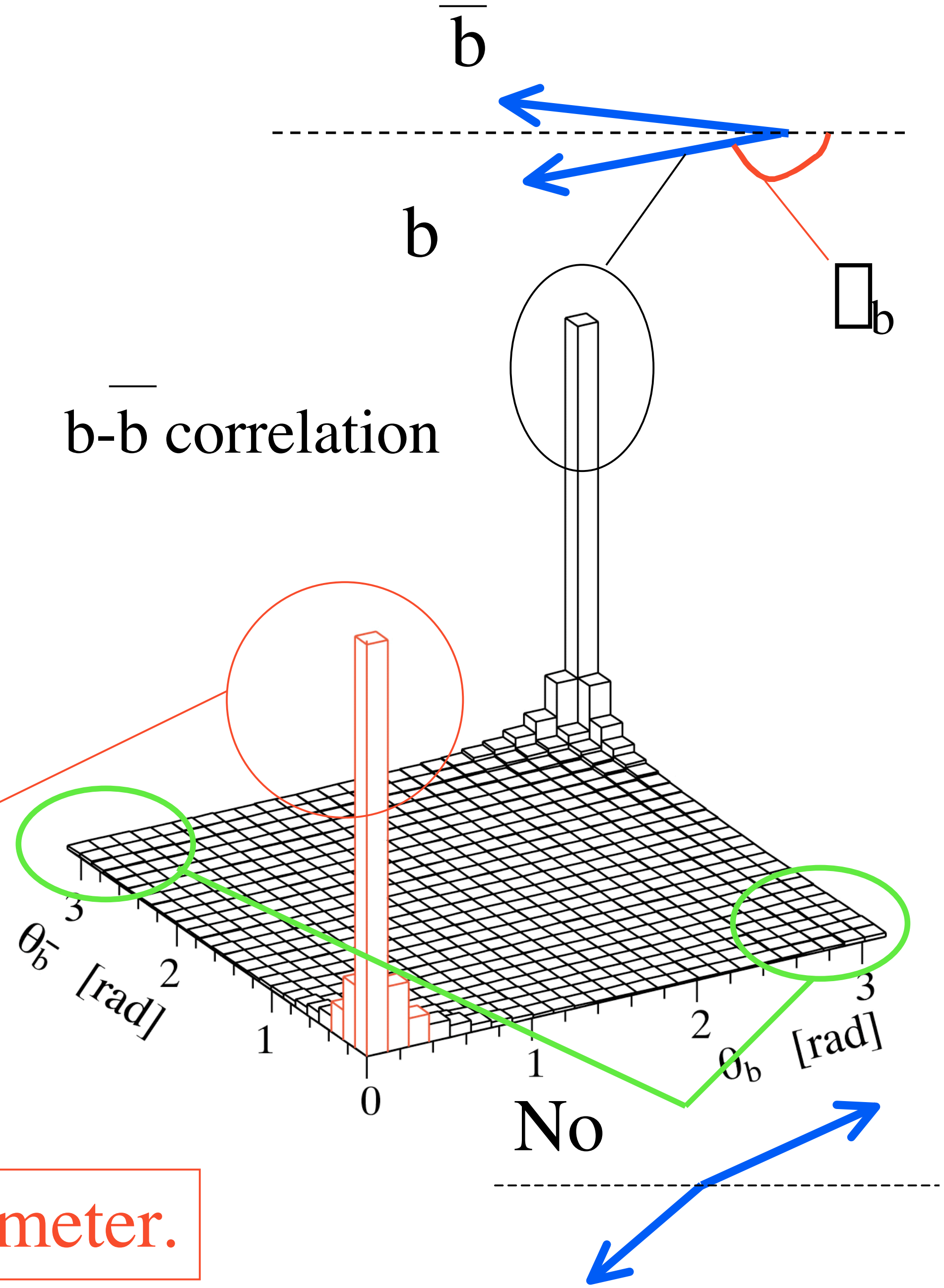
One inelastic interaction per bunch crossing dominates.

- Reconstruction easier (final state and tag)
- Lower radiation level

LHCb experiment: forward spectrometer (10-300 mrad)

$b\bar{b}$ pair production kinematics

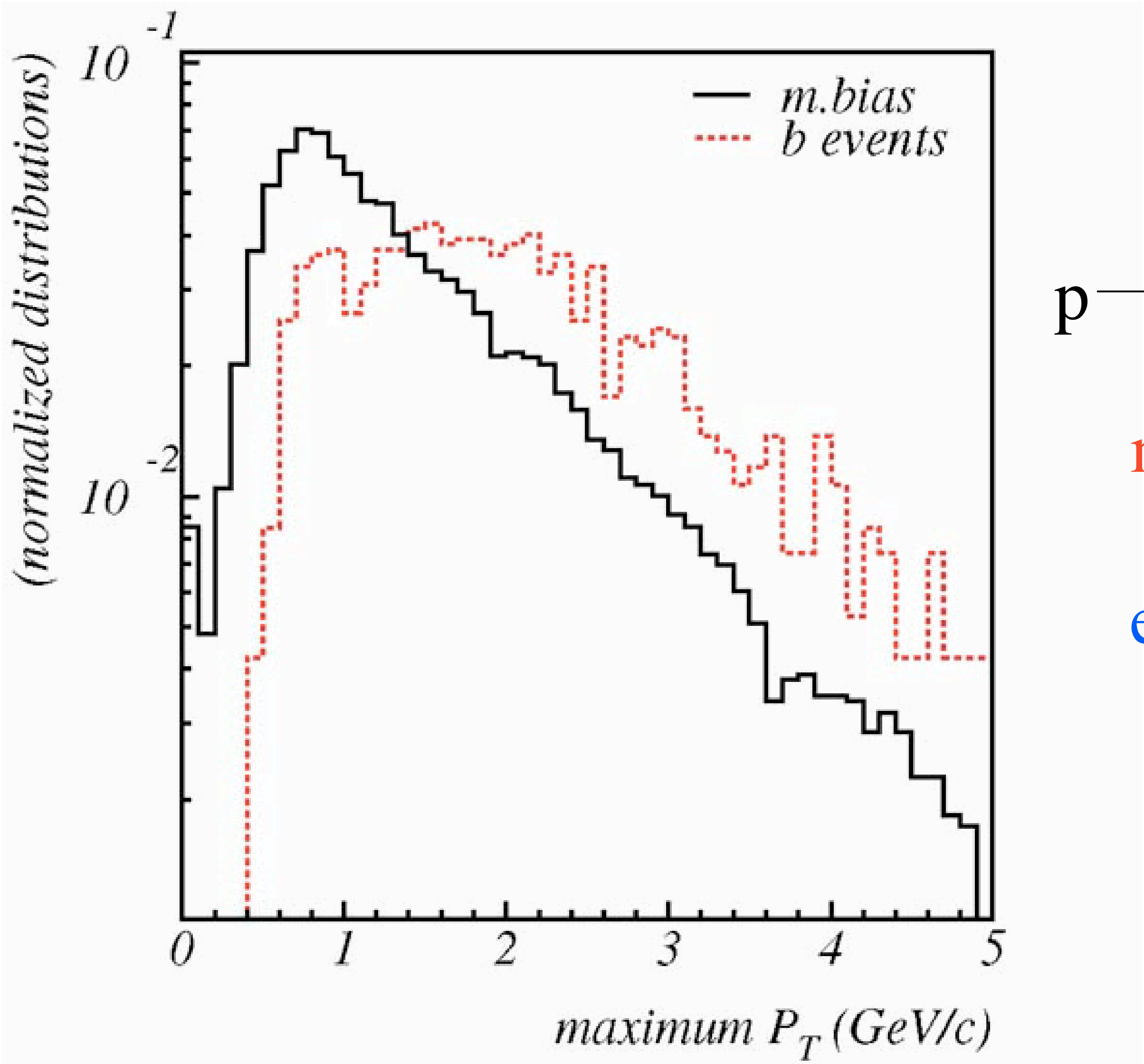


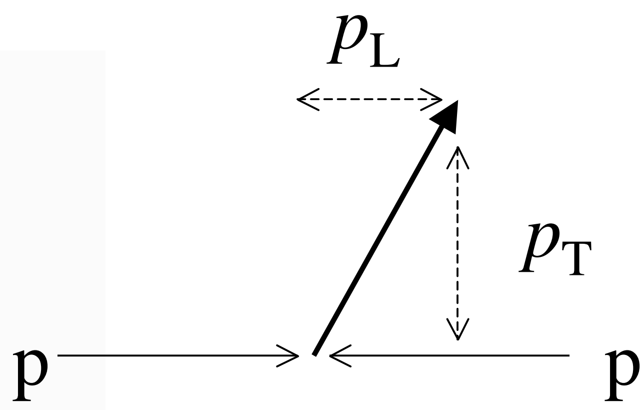


Both b and b̄ are in the spectrometer.

f_{pp} @ LHC = 40 MHz □ simple first level trigger

Single p_T trigger for □, e, h



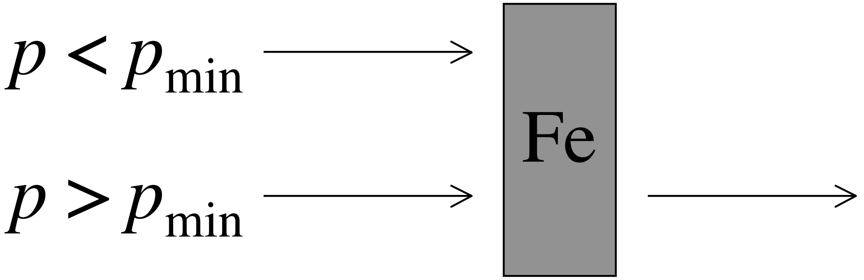


muon system:
low track density

e and h:
calorimeter
E_T measurements

However…. $p > p_{min}$

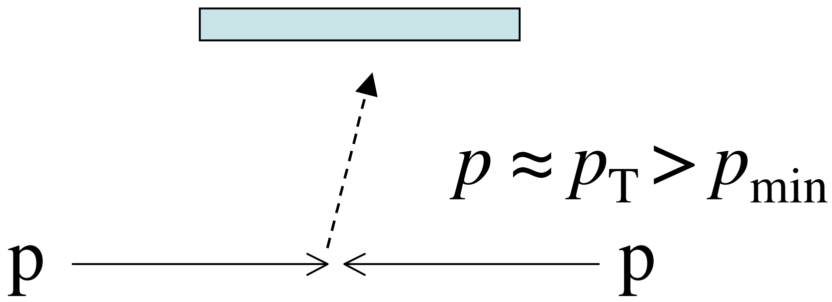
muon:
identification



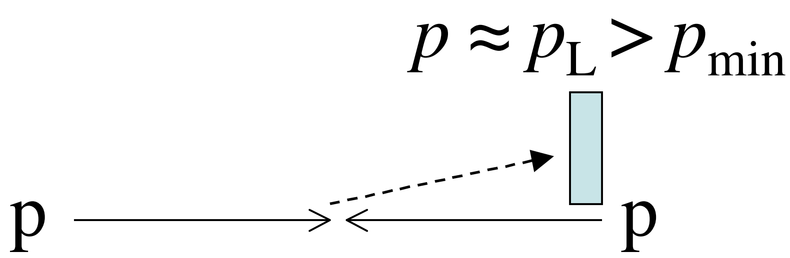
hadron:
energy resolution

$\sigma_E/E \approx \sqrt{70\%}/\sqrt{E}$

central detector

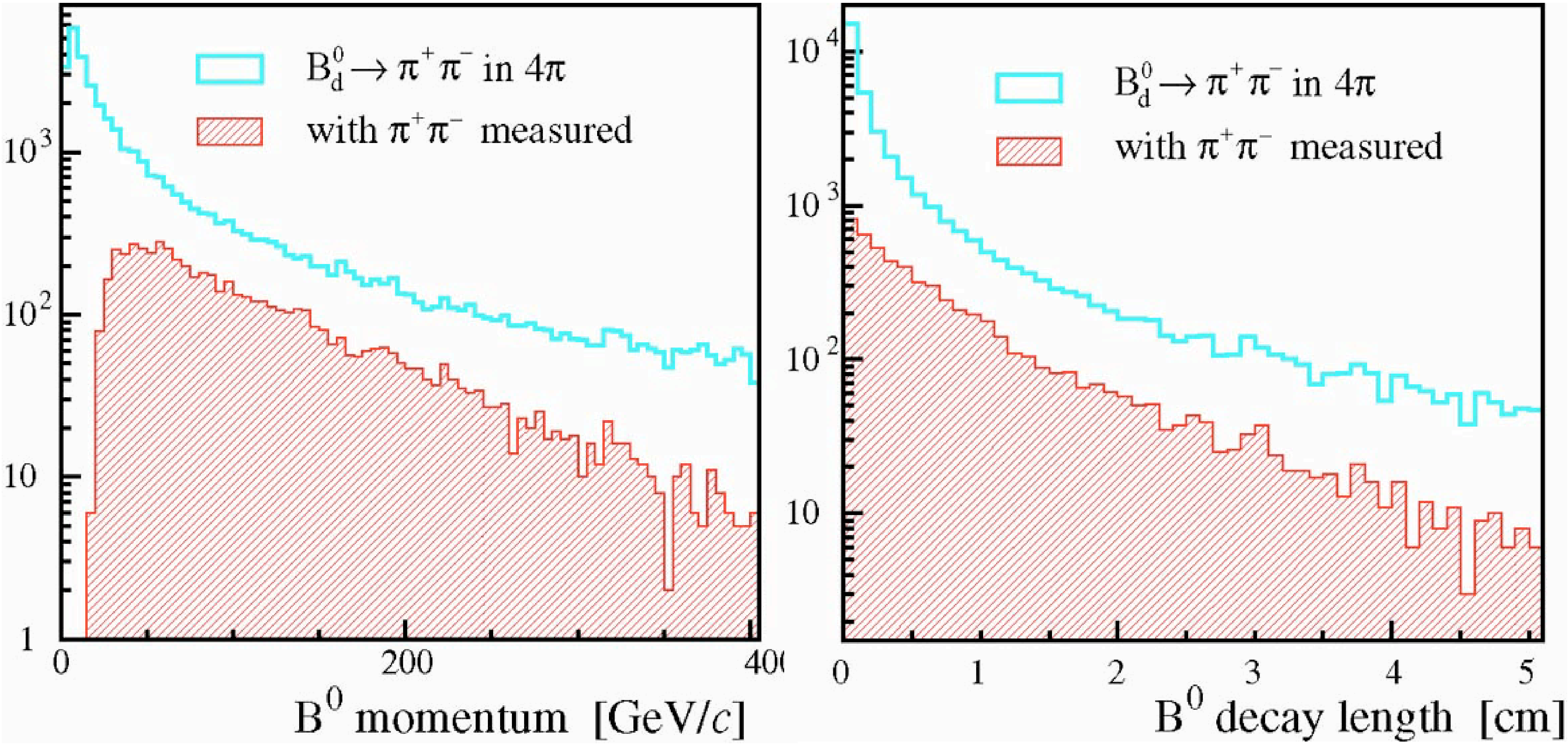


forward detector



p_T threshold can be set low:
⇒ high b efficiency

Momentum spectrum and decay distance for B mesons



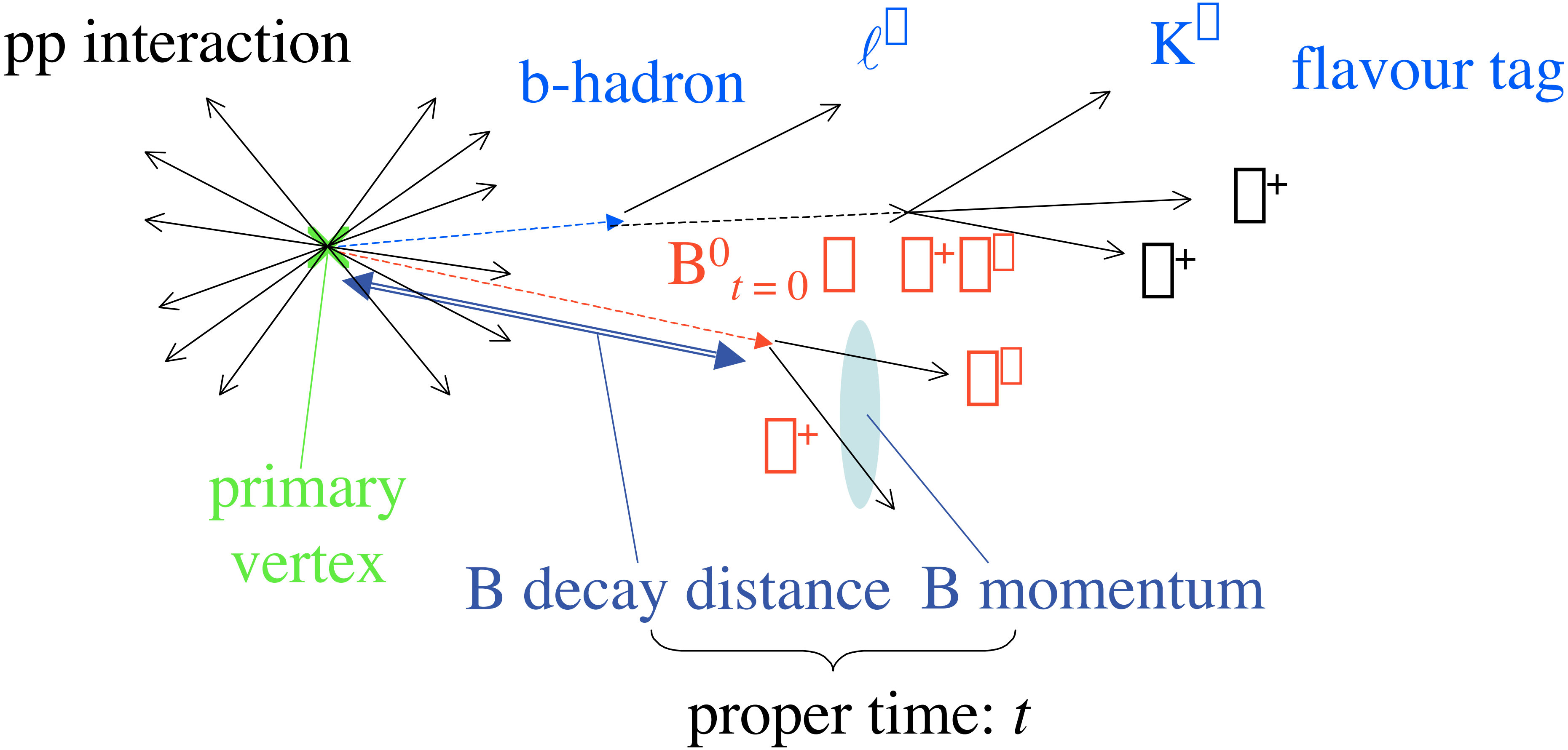
are larger in the forward region.

 average B decay distance in the detector ~1cm

Good proper time resolution.

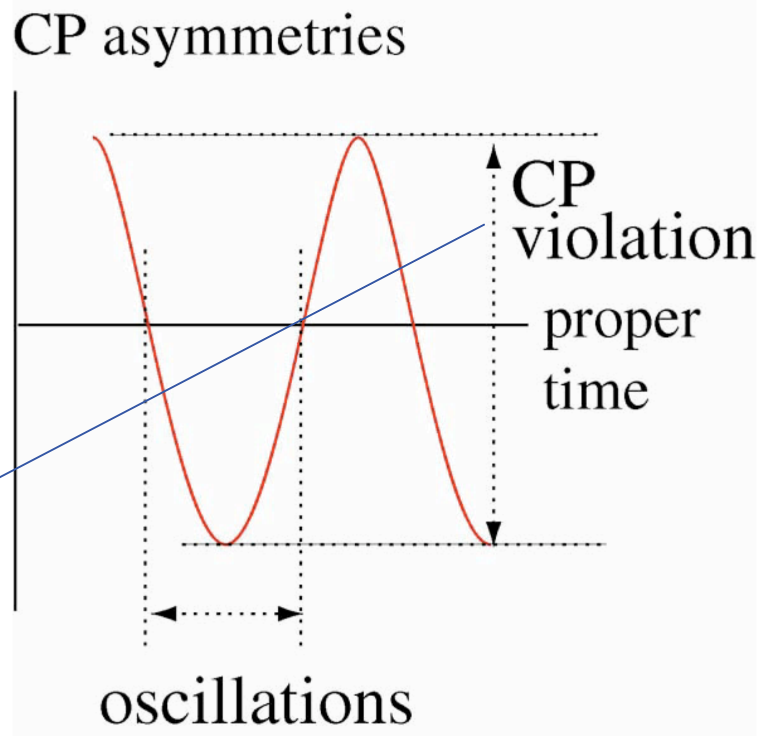
6) Some detector requirements

What do we measure? (an example)



Time dependent CP asymmetry

$$\frac{\overline{B}^0_{t=0} \rightarrow \pi^+\pi^-(t) - B^0_{t=0} \rightarrow \pi^+\pi^-(t)}{\overline{B}^0_{t=0} \rightarrow \pi^+\pi^-(t) + B^0_{t=0} \rightarrow \pi^+\pi^-(t)}$$



CP violating oscillation amplitudes are damped by

proper time resolution	good decay vertex resolution
wrong flavour tag	good momentum resolution
background	good particle identification

Arrows in the diagram:

- proper time resolution → good decay vertex resolution, good momentum resolution
- wrong flavour tag → good particle identification
- background → good decay vertex resolution, good momentum resolution, good particle identification

7) LHCb Detector

VELO

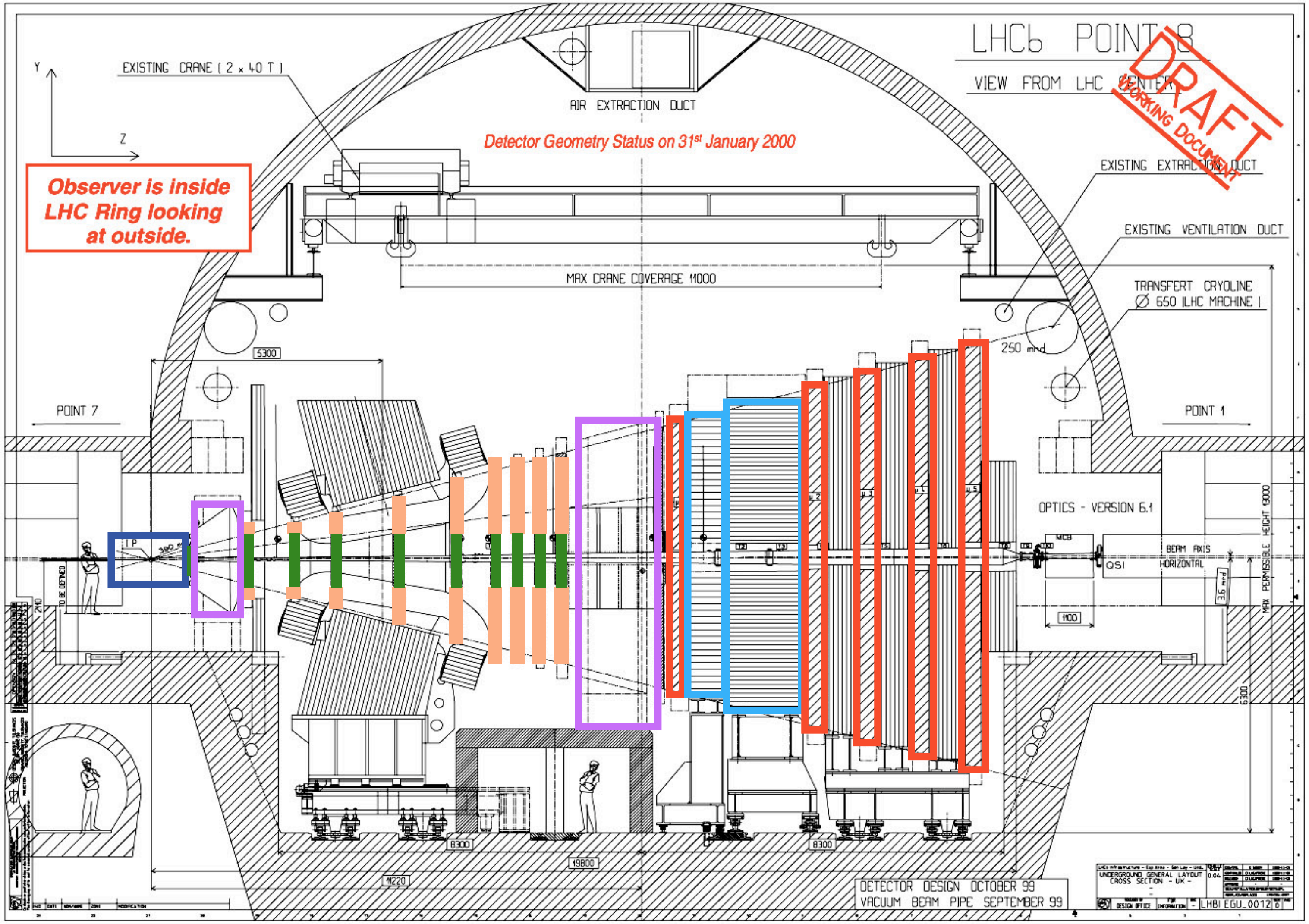
Inner Tracker

Outer Tracker

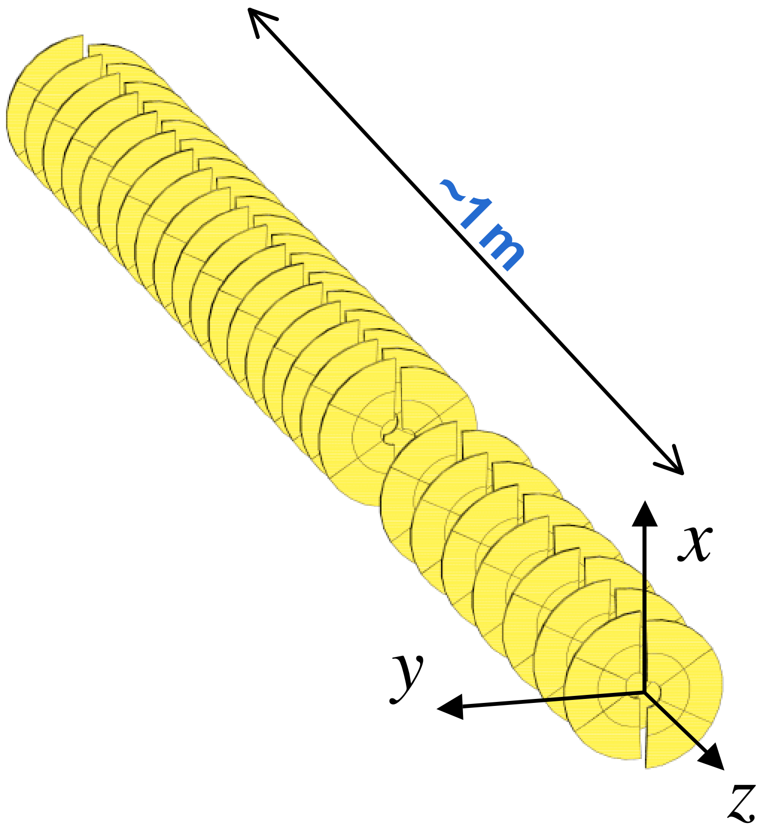
RICH-1
RICH-2

Calorimeters

Muon system

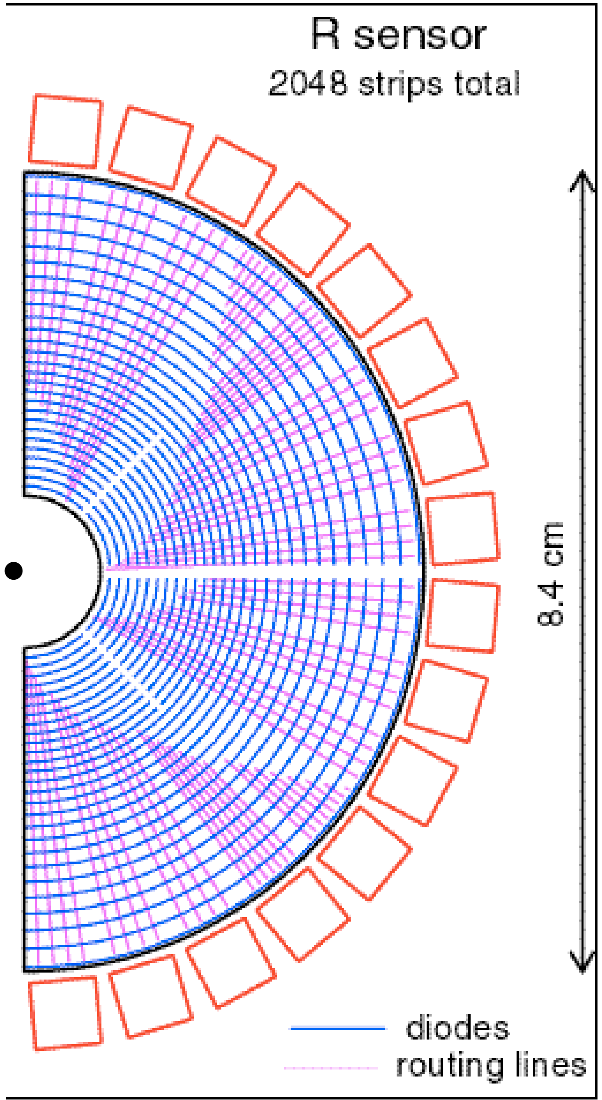


VEetex LOcator(VELO)

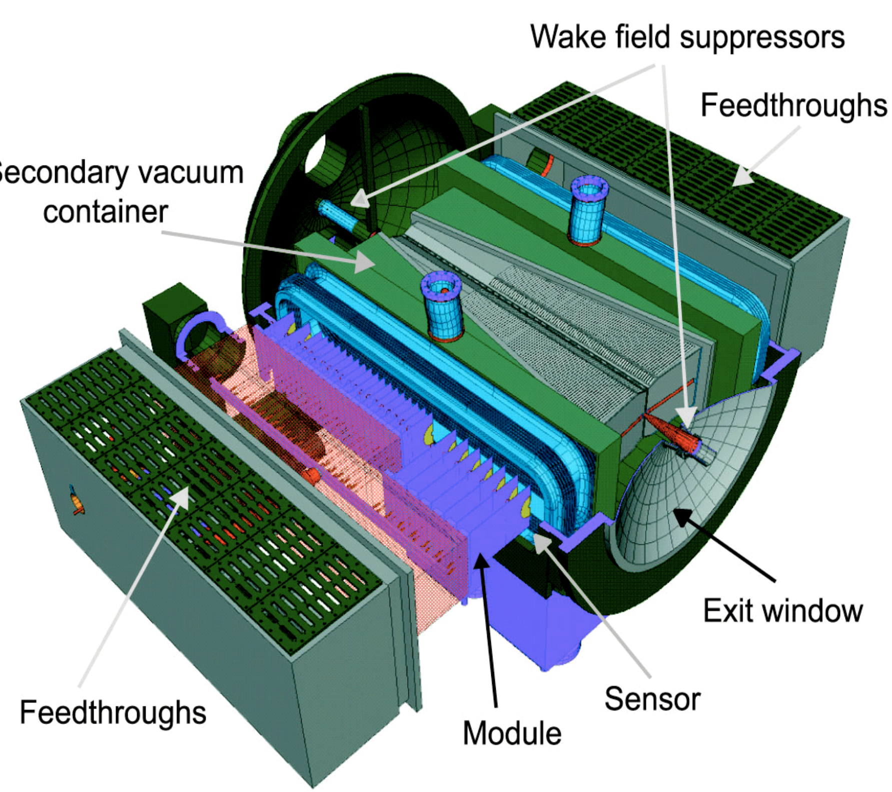


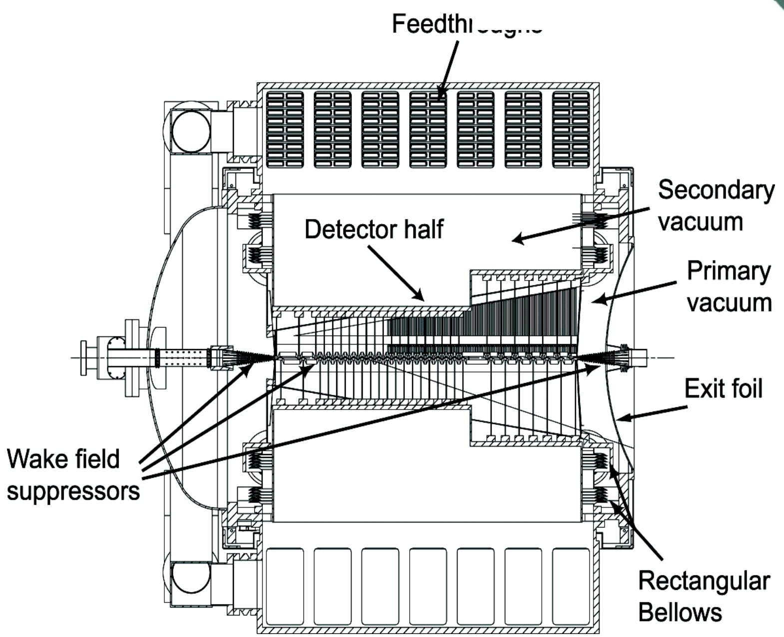
beam

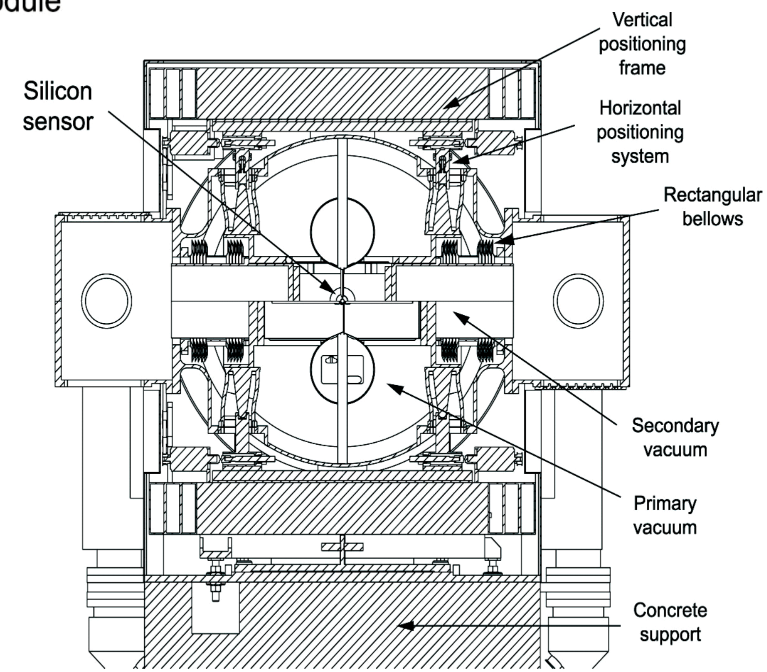
beam



Number of silicon sensors:	100
Area of silicon:	$0.32m^2$
Number of channels:	204,800


Wake field suppressors
Feedthroughs
Secondary vacuum container
Exit window
Feedthroughs
Module
Sensor

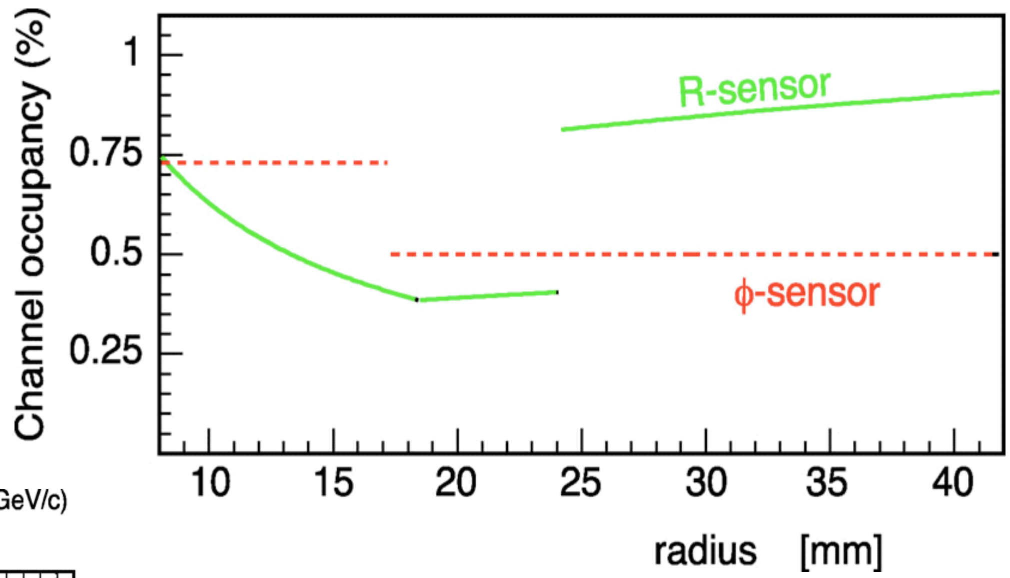

Feedth
Detector half
Secondary vacuum
Primary vacuum
Exit foil
Wake field suppressors
Rectangular Bellows

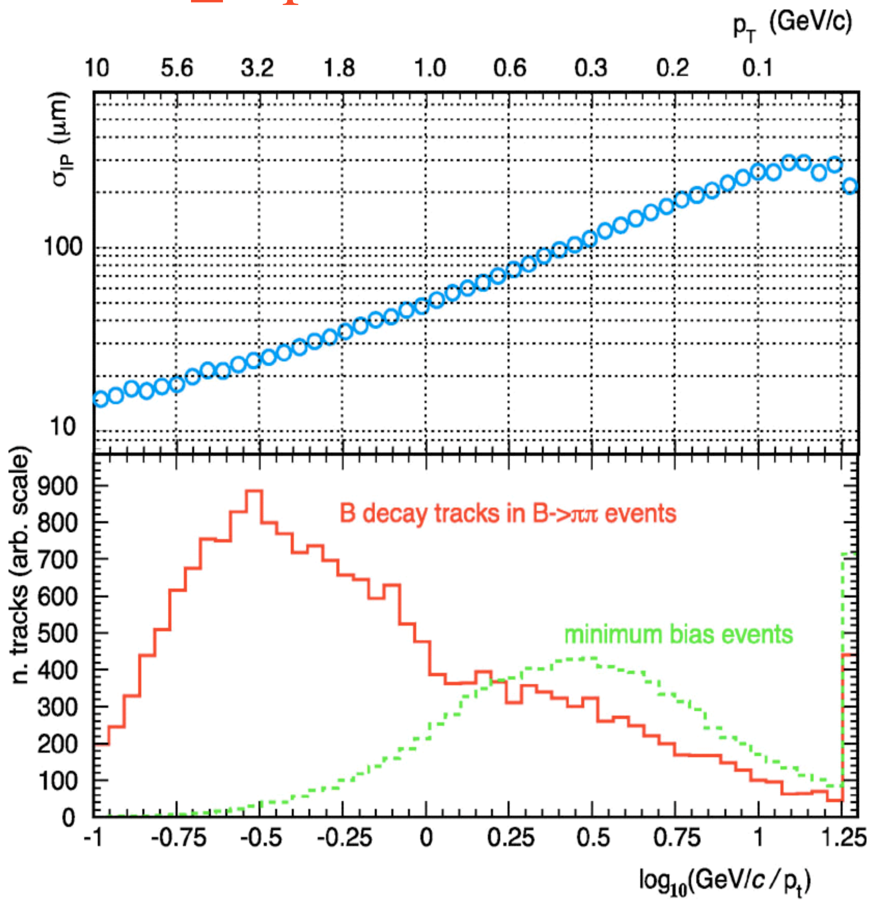

Silicon sensor
Vertical positioning frame
Horizontal positioning system
Rectangular bellows
Secondary vacuum
Primary vacuum
Concrete support

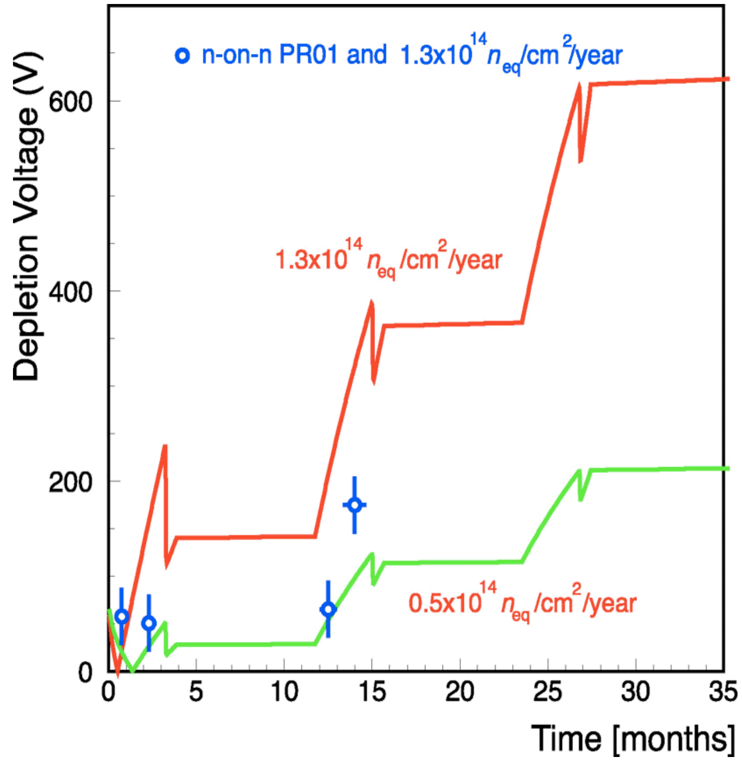
The VELO has
- low occupancy
- high resolution
- radiation hard

with only ~200k channels:

□ optimal choice!

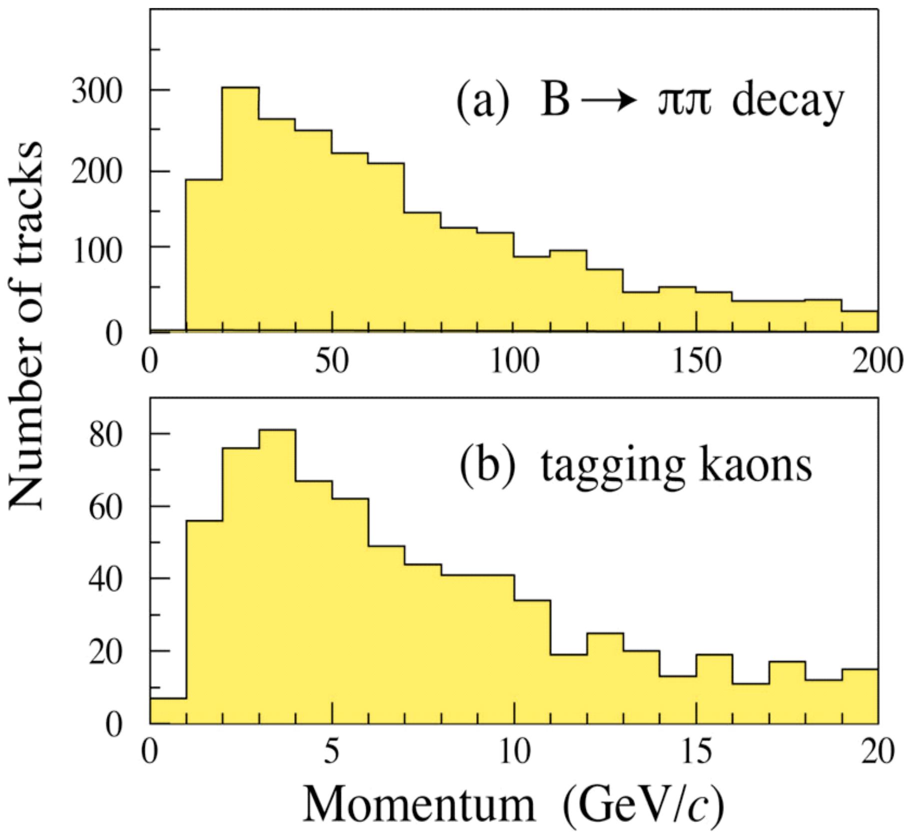


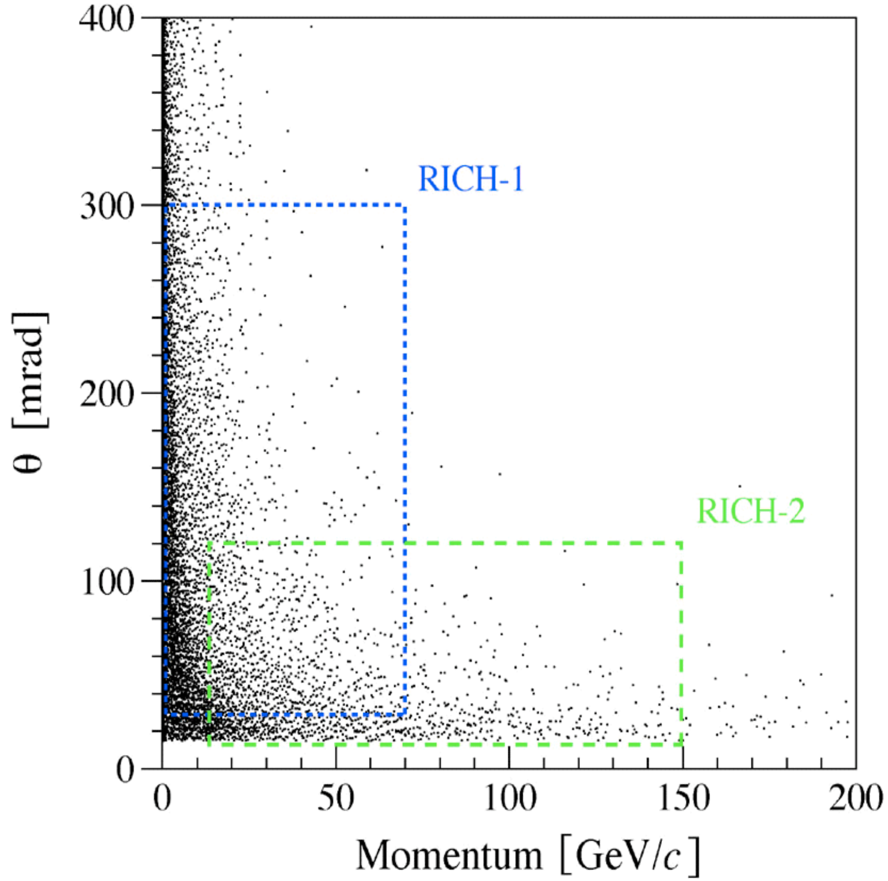




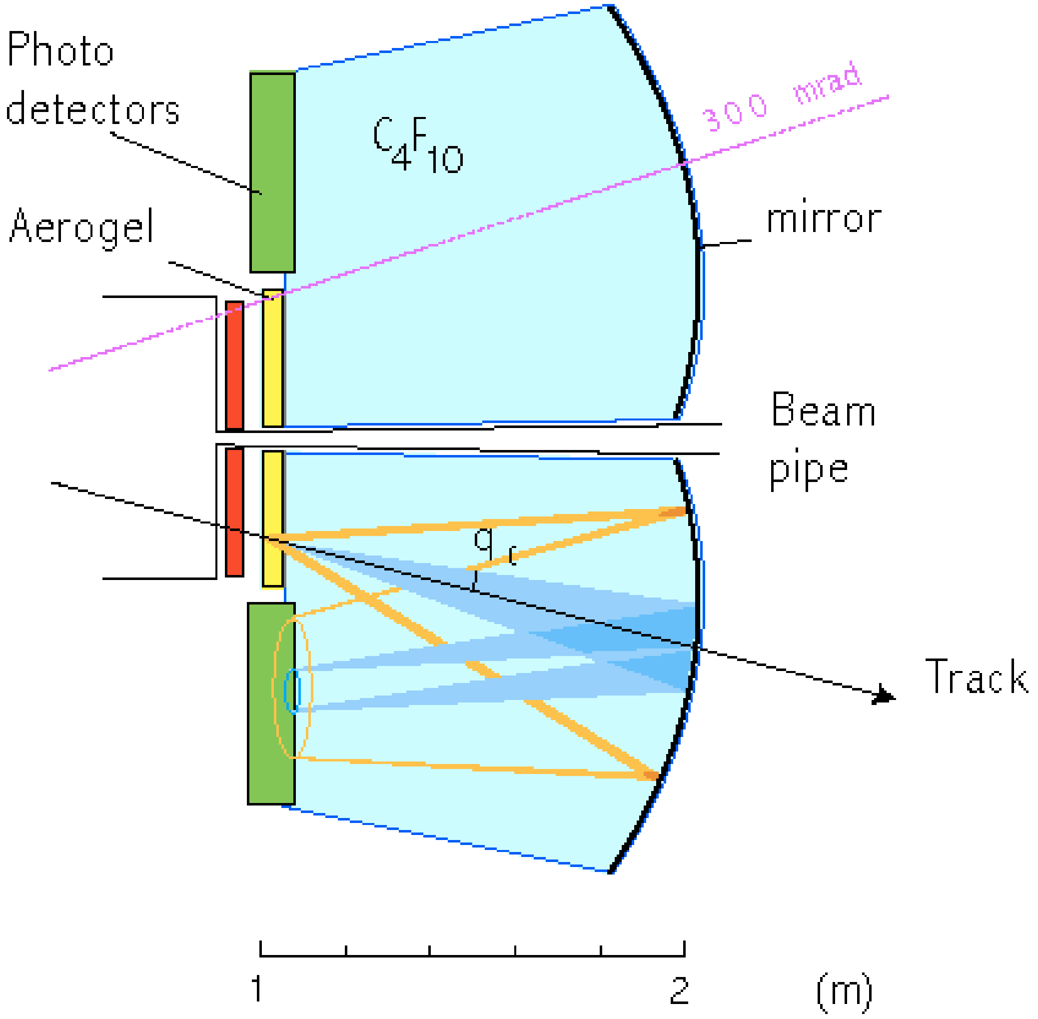
RICH

Required momentum rage and angular coverage.

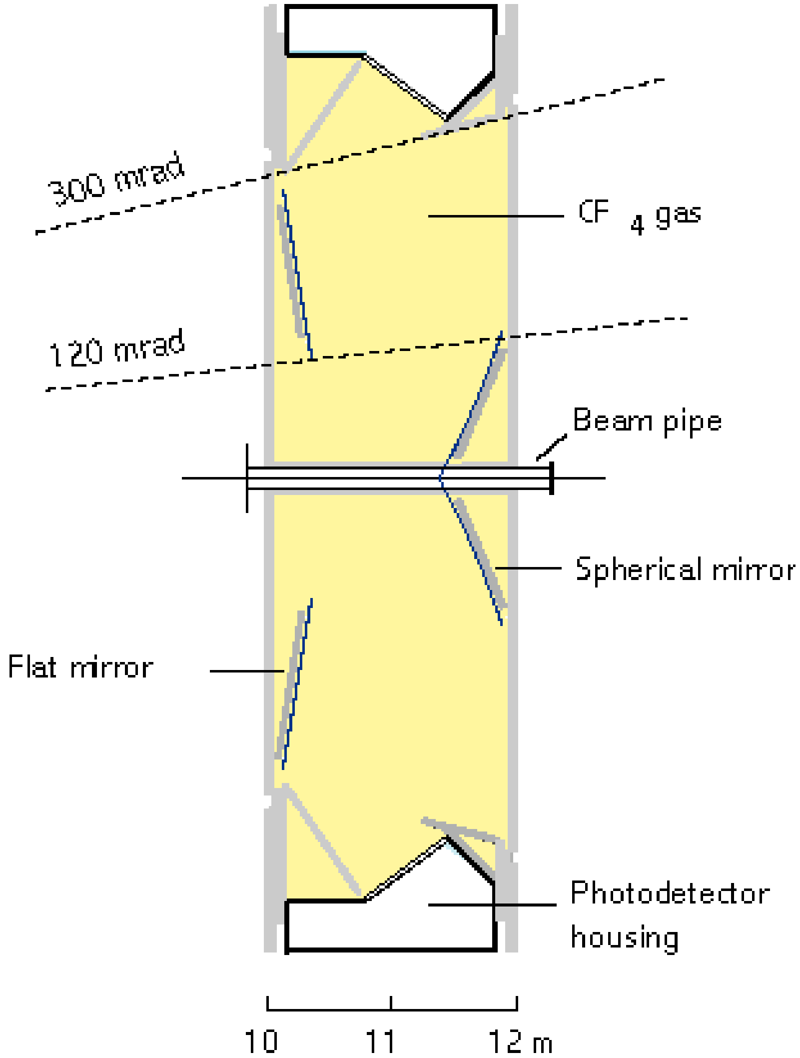




RICH1:



RICH2:

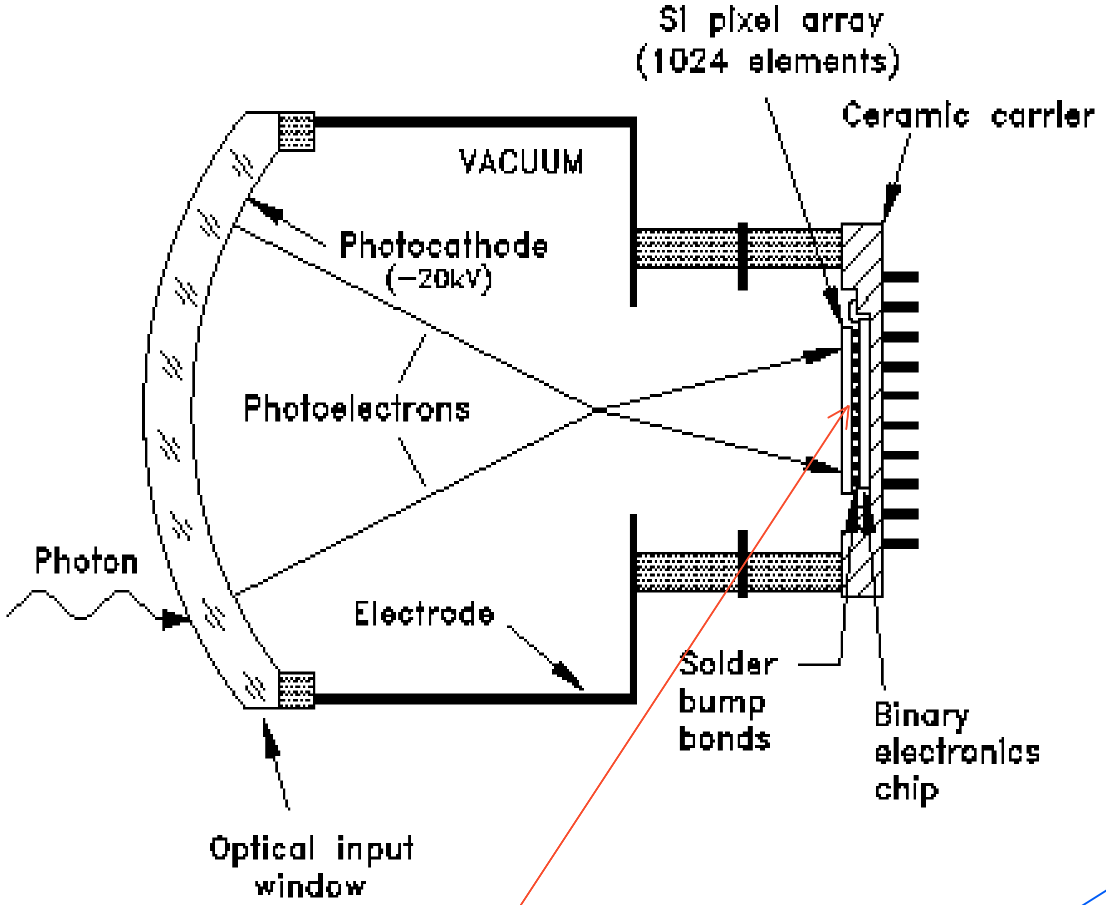


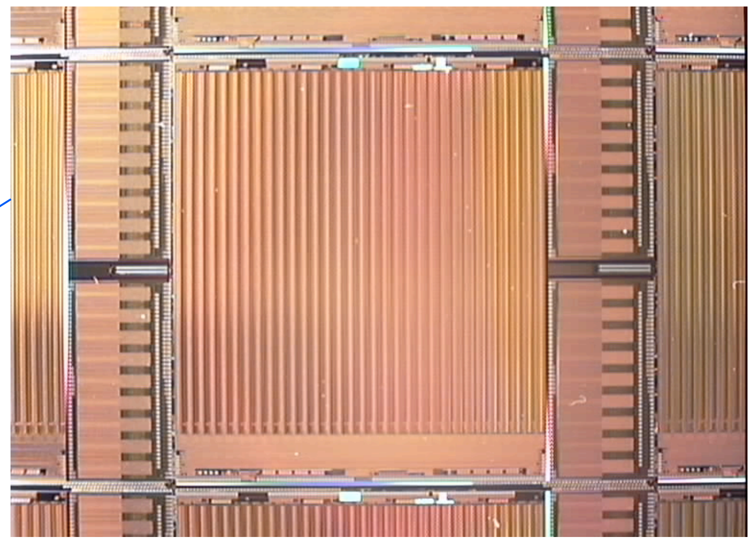
5cm aerogel, n = 1.03, 2-11 GeV
4 m^3 C_4F_{10}, n = 1.0014, 10-70 GeV

100 m^3 CF_4, n = 1.0005
17-150 GeV

Baseline option

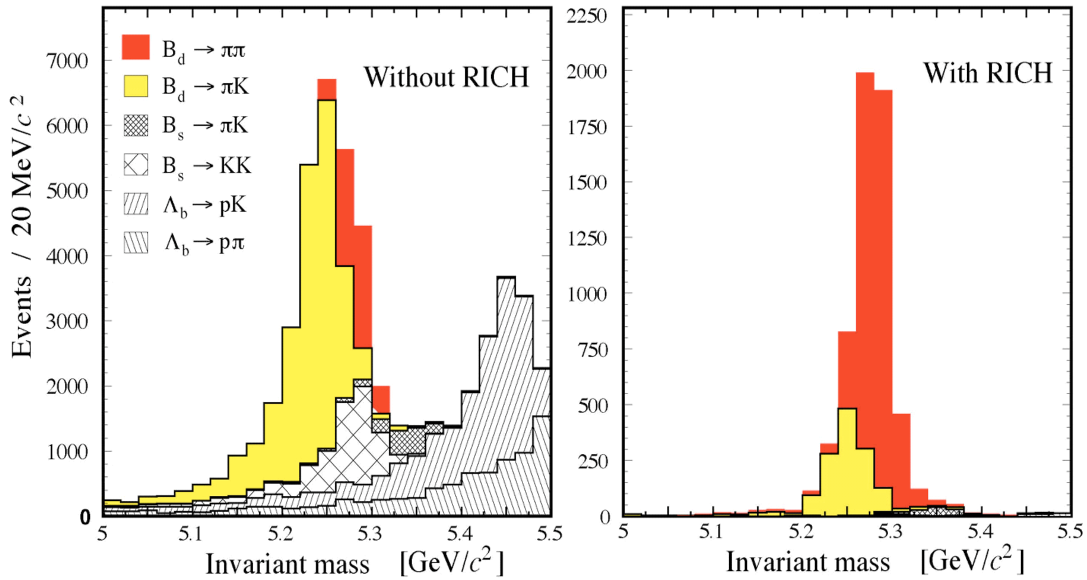
Pixel HPD



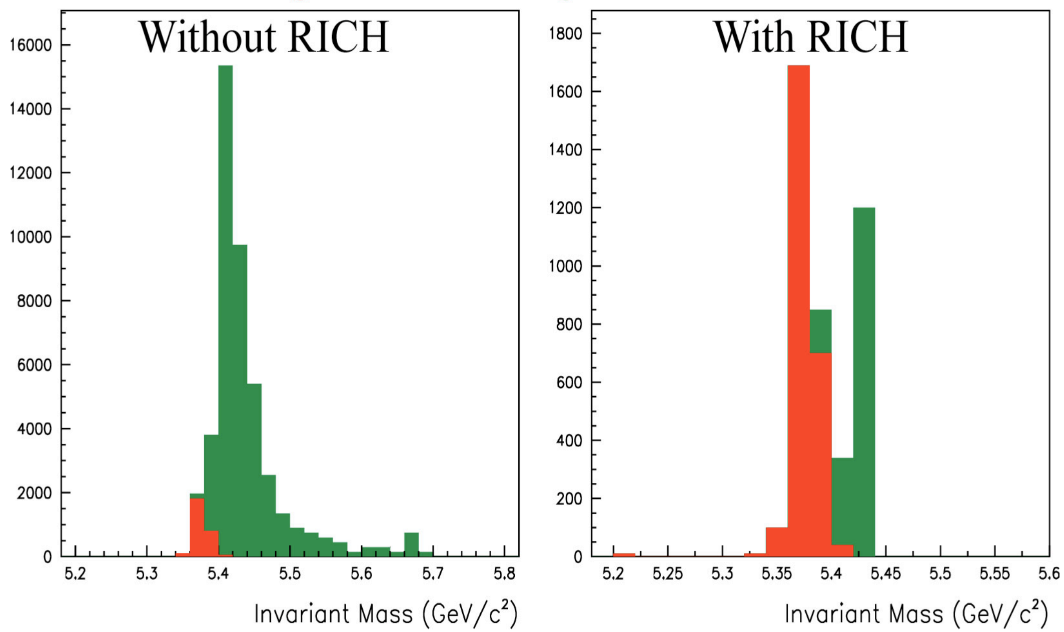


1024 pixel (500□m□500□m) detector and bump bonded pixel readout electronics.

$B \rightarrow \pi^+\pi^-$



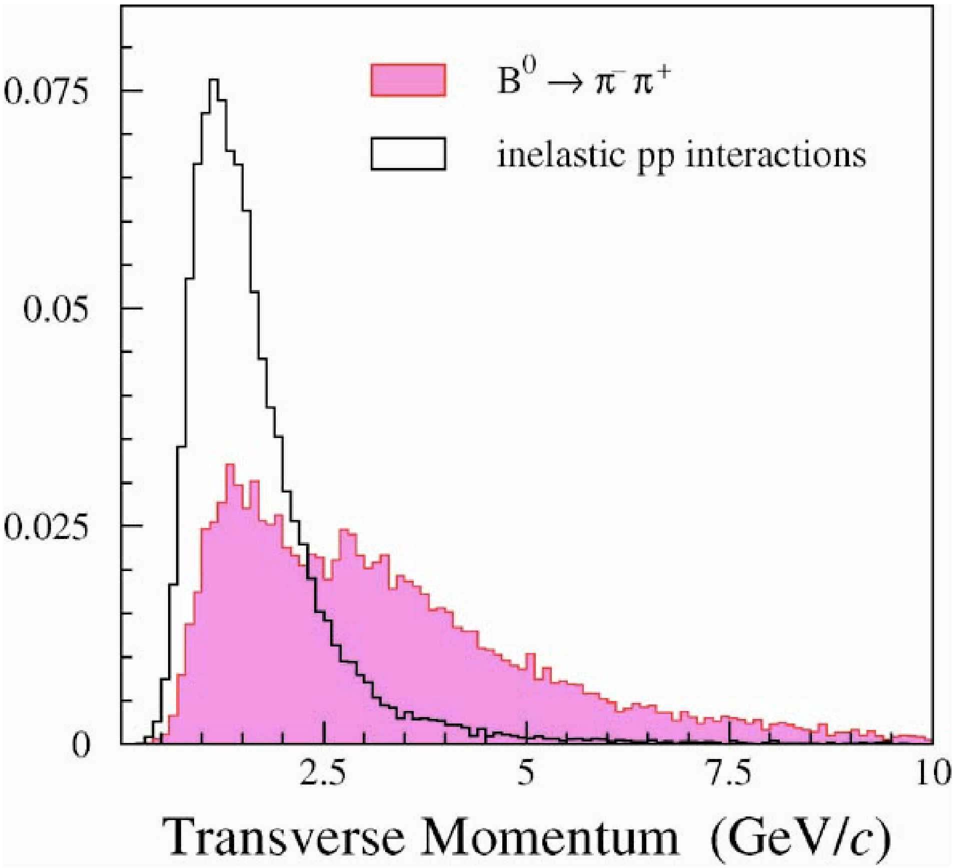
D_sK signal $D_s\pi$ background

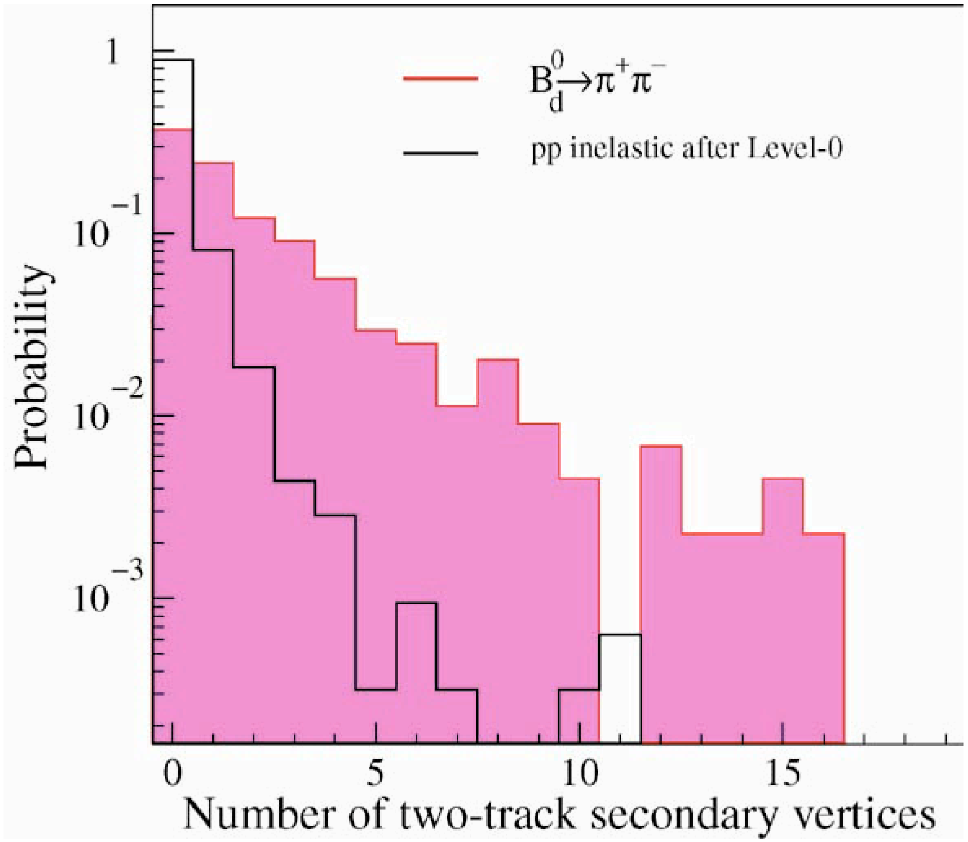


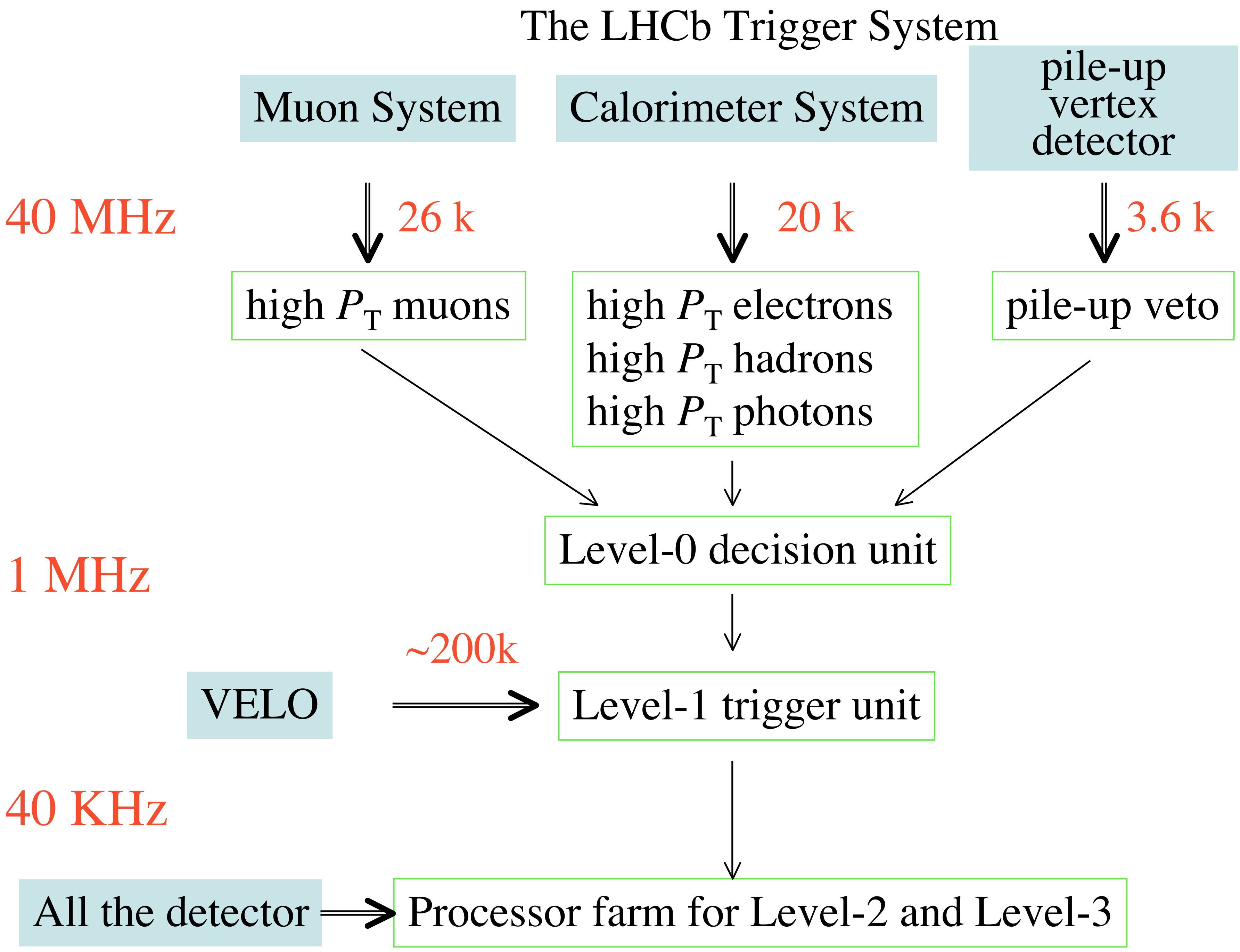
Trigger

Level-0: High p_T leptons and hadrons

Level-1: Detached decay vertices






The LHCb Trigger System
Muon System
Calorimeter System
pile-up vertex detector
40 MHz
26 k
20 k
3.6 k
high P_T muons
high P_T electrons
high P_T hadrons
high P_T photons
pile-up veto
Level-0 decision unit
1 MHz
~200k
VELO
Level-1 trigger unit
40 KHz
All the detector
Processor farm for Level-2 and Level-3

LHCb Trigger Efficiency

for reconstructed and correctly tagged events

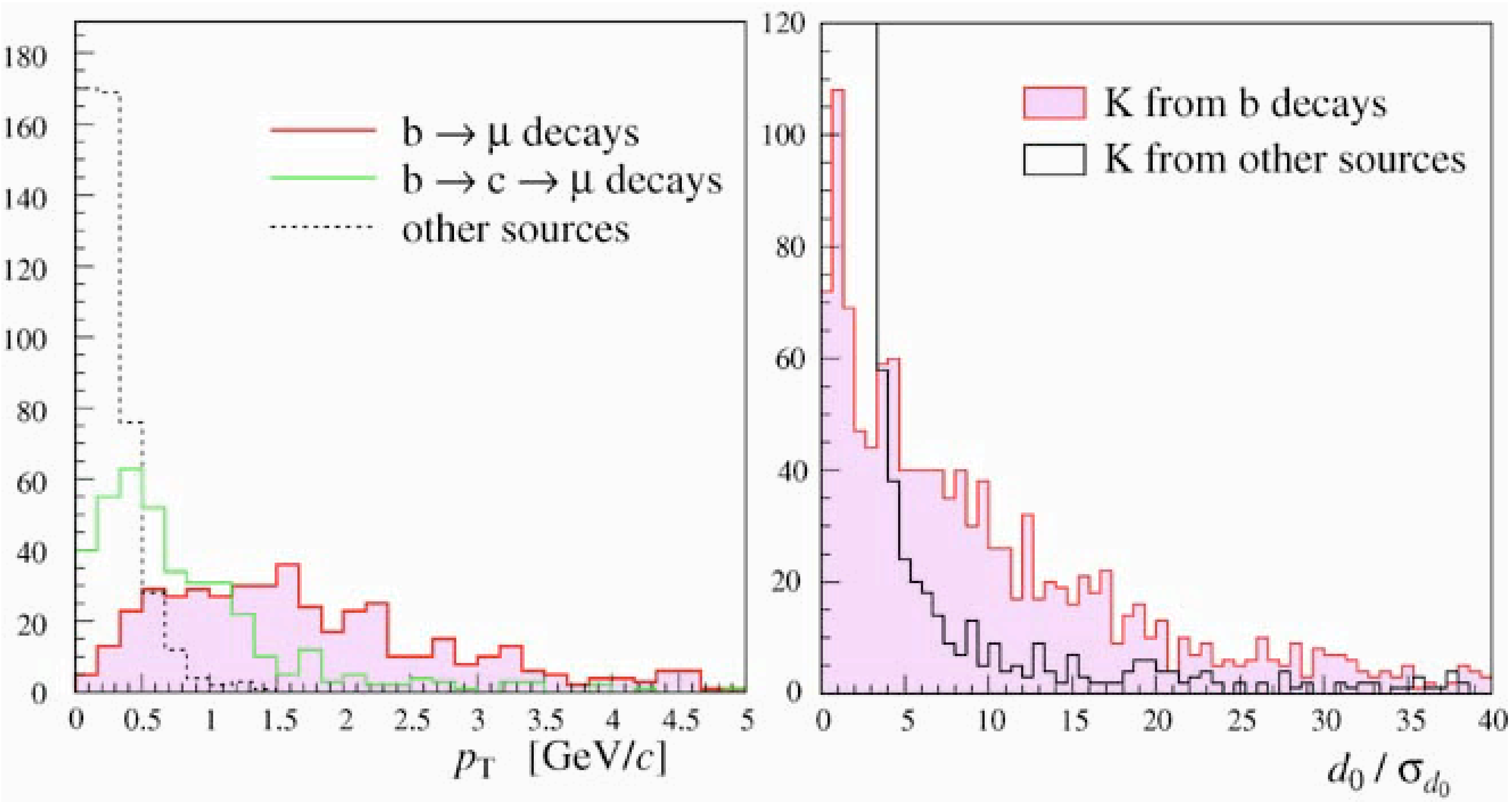
	L0(%)				L1(%)	L2(%)	Total(%)
	μ	e	h	all			
$B_d \to J/\psi(ee)K_S$ + tag	17	**63**	17	72	42	81	**24**
$B_d \to J/\psi(\mu\mu)K_S$ + tag	**87**	6	16	88	50	81	**36**
$B_s \to D_sK$ + tag	15	9	**45**	54	56	92	**28**
$B_d \to DK^{*}$	8	3	**31**	37	59	95	**21**
$B_d \to \pi^+\pi^-$ + tag	14	8	**70**	76	48	83	**30**

- trigger efficiencies are ~ 30%
- hadron trigger is important for hadronic final states
  useful only with the kaon tag
- lepton trigger is important for final states with leptons

evenly spread selectivity = robust and flexible

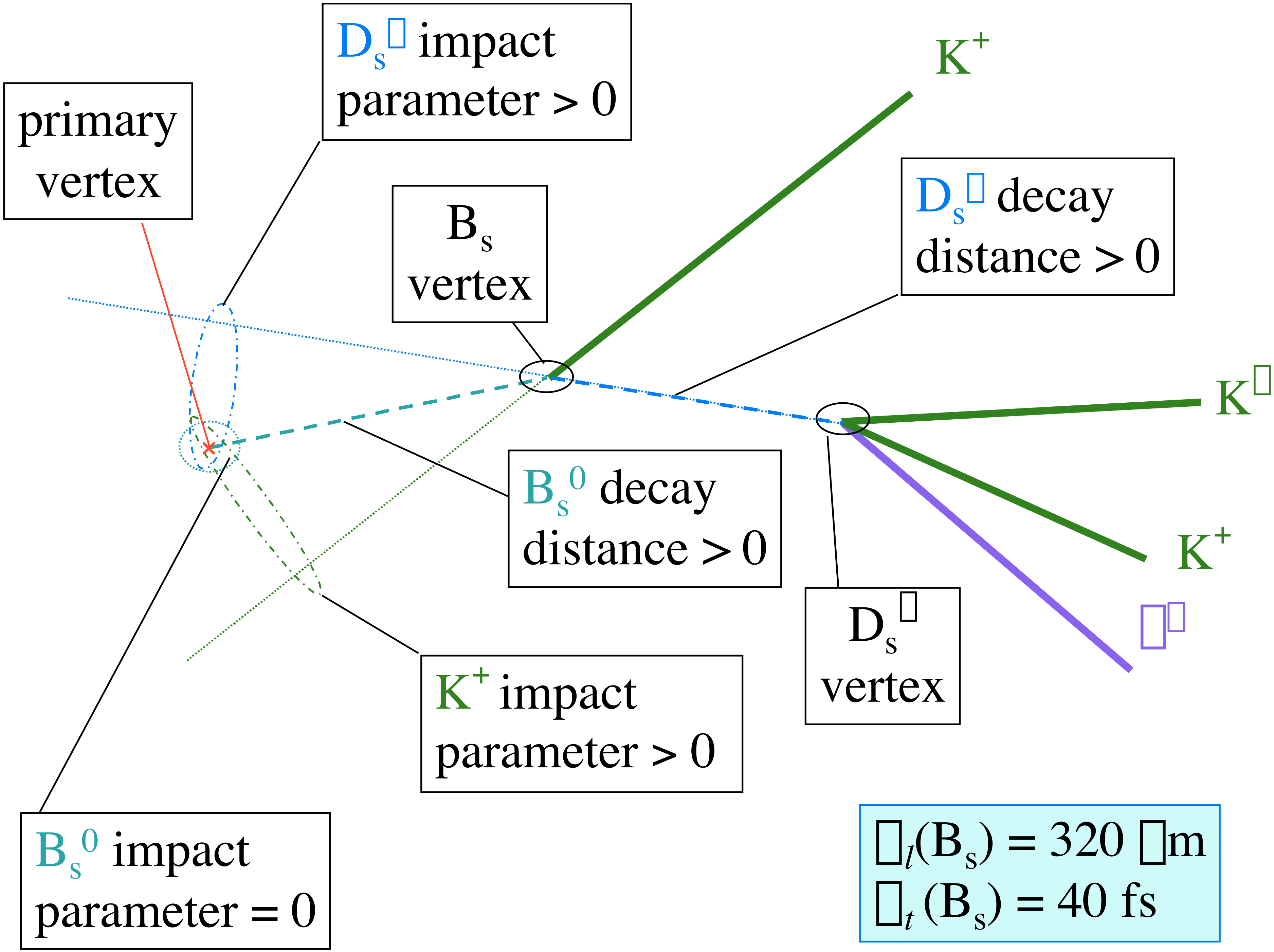
8) Something about reconstruction

Flavour tag with high p_T leptons and large impact parameter (d_0) kaons



B-$\overline{B}$ oscillations: irreducible wrong tag

$\square_{tag} = 0.4$, $\square_{tag} = 0.3$


primary vertex
Ds impact parameter > 0
Bs vertex
K+
Ds decay distance > 0
K
Bs0 decay distance > 0
K+
Ds vertex
K+ impact parameter > 0
Bs0 impact parameter = 0
l(Bs) = 320 m
t (Bs) = 40 fs

9) Some LHCb Physics Performance

CP asymmetries in

$B_d \rightarrow J/\psi K_S$ (>40k tagged /10^7 sec)

$\sigma_{\sin 2\beta}$ = 0.02 /10^7 sec

$B_s \rightarrow J/\psi \phi$ excellent σ_t

$\sigma_{2\delta\gamma}$ = 0.04 - 0.06 /10^7 sec (x_s = 20 - 40)

B_s oscillations: hadron trigger, excellent σ_t

$B_s \rightarrow D_s \pi$ measurable up to $x_s \leq 80$ (54 ps^{-1}) with 5σ

CP violation in radiative decays

$B_d \rightarrow K^{*0}\mu^+\mu^-$ s = 4.5k/ 10^7 sec (Br=1.5×10^{-6}), s/b = 16

error on forward-backward asymmetry ~0.03/10^7 sec

$B_d \rightarrow K^{*0}\gamma$ single photon trigger

s = 26k/ 10^7 sec (Br=4.9×10^{-5}), s/b = 1

error on CP asymmetry ~ 0.01/10^7 sec

CP asymmetries in

B_d □ $D^{□\pm}$ $□^{\mp}$ hadron trigger

260 k tagged /10^7 sec □$_□$ □ 10°

B_s □ $D_s^{\mp} K^{\pm}$ particle ID, hadron trigger, excellent □$_t$

2.4 k tagged /10^7 sec □$_□$ □ 10°

Time dependent Dalitz plot study: hadron trigger

B_s □ $□^+□^□□^0$ □$_{□+□}$ □ 5° to 10°/10^7 sec

CP asymmetries in

B_d □ $□^+□^□$ particle ID, hadron trigger

4.9 k tagged /10^7 sec (Br = 5□$10^{□6}$)

and B_s □ $K^+ K^□$ particle ID, hadron trigger, excellent □$_t$

4.6 k tagged /10^7 sec (Br = 1.9□$10^{□5}$)

□$_□$ □ 5.4°/10^7 sec for □m_s = 20 ps$^{□1}$

Rare decays

B_s □ $□^+□^□$ s = 10 /10^7 sec (Br = 3.5□$10^{□9}$), s/b = 3

10) Conclusions

Unique property of LHC

Large yield for different b hadrons ($10^{12}/10^{7}$ sec)

+

Unique properties of LHCb

Trigger: high P_T lepton or hadron + secondary vertex

Sensitive to final states: lepton only & leptons+hadrons & hadron only

RICH system: clean K/π separation over wide range of *p*

Kaon tag (enhancing the importance of the hadron trigger),

Clean reconstruction of hadronic final states

Vertex detector: excellent decay time resolution

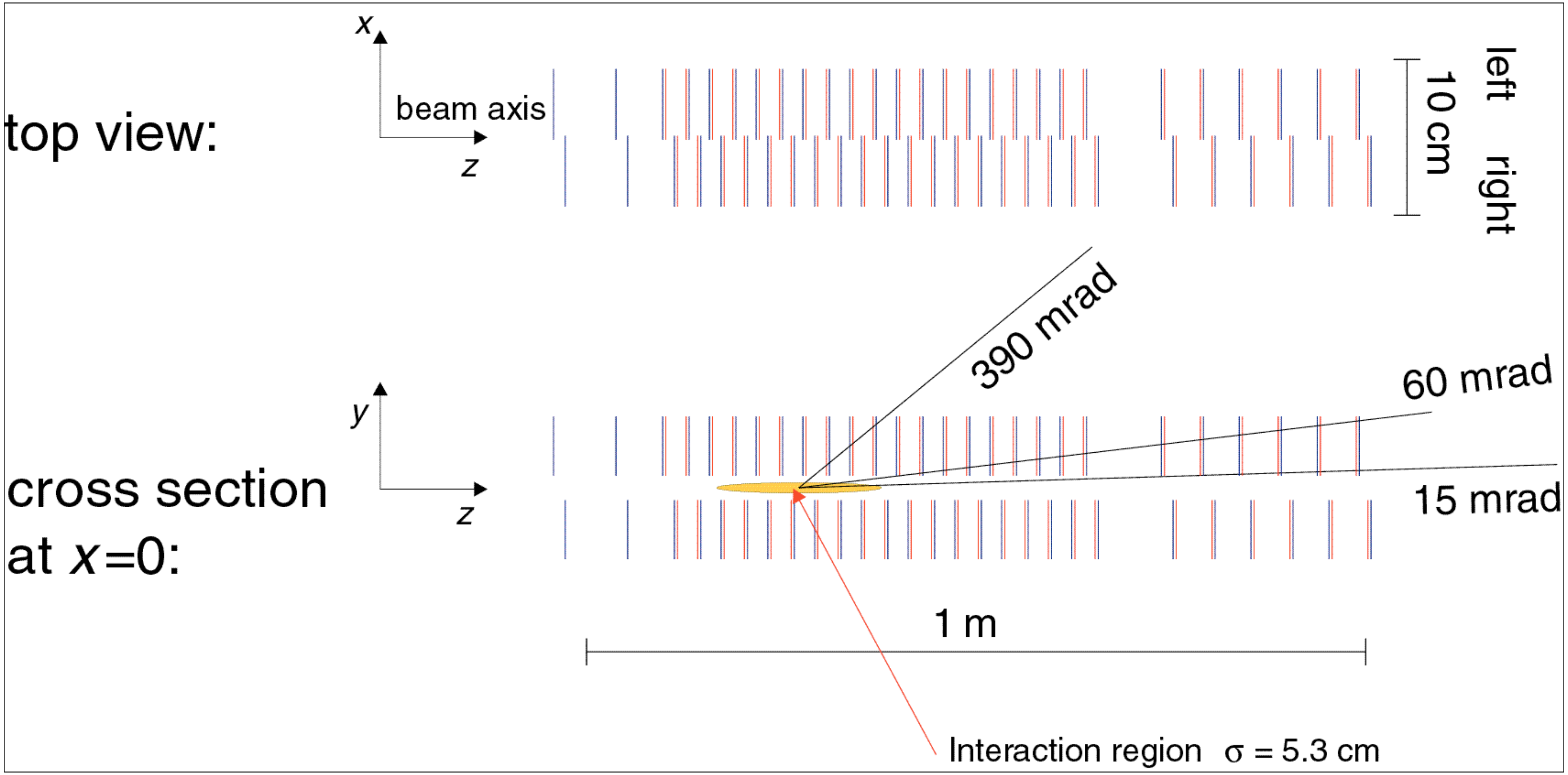
High CP and oscillation sensitivities for the B_s system

=

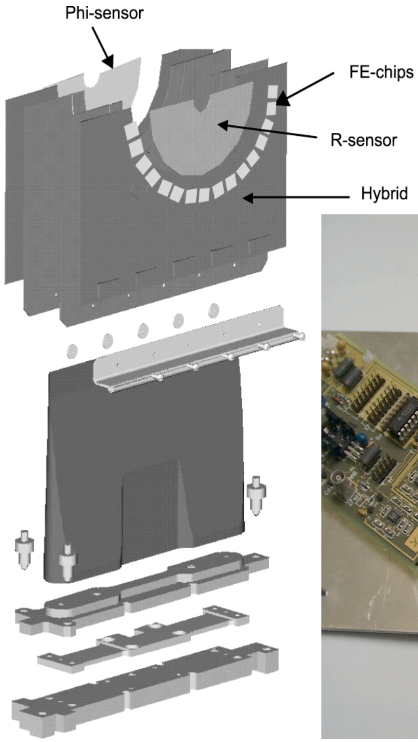
Unique opportunity to search for new physics

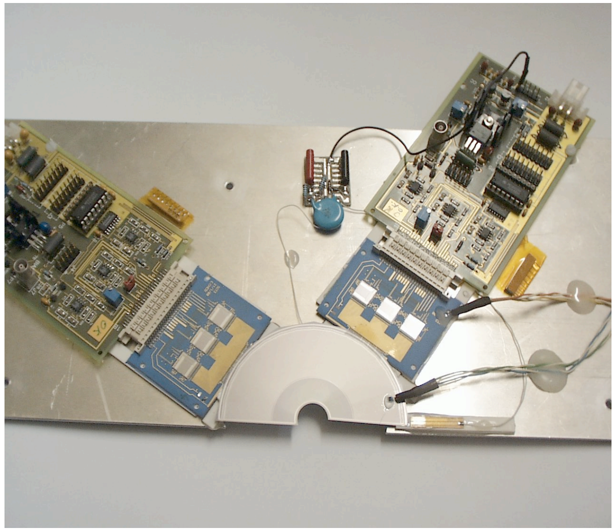
through CP violation and rare decays in B-meson decays!!

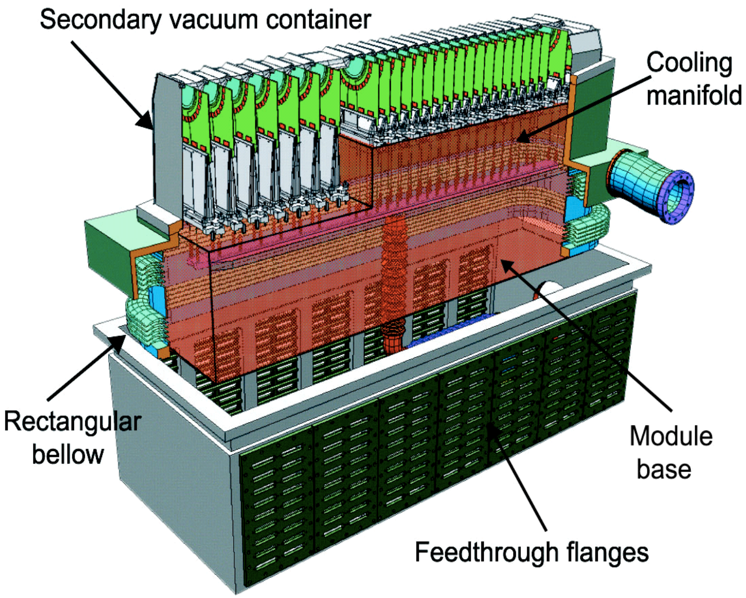
stations are overlapped

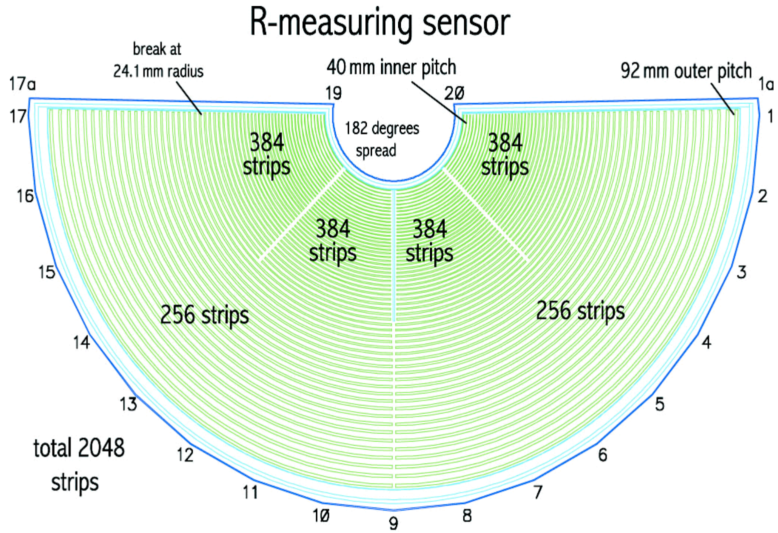


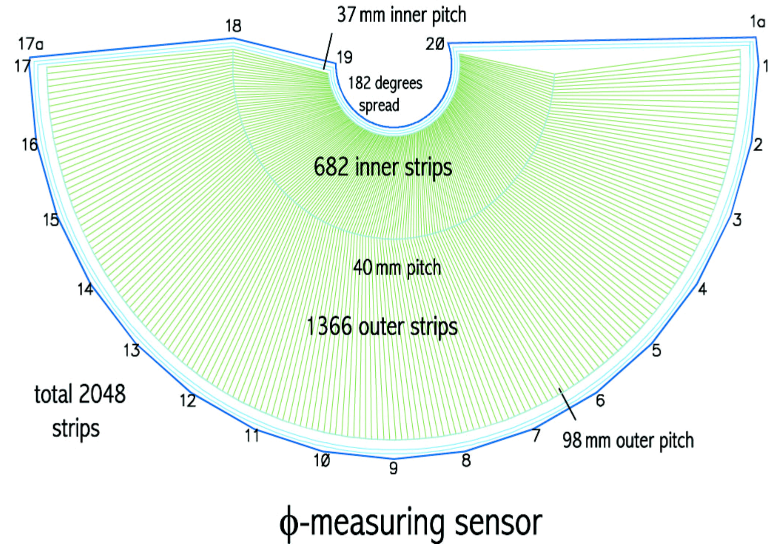
Small *r*-□ strip Si detector:
300□m n-on-n double metal layer



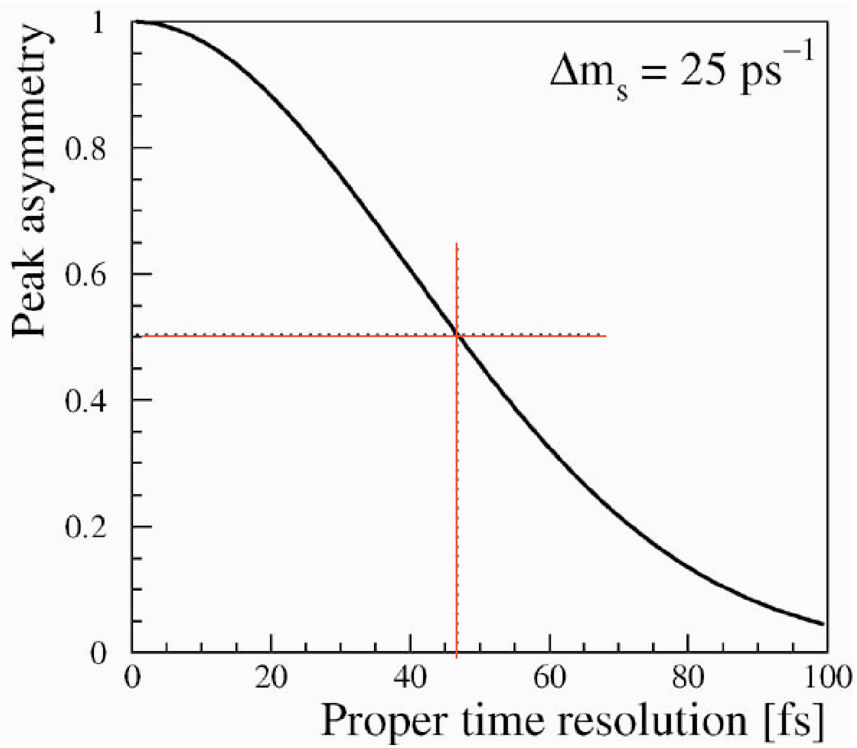








Decay time resolution…



Dilution of CP asymmetry for B_s due to σ_τ must be less than due to other sources: < 0.5

$$\sigma_\tau < 50 \text{ fs} \approx 0.03\, \tau_B$$

$$\langle l_B \rangle \approx 1 \text{ cm}$$

$$\sigma_l \approx 300\ \mu\text{m}$$

RICH Performance

Realistic simulation:

- tested by the test beam dat
- engineering design
- measured HPD performan
- all the background photon
- pattern recognition

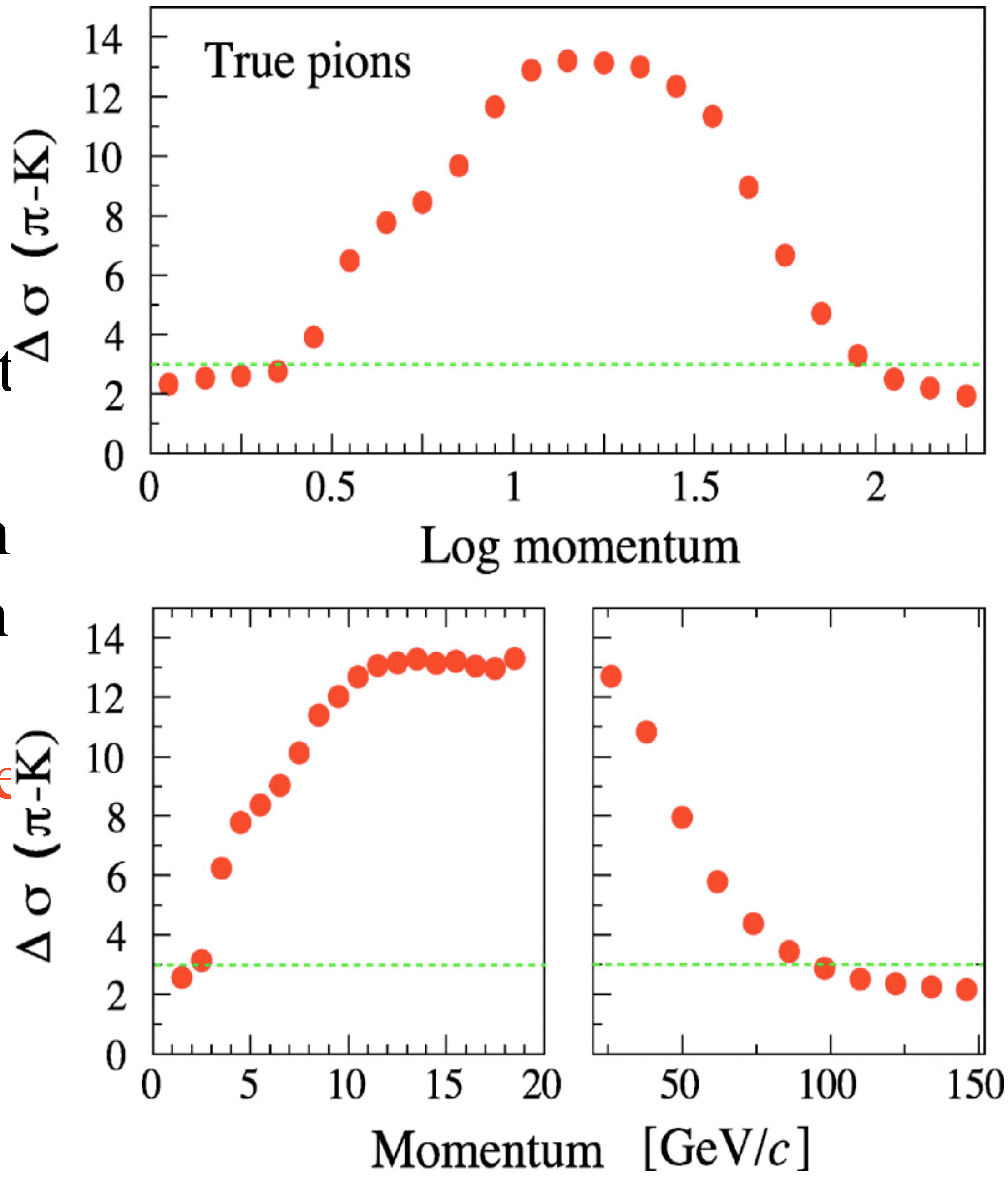
(some can still improve

No. of detected photons

6.6: RICH-1 aerogel

32.7: RICH-1 C_4F_{10}

18.4: RICH-2 CF_4

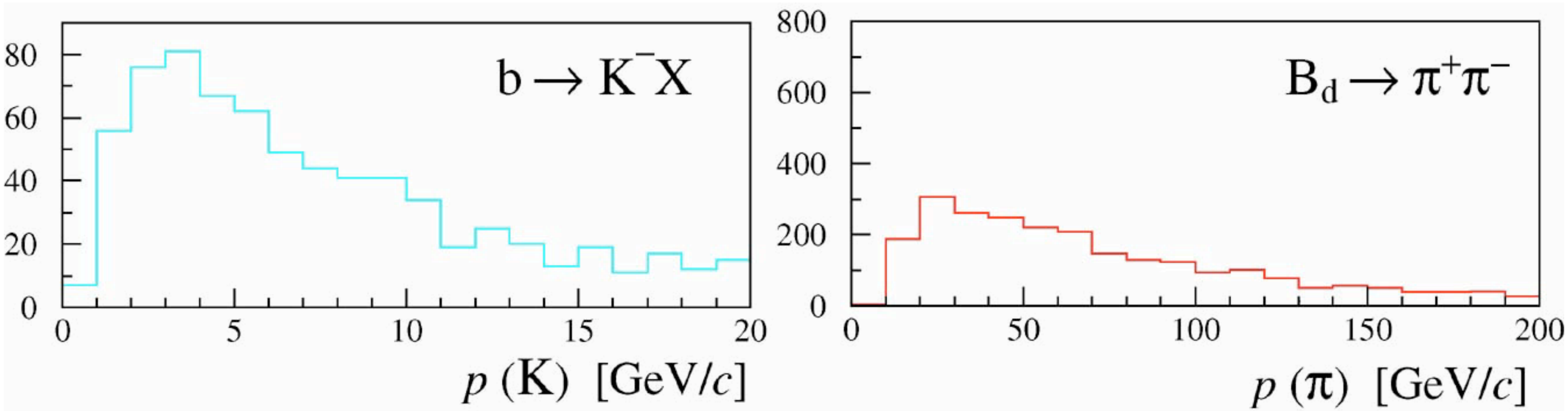


Particle identification is required in a momentum rage of

p_{min} = ~1 GeV/c (Kaon tag)

to

p_{max} = ~100 GeV/c. (two-body B decay products)



Ring Imaging Cherenkov is a suitable technique.

Can new physics make CP violation in oscillation to be large?

$\delta_{bd(s)}^{NP}$ can increase arg M_{12}/Γ_{12}

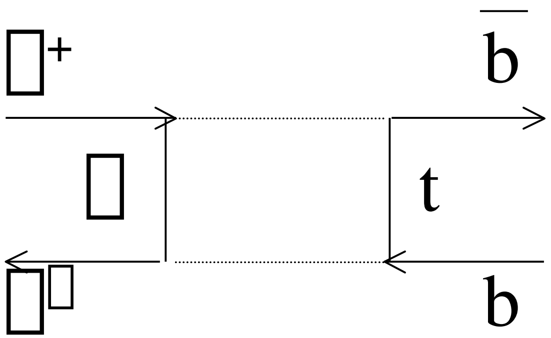
$$d \equiv \mathrm{Im}\,\frac{\Gamma_{12}}{M_{12}} = -\frac{\Delta\Gamma}{\Delta m}\,\sin\left(\arg M_{12}/\Gamma_{12}\right)$$

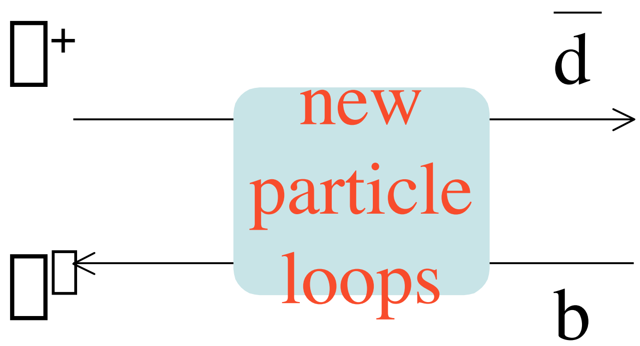
This may increase

This can hardly change from $\sim 10^{-3}$.

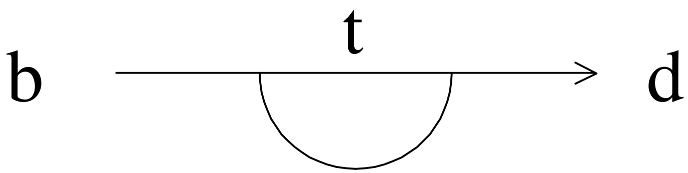
$d > 10^{-3}$ is not really possible.

But could enhance $B_s \to \mu^+\mu^-$

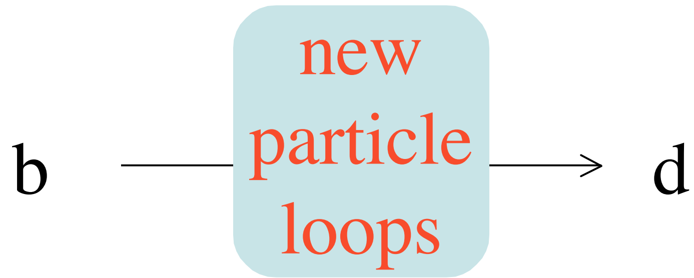




Even better would be?



$V_{bt}V_{td}^{*} \propto e^{i\beta}$



$A_{bd}^{NP} \propto e^{-i\phi_{bd}^{NP}}$

$$\left|V_{bt}V_{td}^{*}\right| = \lambda\sqrt{(1-\rho)^2+\eta^2}\,\left|V_{bt}V_{ts}^{*}\right|$$

more suppressed

⇓

New physics can have a larger influence.

$B_d \to \phi\pi^0,\ B_s \to \phi K_S$