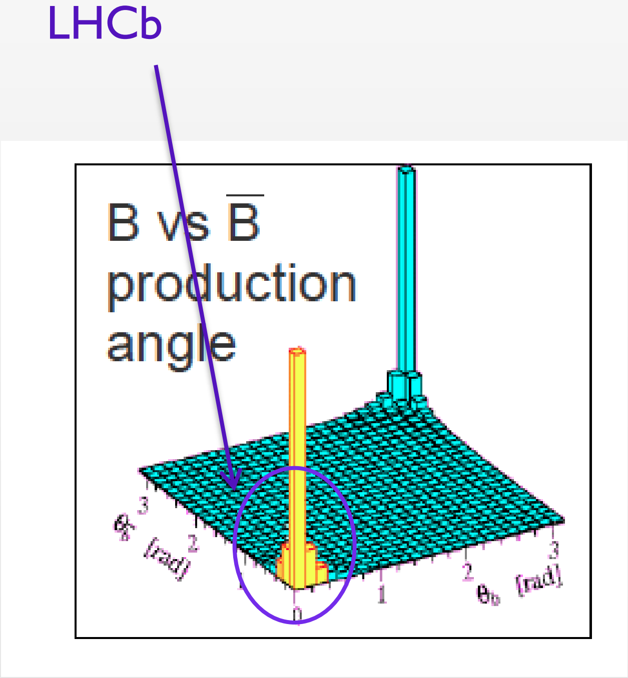
The LHCb Upgrade

Marina Artuso (Syracuse University) on behalf of the LHCb collaboration

- ❑LHCb now
- ❑Upgrade motivation
- ❑New trigger and DAQ
- ❑A two-stage plan for LHCb detector upgrade
- ❑Conclusions

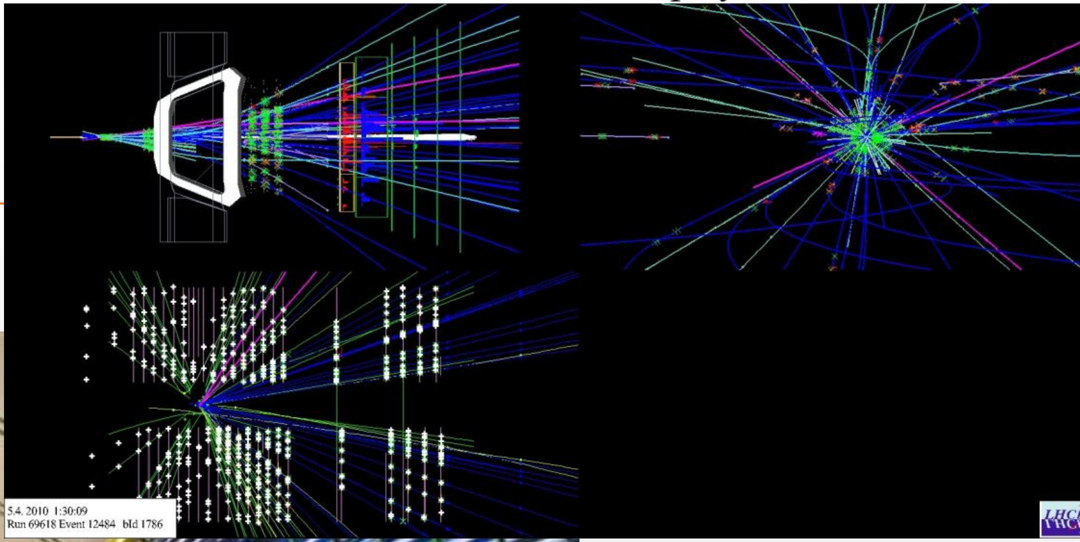
LHCb in 30 seconds (or less)

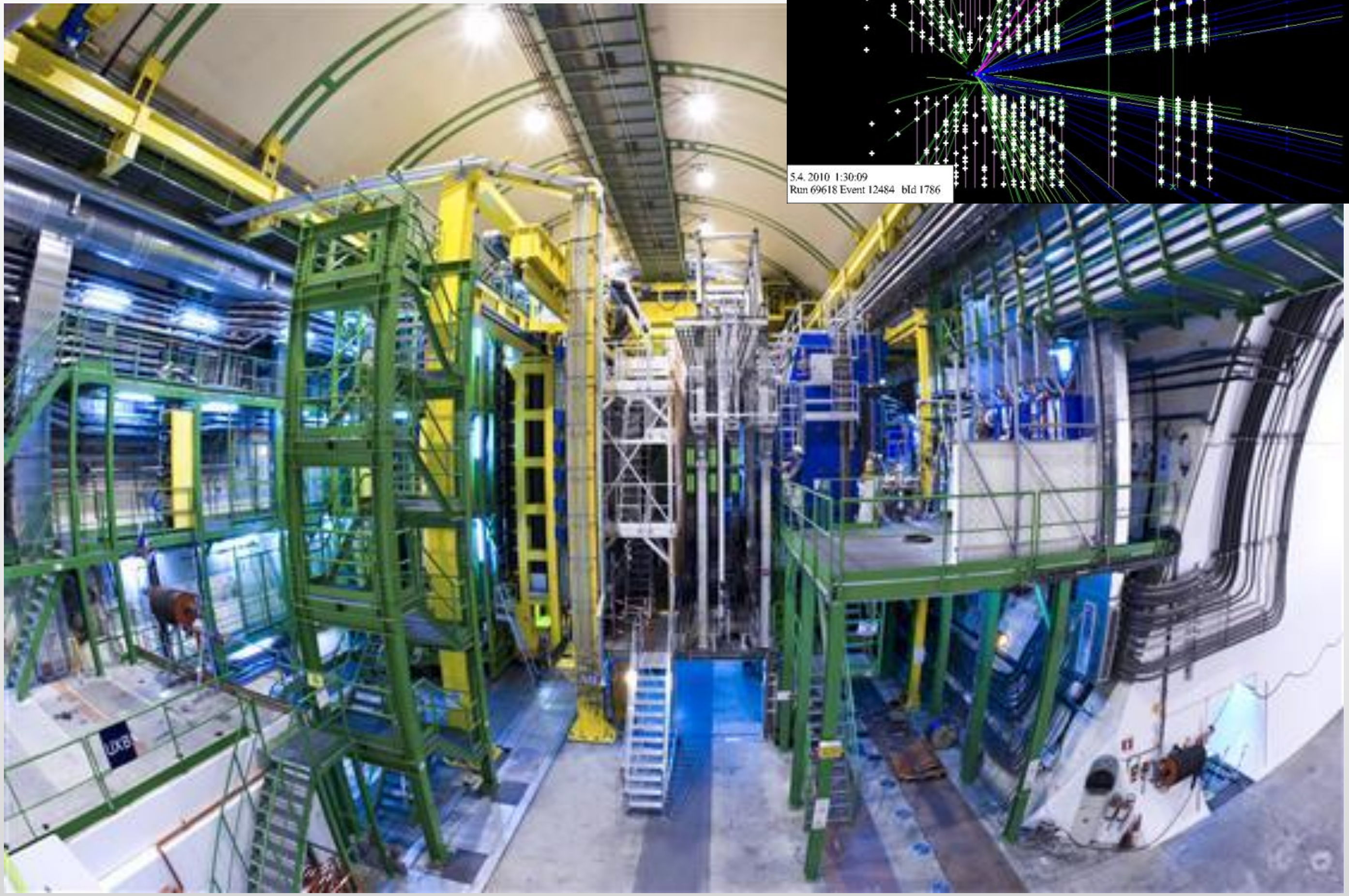
- LHCb is an experiment optimized to study beauty and charm decays at LHC, exploiting the high $b\bar{b}$ and $c\bar{c}$ production cross section, spatial correlation between b and $\bar{b}$, and long b decay distance because of the high boost
- A few important numbers:
  - Track acceptance $1.9<\eta<4.9$
  - $\sigma_{bb} \approx 300$ μb at 3.5+3.5 TeV [see Passaleva & Stone talks]
  - Nominal luminosity 2×10^{32} cm^{2}s^{-1}



LHCb now

LHCb Event Display





See contributions by Borghi [01], Powell[01], Stone [01], Van Herwijnen [01], Blanks[04], McNulty[04], Passaleva[05], Mancinelli [06], Belyaev [06], Bediaga [06], Haines [06] Raven[06], Adinolfi [13]

Upgrade goals

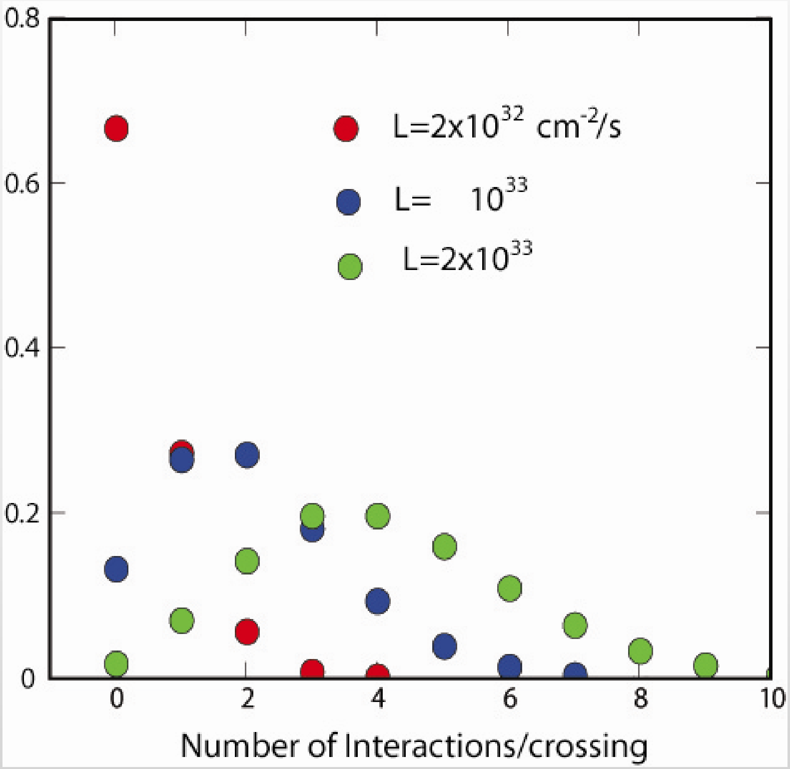
- We expect new physics to be seen at LHC (complementary information from ATLAS/CMS and LHCb), the next step is a characterization of new physics through virtual interference with W & Z in the b and c decays
- Thus we want a ≥ 10 increase in sensitivity through:
  - Increase nominal luminosity
  - Increase efficiency on b hadron trigger (×≈2)
- Planned in 2 phase matching LHC schedule: phase I (nominal $\mathcal{L}=1\times10^{33}cm^{2}s^{-1}$) and phase II (nominal $\mathcal{L}=2\times10^{33}cm^{2}s^{-1}$)

(Most of the talk focuses on phase I)

The high luminosity challenge

At $\mathcal{L}=2\text{x}10^{32}$ cm^2s^{-1} [nominal running conditions envisaged for the present detector] most crossings do not have an interaction and the mean number of interactions per crossing is 0.4.

- At $\mathcal{L}=10^{33}$ cm^2s^{-1} [phase I] the mean number of interactions per crossing is ≈2.3 & 15% of the crossings are empty
- At $\mathcal{L}=2\text{x}10^{33}cm^2s^{-1}$ [phase II] the mean number of interactions per crossing is ≈ 4.6 and all the crossings have at least 1 interaction



The solution: software trigger

<u>Concept</u>:

we need to follow all the clues that will emerge in the next few years with a strategy flexible and highly selective ➔ software trigger exploiting detached vertex information early on

<u>Implementation:</u>

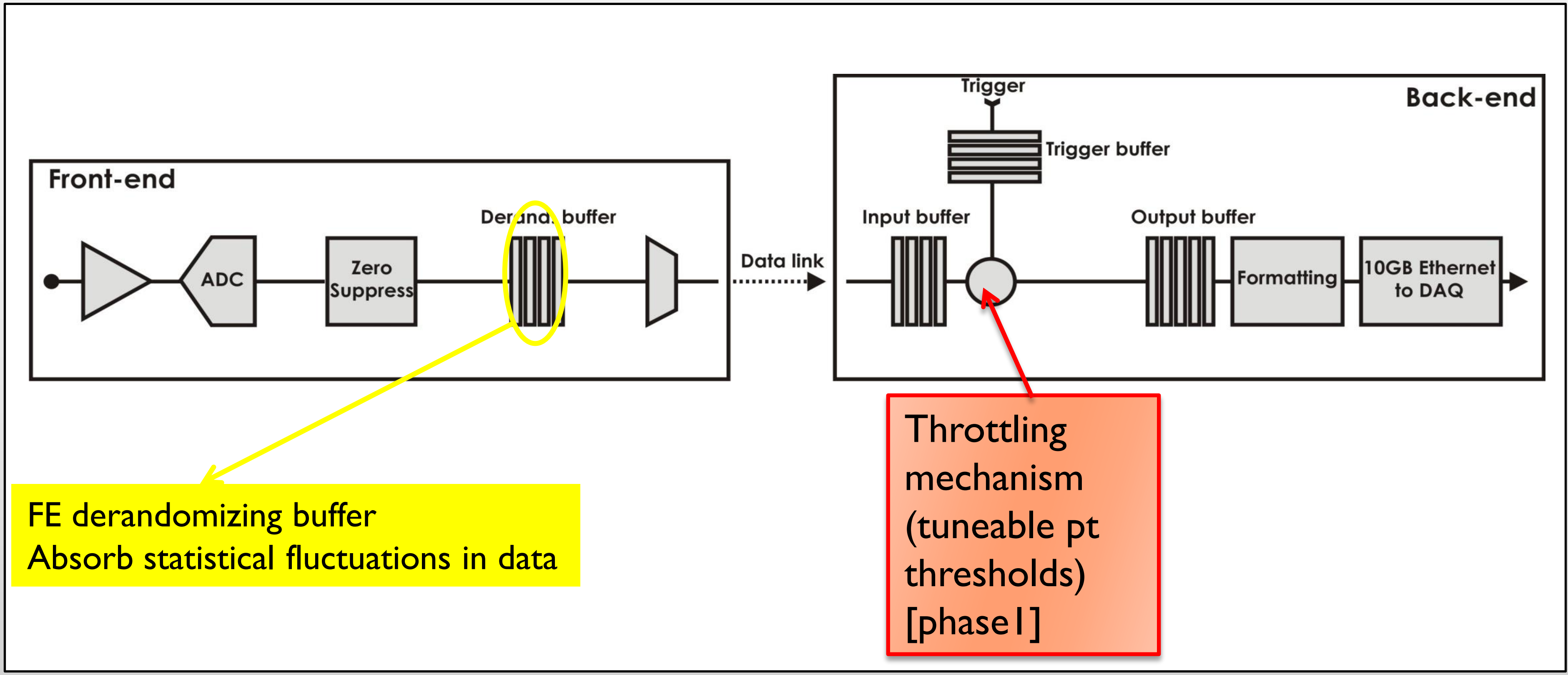
Read out the detectors at 40 MHz and use all the relevant information to suppress background (minimum bias, but also not so interesting beauty and charm signals)

<u>Goals:</u>

- ❑20 KHz on tape (now 2 KHz)
- ❑10^5 reduction factor on minimum bias
- ❑Trigger efficiency for interesting B hadronic decays 50 %

Electronics & DAQ for 40 MHz readout

- Zero-suppressed readout
- Fast optical link used
- Readout boards common to all subdetectors



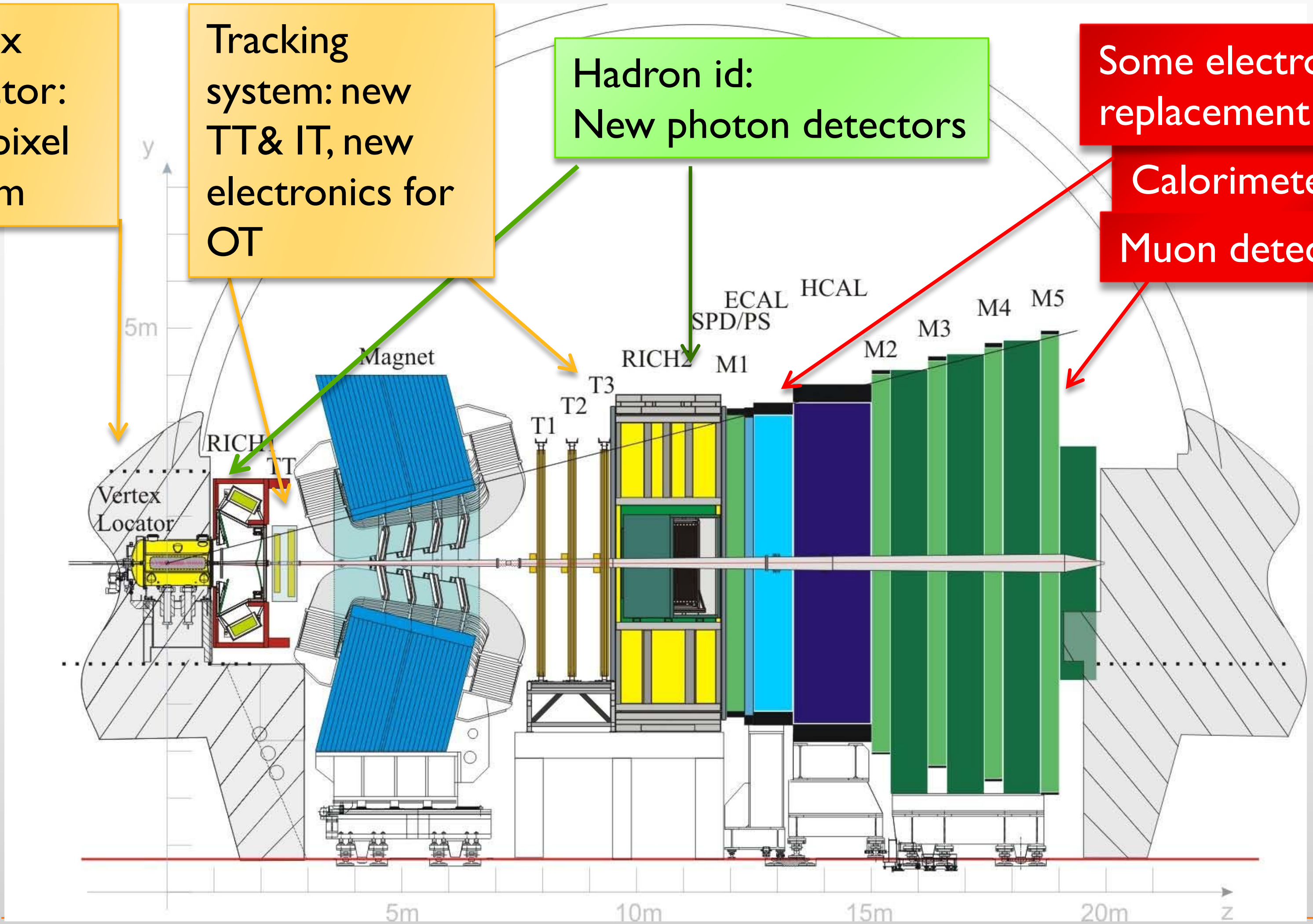
LHCb detector evolution in Phase I

Vertex detector: new pixel system

Tracking system: new TT& IT, new electronics for OT

Hadron id: New photon detectors

Some electronics replacement for Calorimeter Muon detector

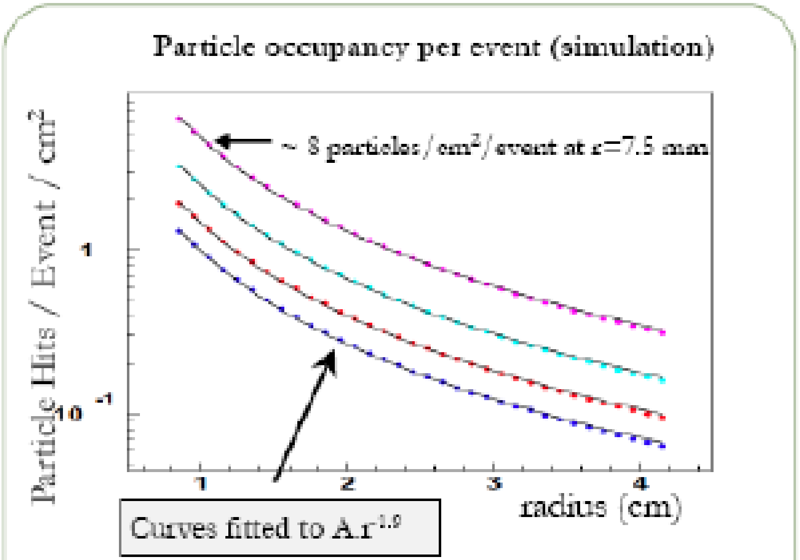


Upgrade schedule (matched to LHC)

- phase I: ≈2016 LHC shut-down
  - Novel pixel based vertex detector (VELOPIX)
  - New front end electronics
  - New trigger and data acquisition concept to achieve better efficiency for hadronic B decays
  - RICH photon detector replacement
  - New TT & IT tracking systems
- phase II:
  - new hadron ID system (torch) bases of precision time of flight
  - Better electromagnetic calorimeter segmentation
  - Change to tracking: IT & OT geometry

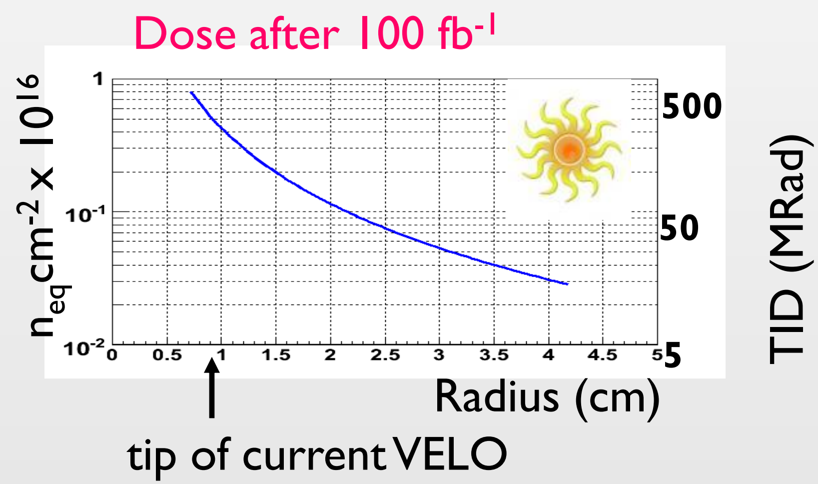
Challenges for the tracking system

occupancy



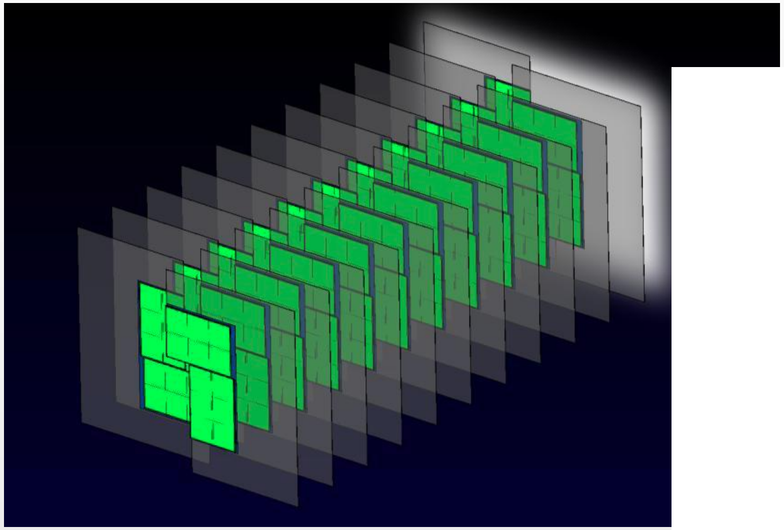
Luminosity ($cm^{-2}s^{-1}$)	2.10^{32} Current	5.10^{32}	10.10^{32}	20.10^{32} Upgrade
A=	0.98	1.46	2.46	4.80

Radiation environment

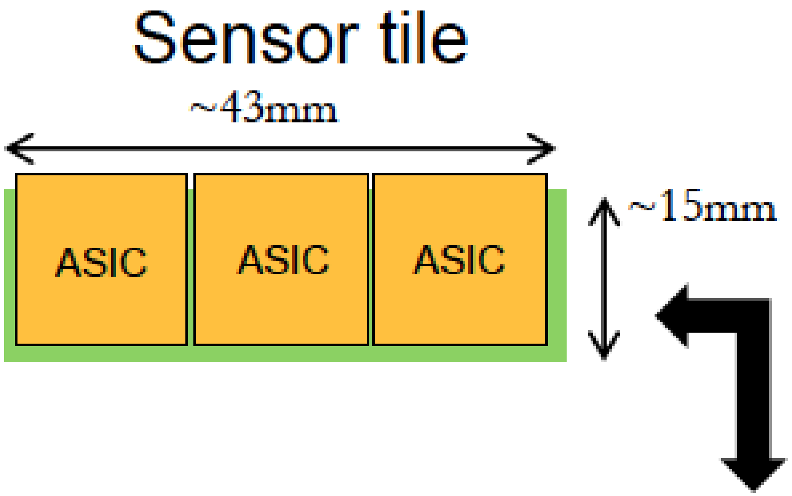


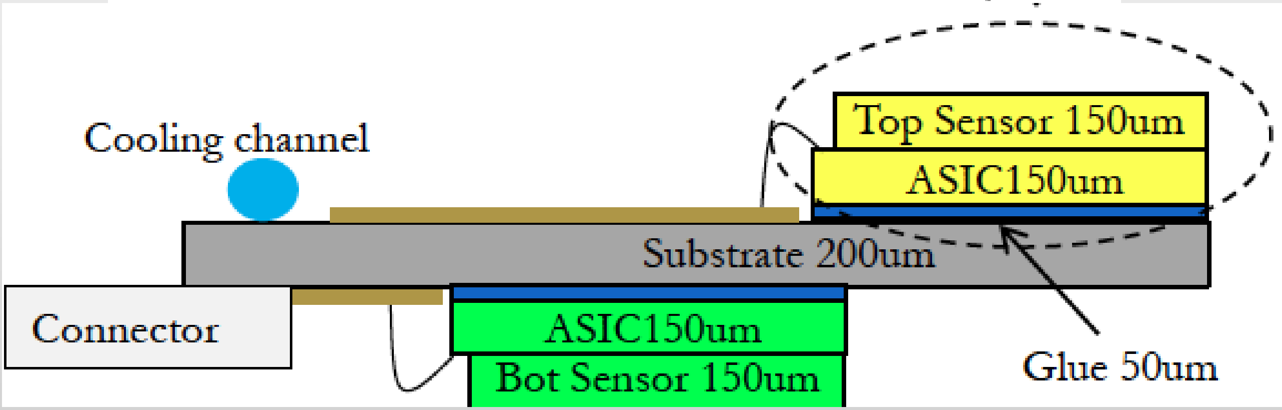
Danger of thermal runaway
Si must be cooled down to -10°C°

The VELO PIXEL Detector System



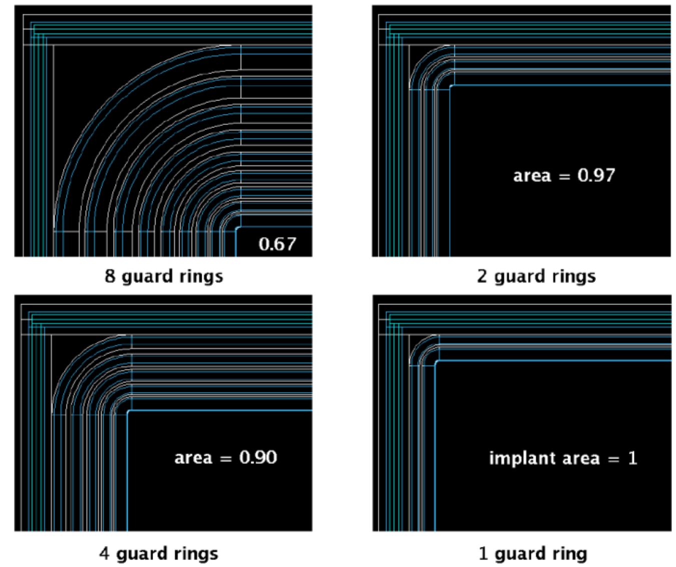
ASIC IS AN ARRAY OF 256X256 SQUARE PIXELS (55 μm X 55 μm)

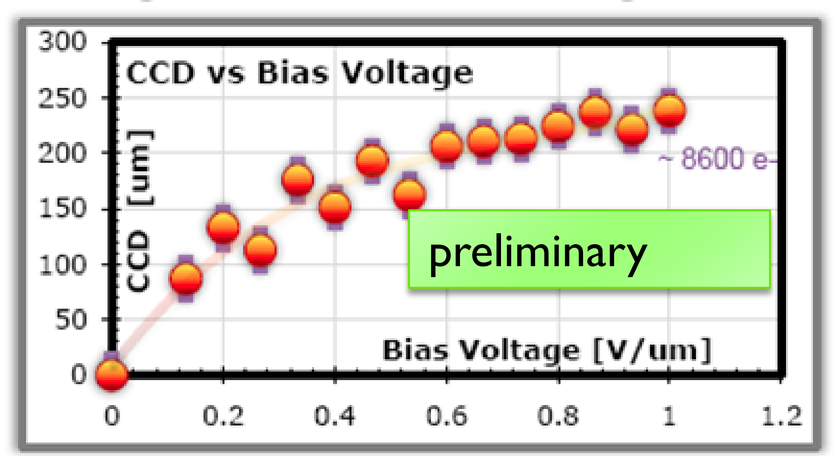




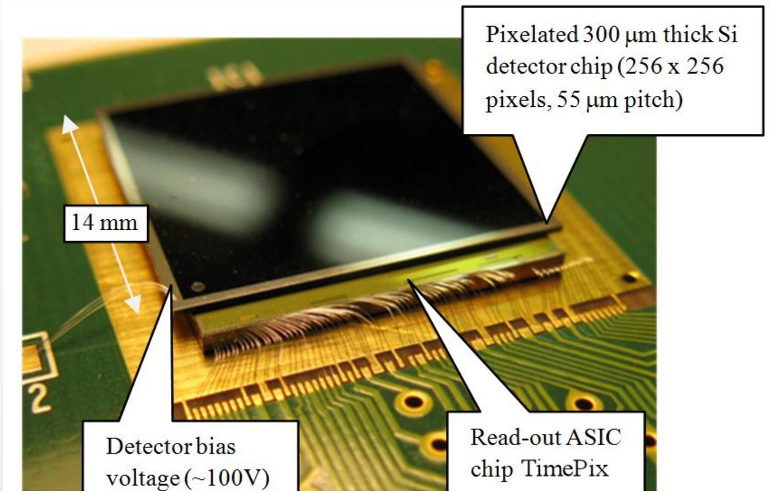
Velopix Sensor Choices

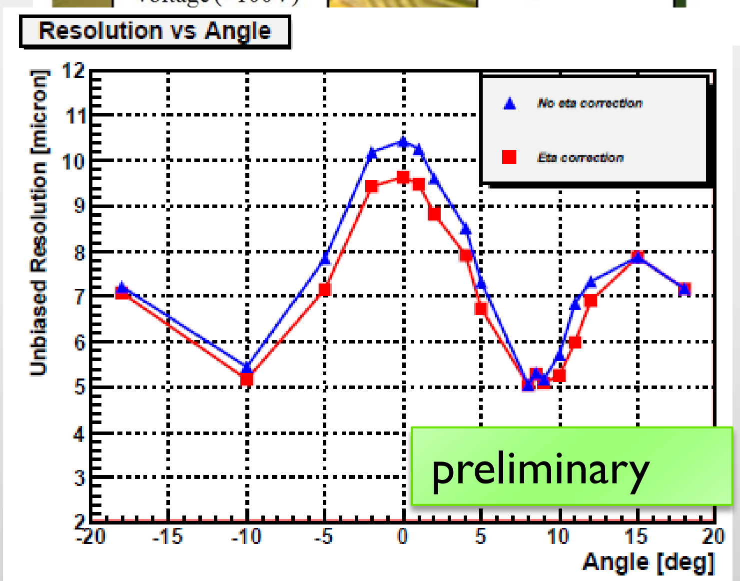
- 3 options being pursued:
  - Planar silicon n-in-p 150 μm thick (started studies of 150 μm thick p-in-n USC/CNM)
- 3D silicon under investigation (Glasgow/CNM)
- Diamond pCVD: advantages no thermal runaway, produced 1.43x1.43 cm^2 750 μm thick sensors.
  - metallized with a large pad & measured collection distance using Sr^{90} source
  - 1 sensor metallized with strips, test beam underway
  - Will produce pixel devices in the fall





The VELOPIX ASIC



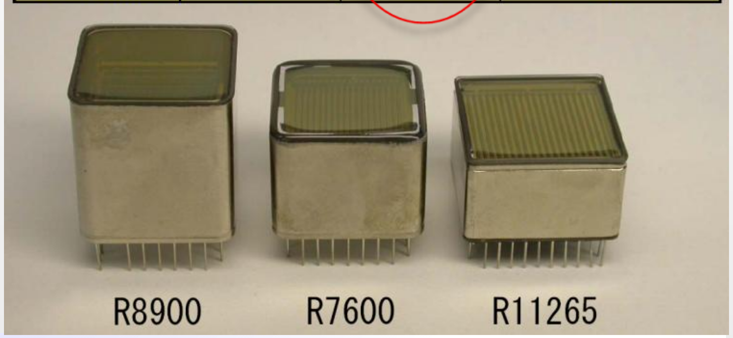


- Starting point TIMEPIX (imaging ASIC developed by the MEDIPIX collaboration)
- Studied in the test beam gave excellent spatial resolution (≈5 µm at 8°) still including 2.3 µm track prediction error. Red curve is with non-linear charge weighting correction.
- VELOPIX will be derived from TIMEPIX2 development (faster analog front end, simultaneous TOT & time of arrival measurement, faster output data rates)

Unique to VELOPIX: clustering of the sparsified information, data formatting and buffering, additional multi-Gbit output links for 40 MHz readout

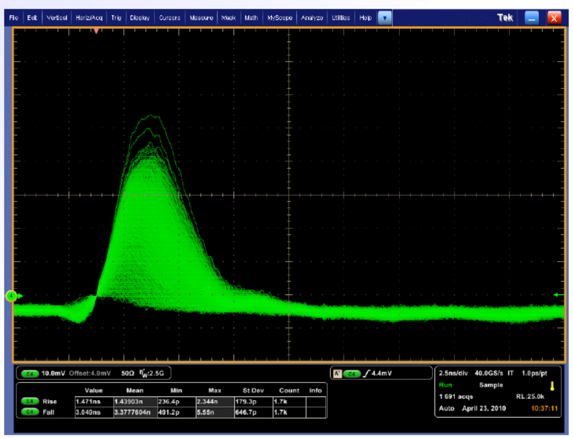
RICH Upgrade Phase I

	R8900	R7600	R11265
Total length	34mm	27mm	23mm
Effective area	23.5mm	18mm	23mm
CE (Simulation)	75%	80%	90%



Discrete components prototype: performances

Signals from single photons on a MA-PMT pixel



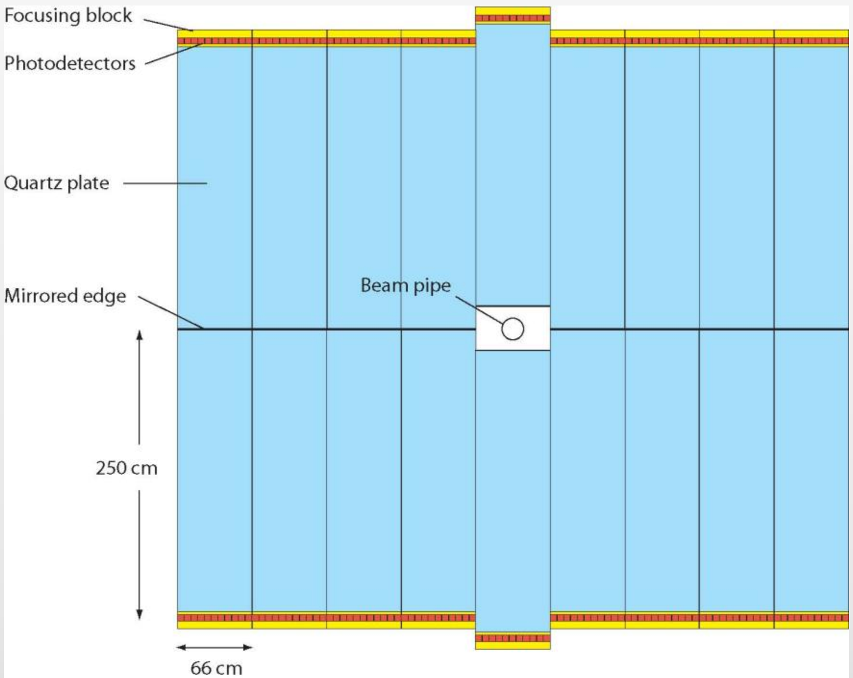
- **Risetime 1.4 ns**: maybe limited by the PMT?
- Falltime 4 ns

June 10, 2010 MA-PMT Upgrade: Front-end 6

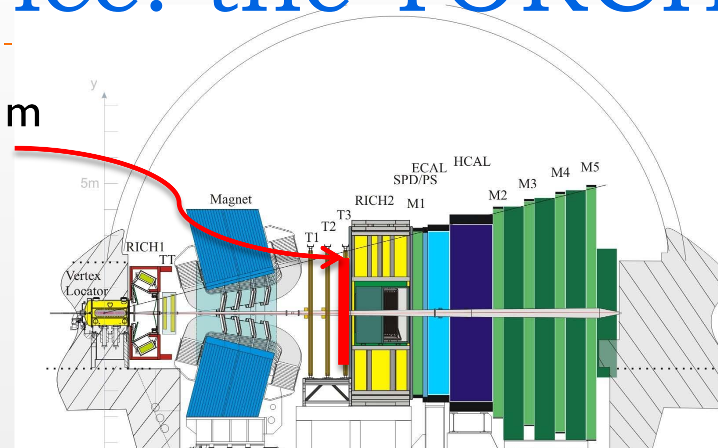
- Photon detector candidate MaPMT R7600 from Hamamatsu
- Performance studies under way (pulse shape, timing)
- New 40 MHz readout under development

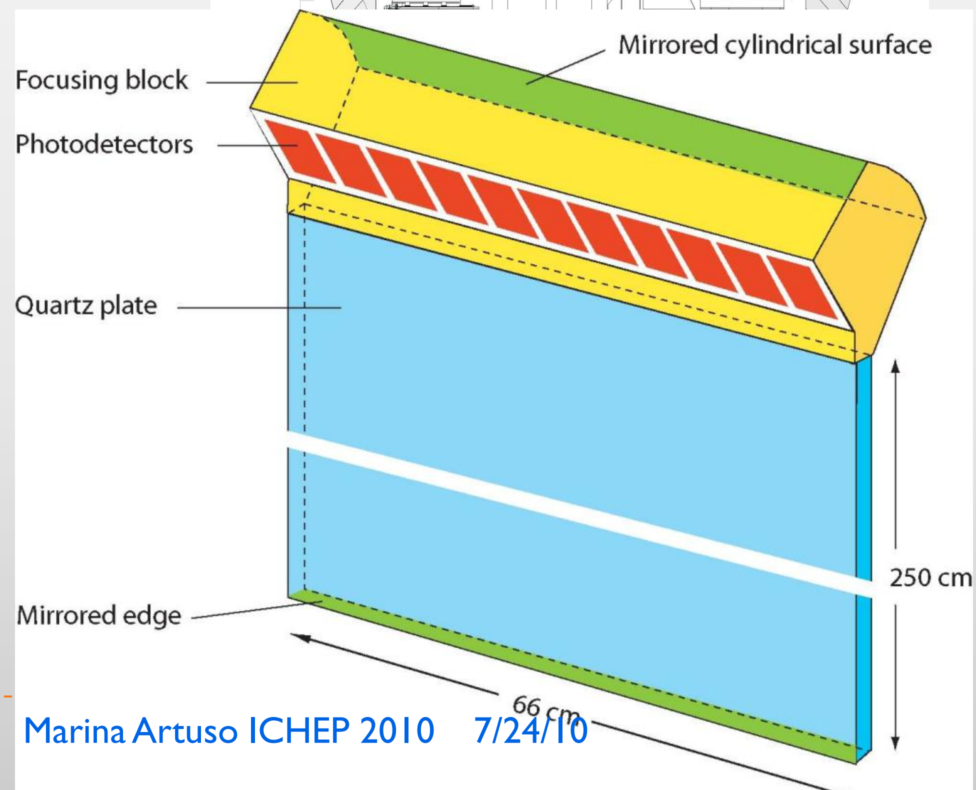
A new hadron ID device: the TORCH

Modular design:

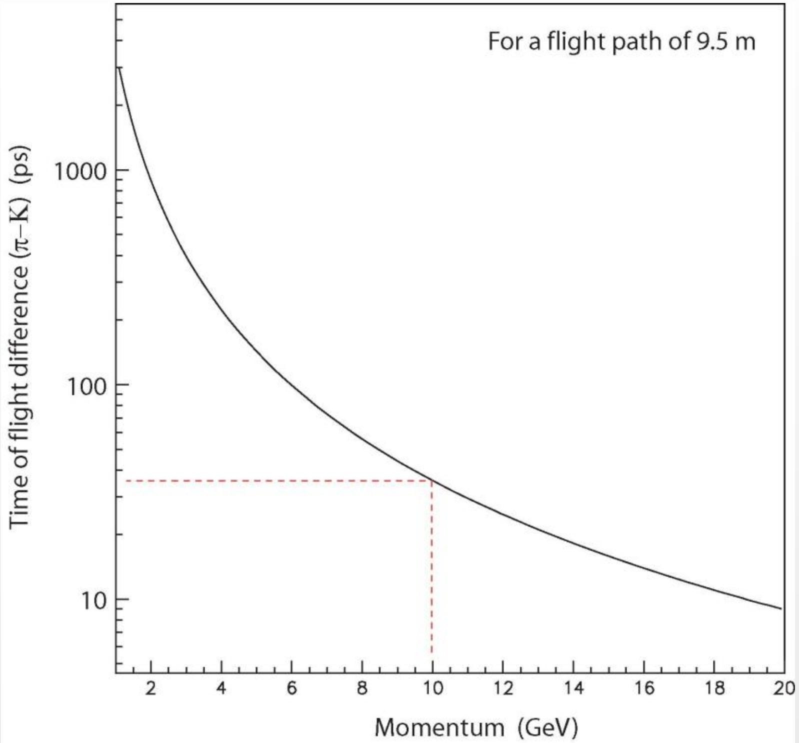


1cm quartz at z≈9.5 m

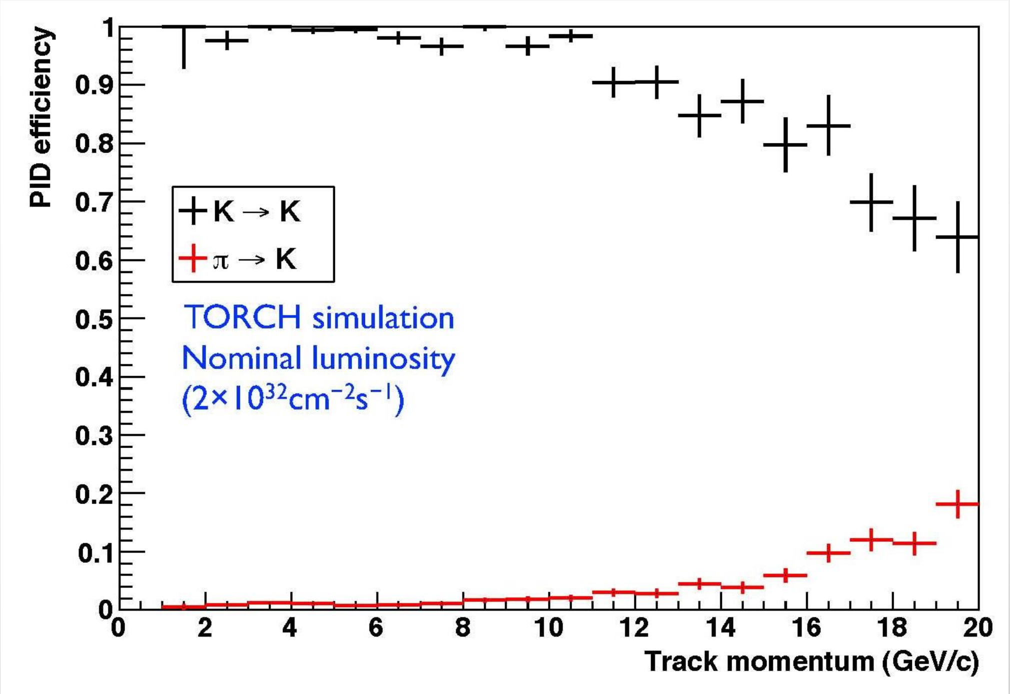




Performance goals and requirements



Requirement: time resolution per photon 50 ps, not unreasonable, see work by P. Krizan Pos (PD07)021



Calorimeter & Muon system

- Currently trigger processor read out at 40 MHz
- Modifications to electronics needed:
  - Upgraded FE boards to read out all the detector information at 40 MHz

Conclusion

- LHCb has a well developed plan and timeline for a staged upgrade (first step in ≈2016)
- The upgrade strategy is SLHc independent
- We are poised for a long and exciting physics program
- NEW COLLABORATORS ARE WELCOME!

Upgraded Sensitivities (50 fb^{-1})	
Observable	Sensitivity
$CPV(B_s \to \phi\phi)$	0.024
$CPV(B_d \to \phi K_s)$	0.027-0.064
$CPV(B_s \to J/\psi\phi)$ $(2\beta_s)$	0.004
$CPV(B_d \to J/\psi K_s)$ (2β)	0.004-0.014
$CPV(B \to DK)$ (γ)	<1.4°
$CPV(B_s \to D_s K)$ (γ)	1.4-2.8°
$\mathcal{B}(B_s \to \mu^+\mu^-)$	~15% of SM
$A_{FB}(B \to K^*\mu^+\mu^-)$	Zero to ±0.1 GeV^2
$\sigma(\sin 2\psi)(B_s \to \phi\gamma)$	0.03
Charm mixing x'^2	$3x10^{-5}$
Charm mixing y'	$4x10^{-4}$
Charm CP y_{CP}	$2x10^{-4}$