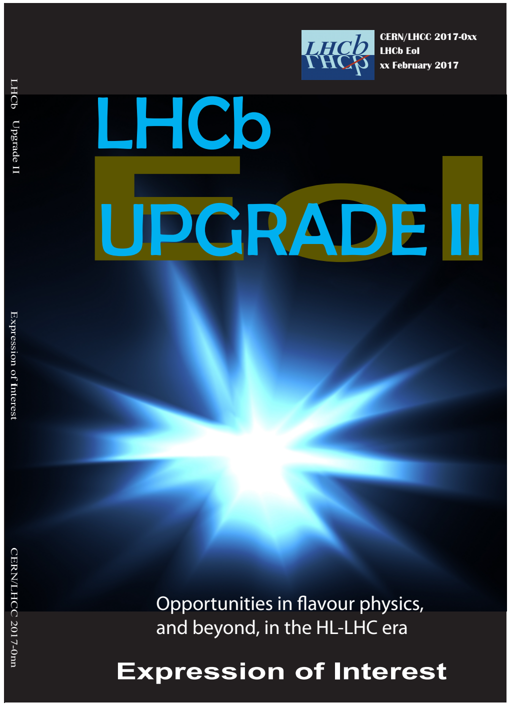
The University of Manchester

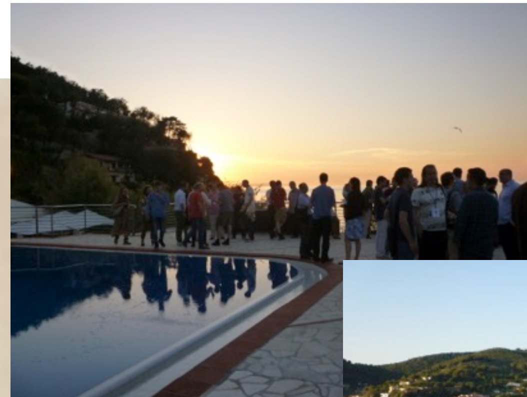
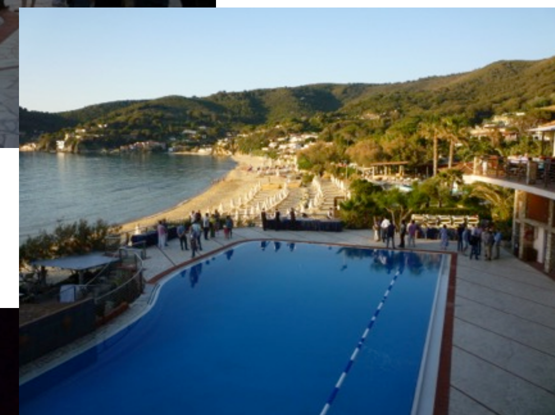
Phase II – Detector summary: Where next?



Chris Parkes

“I have met my destiny in quite a similar way”

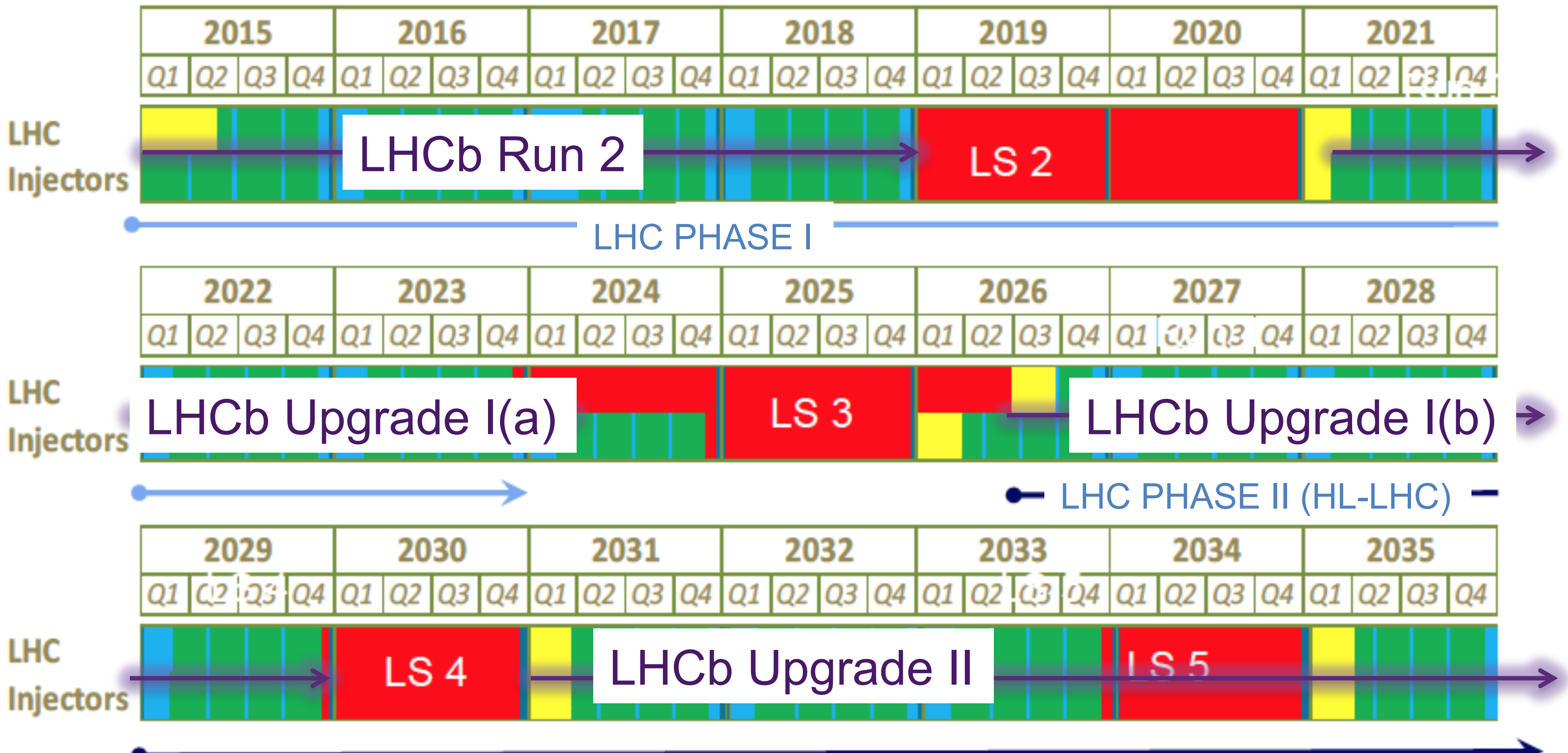
“I have met my destiny in quite a similar way”


Could have chosen to rest on his laurels but no he dreams of further triumphs !

LHC Schedule & LHCb

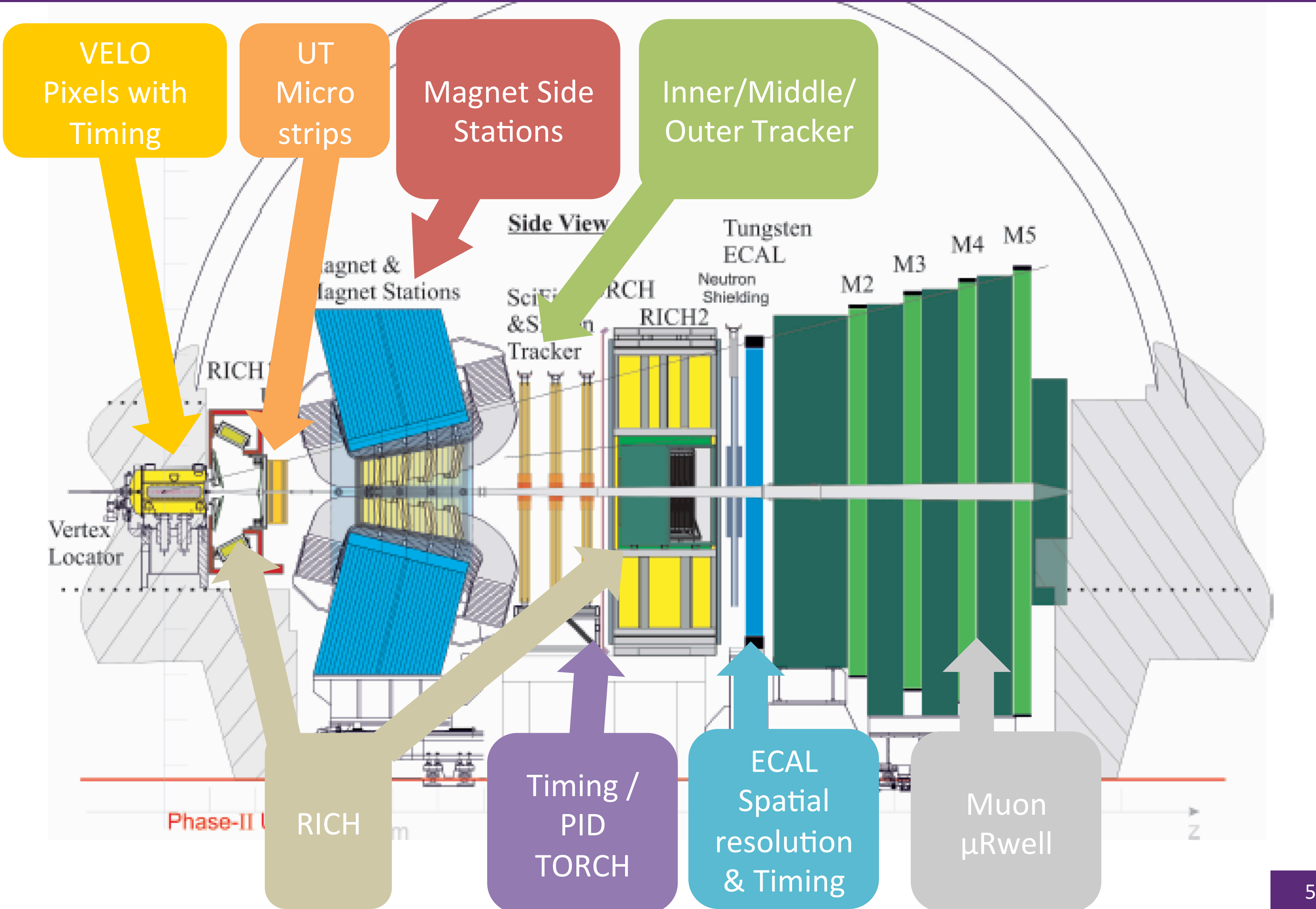
"I tried to hold you back but you were stronger"



- Schedule till 2020 reasonably firm
- GPD main upgrades (phase II) scheduled for LS3
- HL-LHC upgrade in LS3
- **Belle II finishes ~ 2025**

Phase-II Detector

"So how could I ever refuse ?"



HL LHC for LHCb Phase II

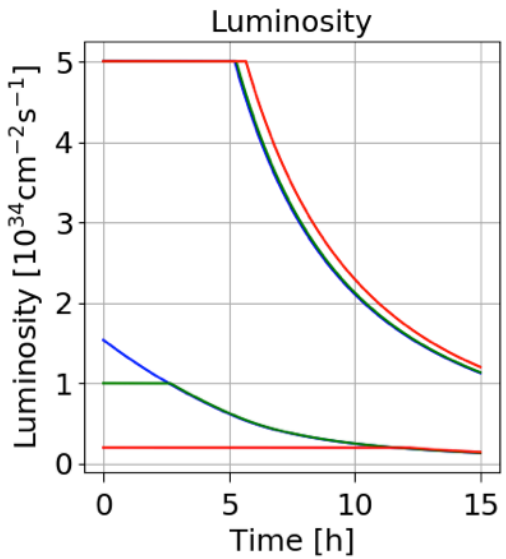
Ricardo De Maria

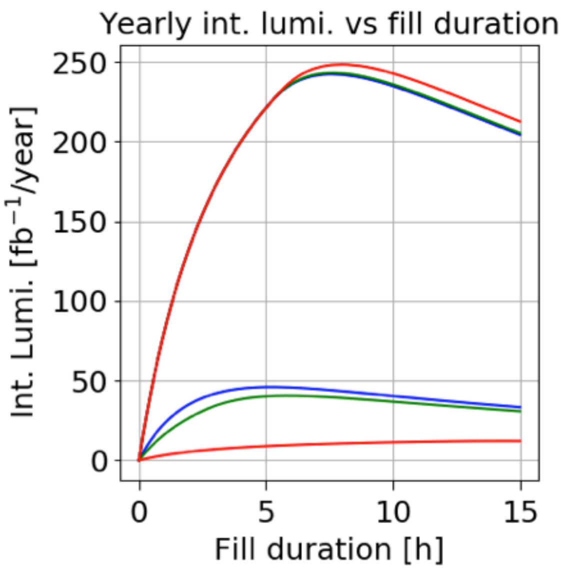
Challenges in machine parameters

- Reduce β* in IP8 below 3 m
- Reduce crossing angle
- Reduced levelling time

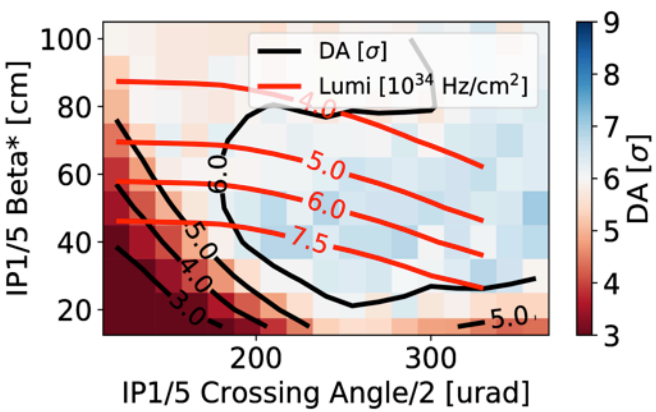
Assume new TCDDM

β* [m]	H* [μrad, σ]
1	±220, 15.5
1.4	±270, 22.5
2	±310, 30.9





Min DA; I = 2.2e11; I_{MO} = -570 A; Q' = 15 #;
LHCb@2e33 Hz/cm², 170 urad.



Impressive progress since EOI

- Working point exists to run in nominal scenarios.
- Beam separation and crossing angle of LHCb, have a visible impact on DA therefore lifetime
- Limit in triplet heat load at 1.6 x 10^{34} cm^{-2}s^{-1}

HL LHC - questions for us

- Do we want levelling at a maximum luminosity ?
  - For discussion: 1.6 x 10^{34} cm^{-2} s^{-1}
- Do we need equal samples of each magnet polarity ?
  - Magnet reversals will be infrequent
  - For discussion:
    - "maximise" integrated Luminosity
      - Take 300 fb^{-1} in two LHC runs
    - Retain ability to reverse magnet
      - Unfavourable polarity as calibration sample
- Need dedicated meeting session with HL LHC

to develop strategy & discuss responses for LHCC

VELO

Mark Williams

Challenge A: 10x particle multiplicity — Small Pixels

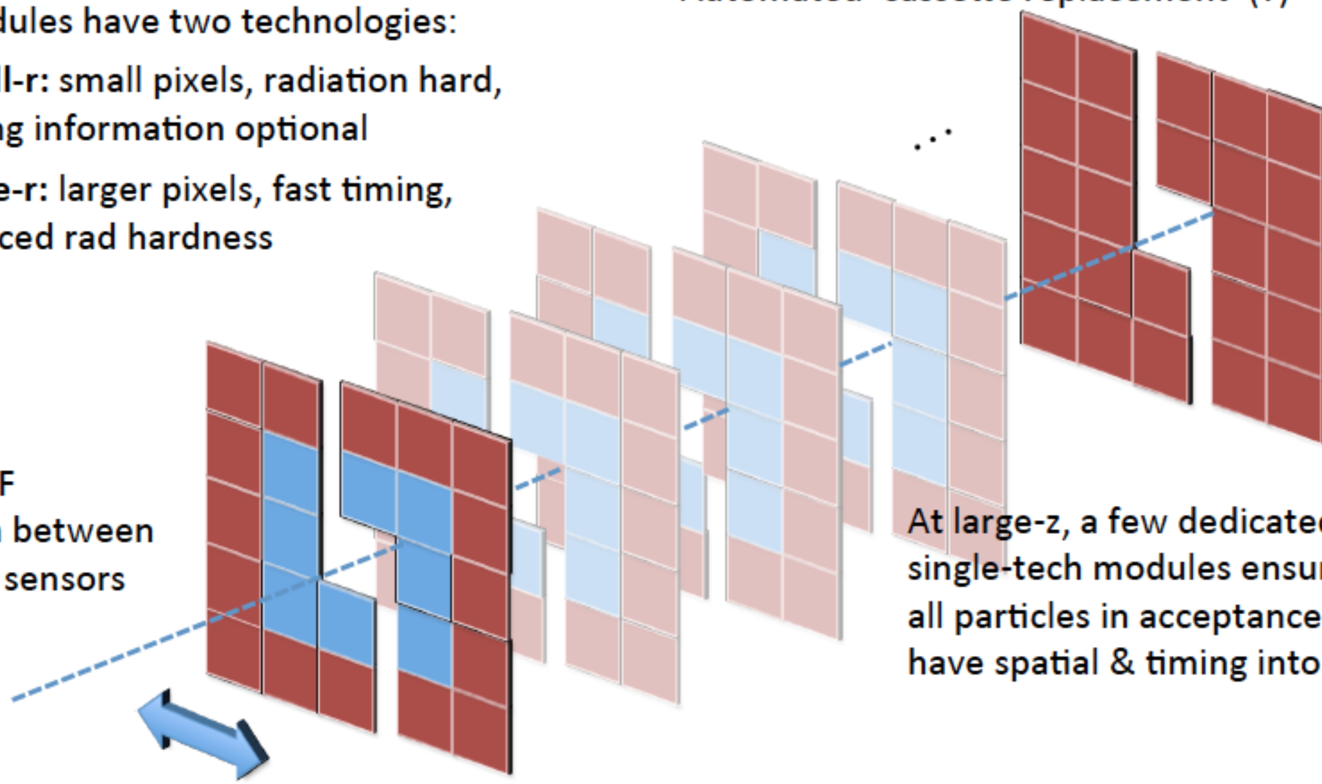
Challenge B: 10x vertex multiplicity — Timing

Challenge C: 10x radiation damage — Replacement

Automated 'cassette replacement' (?)

Main modules have two technologies:

- **Small-r:** small pixels, radiation hard, timing information optional
- **Large-r:** larger pixels, fast timing, reduced rad hardness



Minimal RF protection between beam and sensors

At large-z, a few dedicated single-tech modules ensure all particles in acceptance have spatial & timing into

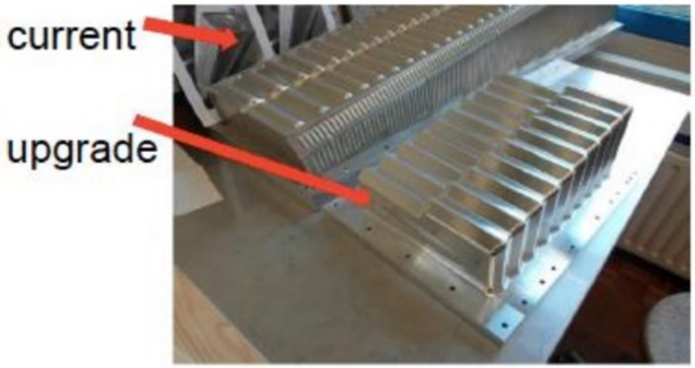
Retractable modules as in current/phase-I VELO

Cooling from evaporative CO_2 in microchannels? (benefit from phase-I experience)

RF Foil

N.Biancacci

Reaching Further: Removing RF Foil



Upgrade Phase II

CAD diagram
Ready for PRR
& material map
for Mike

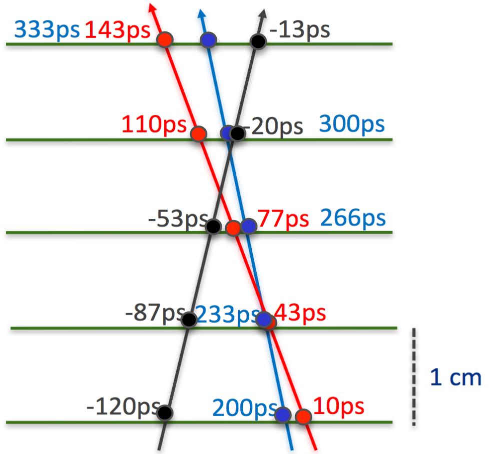
- Advantages:
  - Low Material Budget
  - Highly uniform
  - Easy to construct
  - Easy to describe in XML

Alternatives:

- Thinning by etching/polishing
- Soldered 10μm windows
- Metal coating on polymer
- Wire-cage structure

VELO – Fast Timing

Margherita Obertino



- ASIC **Timepix4 aiming for 200ps timing information**
- Sensors:

Ultra Fast Silicon Detectors final goal

90 x 90 μm^2

- c.f. VELOPIX 55x55 μm^2

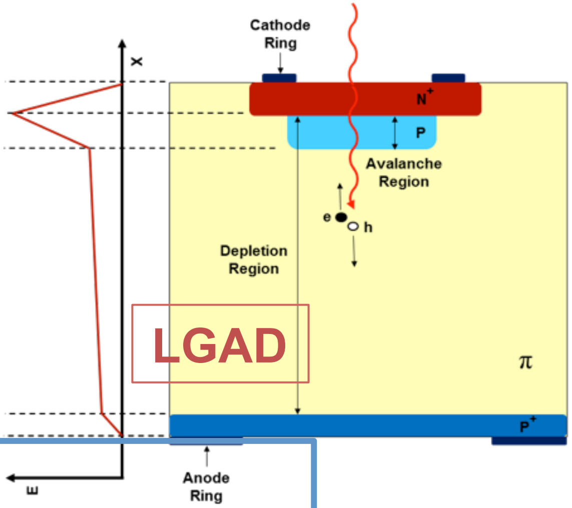
d ~ 50 μm

- Low material but support

σ_t ~ 30 ps

- Exceeds our specs

Use only "time compatible points"



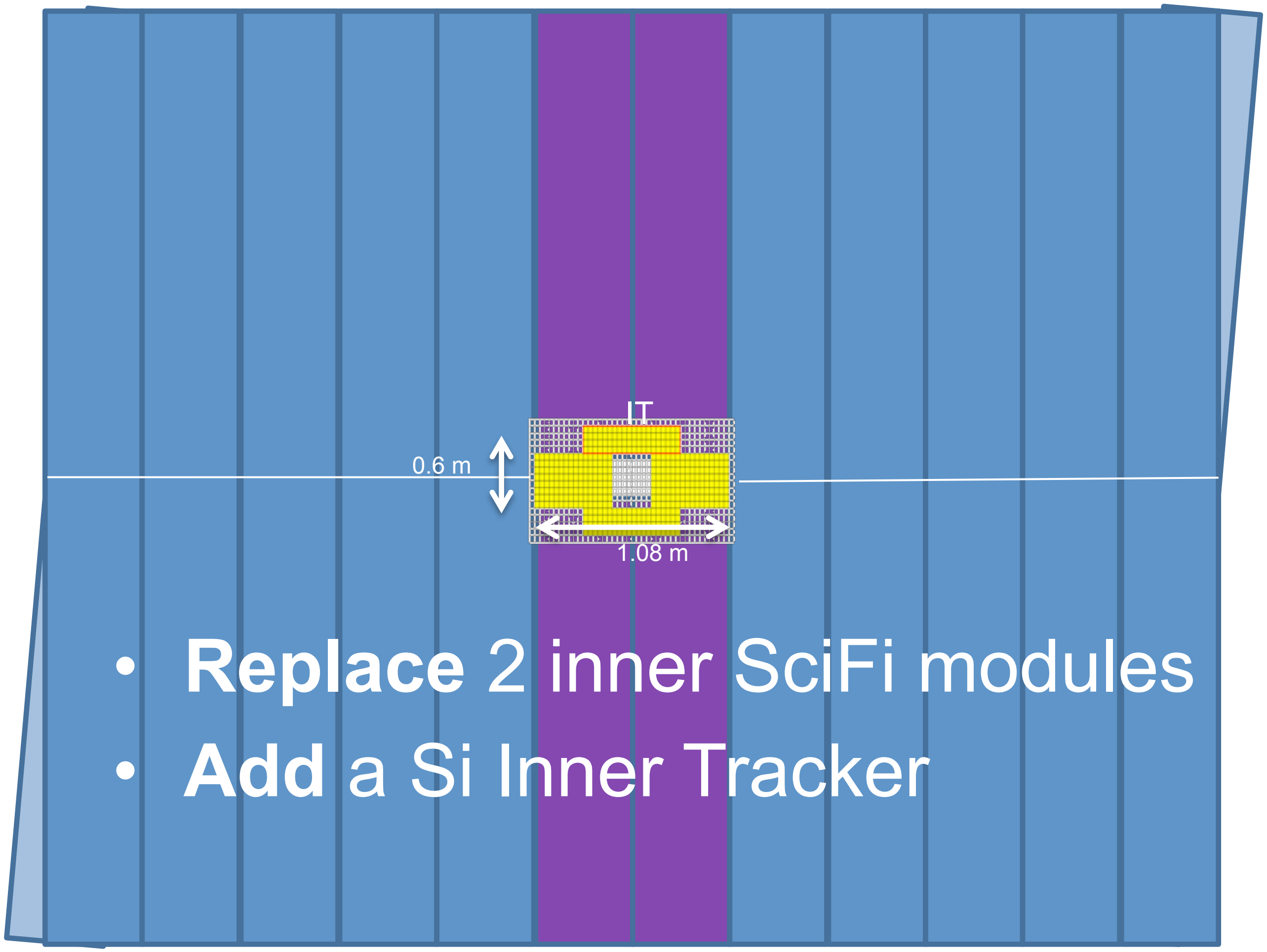
- Issues: Radiation Tolerance
  - Achieved is **100 times** less than we need

  Small Segmentation
- Achieved 30ps with **300 times** larger than VELOPIX

- Potential relevance to tracking timing planes also

Phase 1b Tracker

- Expand IT relative to EOI to assist Sci-Fi –$O(5)\mathrm{m}^2$

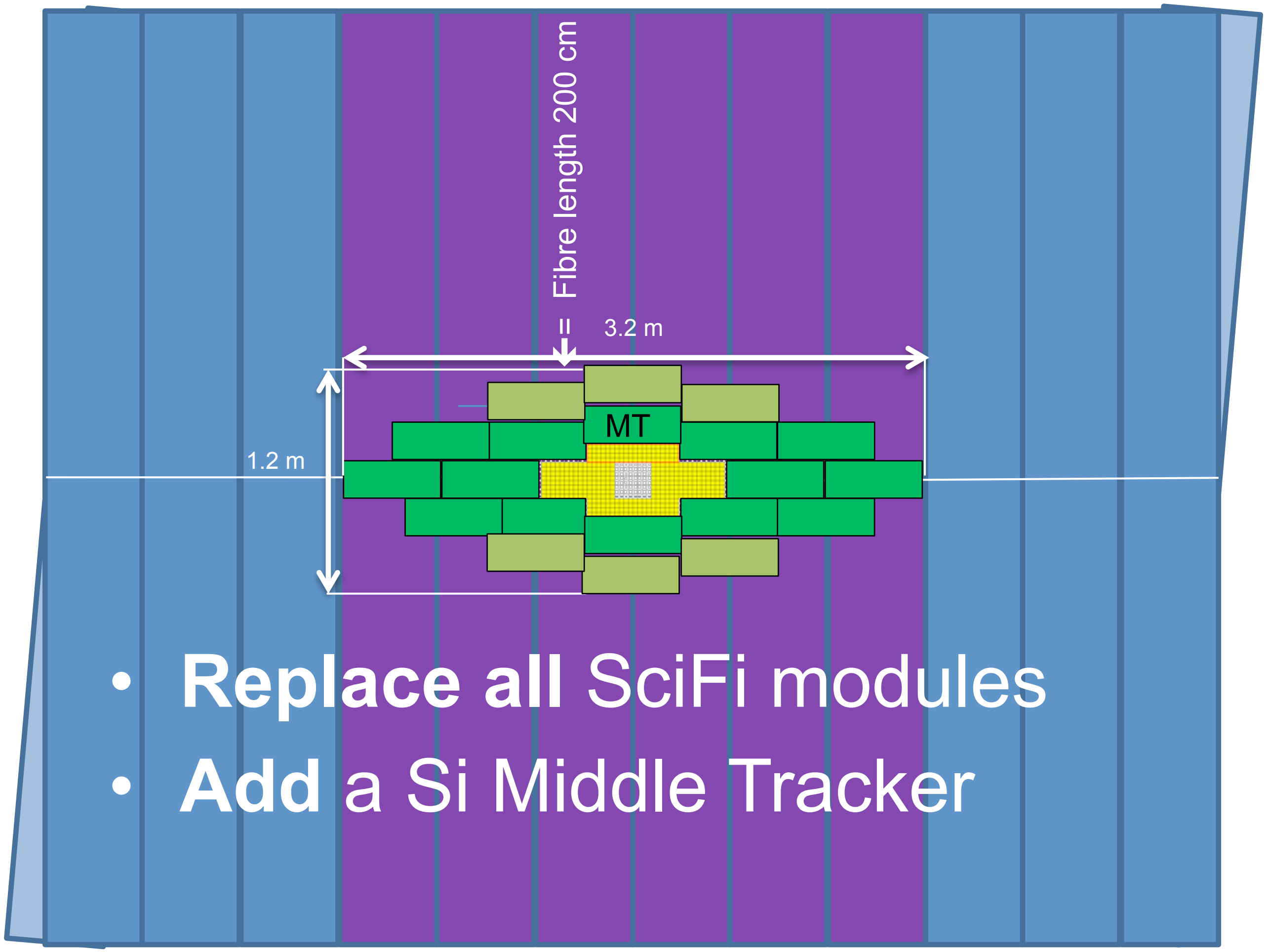


- **Replace** 2 inner SciFi modules
- **Add** a Si Inner Tracker

Sci-Fi Fibres order by end 2017 at current price? Construct 2021/2022

Phase II Tracker

- Expand MT relative to EOI to assist Sci-Fi -$O(20m^2)$

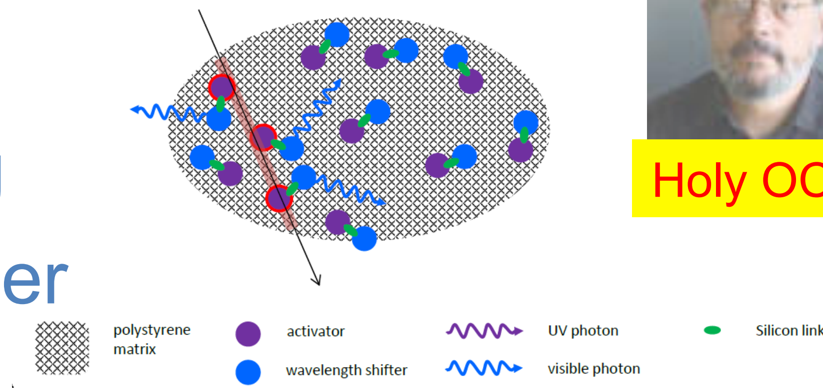


- **Replace all** SciFi modules
- **Add** a Si Middle Tracker

Sci-Fi

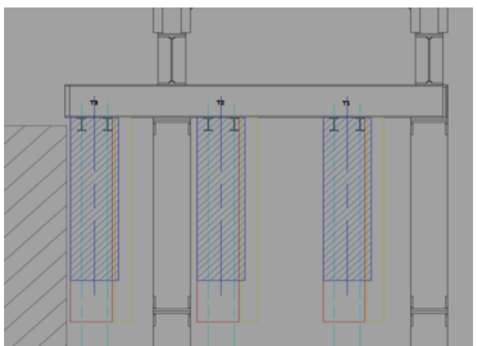
Christian Joram

- Neutron “torture”
  - Huge dark current rate
  - Temperature, shielding
  - SiPM E Field, FE shaper
- NOL Fibres



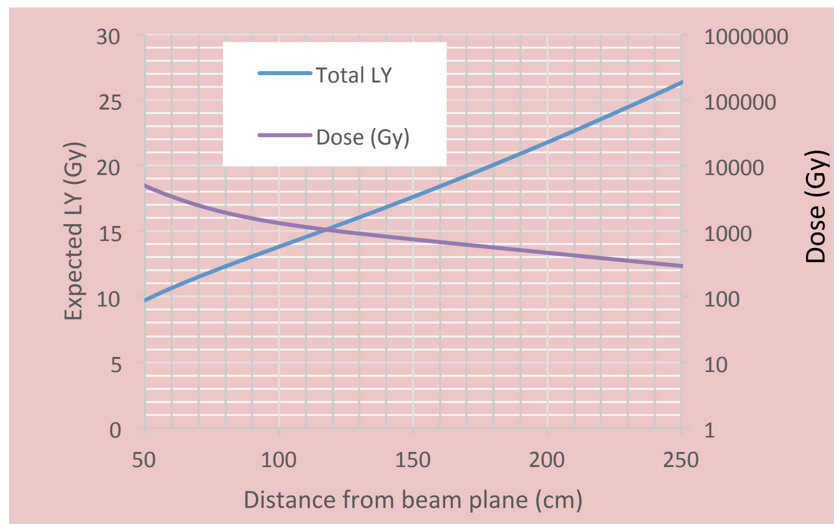
Holy OCL

- Services constraint



Limited z-space
For IT
Shared mechanics?

Alternative?
Micro Pattern Gas Detectors
attractive features but
higher non-uniform material budget

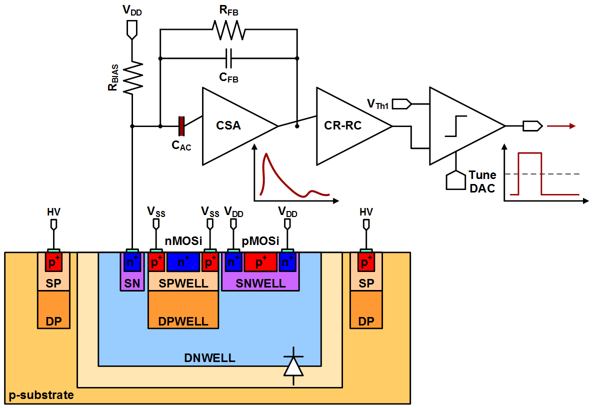


Fibres may just survive 300 /fb!

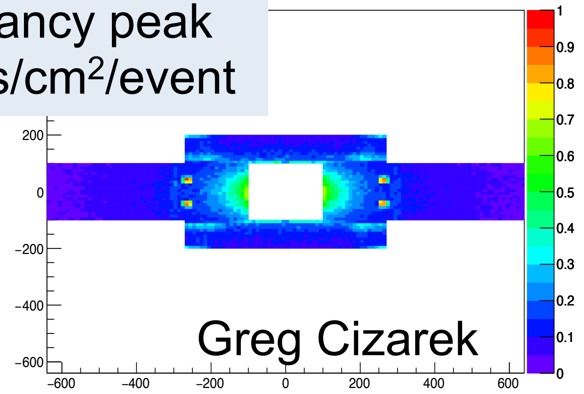
Inner Tracker - HVCMOS

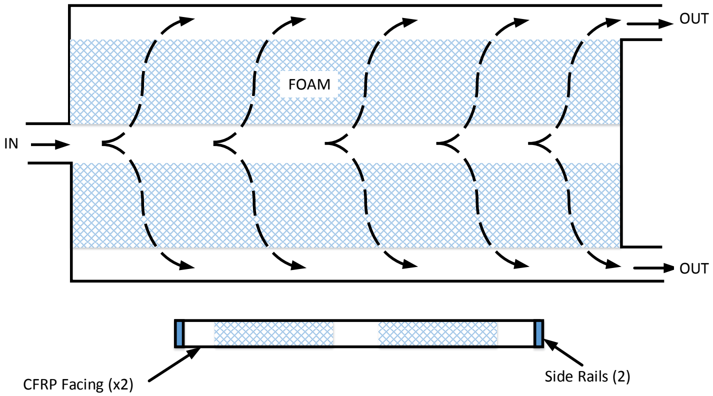
Themis Bowcock

- Sensor & Electronics on same chip
- Commercial Foundries
- Low cost (few CHF/cm^2)
- High granularity
- High signal/noise
- Low material (50μm)
- Radiation tolerant (>10^{14} 1 MeV n_{eq}/cm^2)



Occupancy peak
0.7 hits/cm^2/event

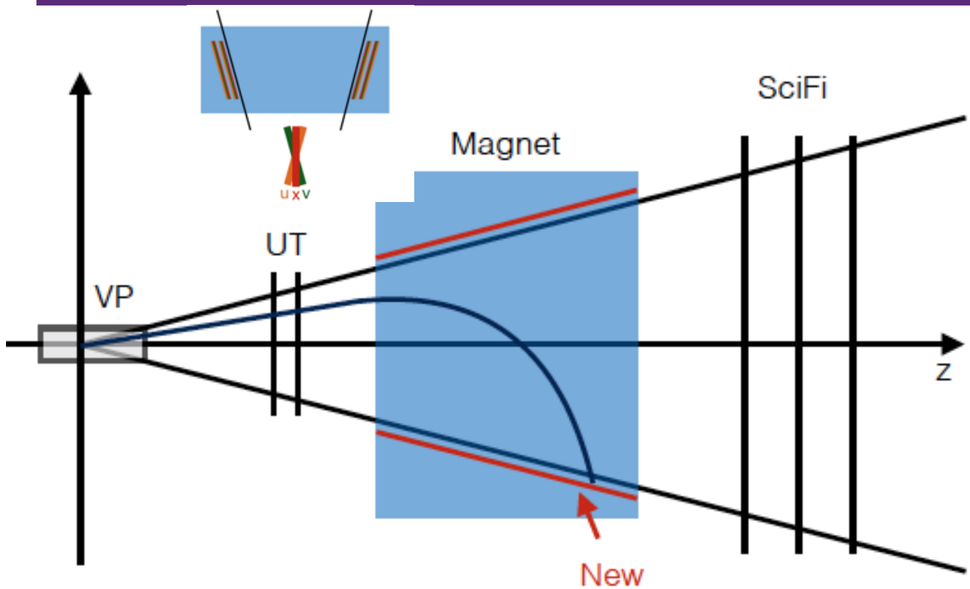




Support/Cooling Prototype

Magnet-side Stations

Maurizio Martinelli
Marcin Chrzaszcz



Prompt charm decays

$\Lambda_b \to \Lambda_c^* \tau \nu$

$B \to D^* \tau \nu$

$B \to \eta K$

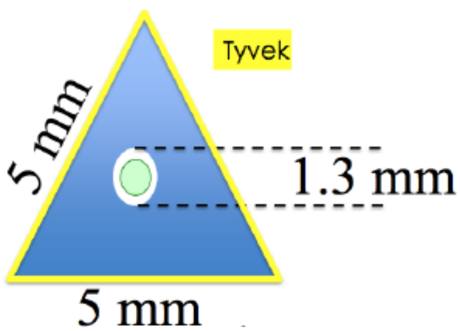
& Soft Bombs !

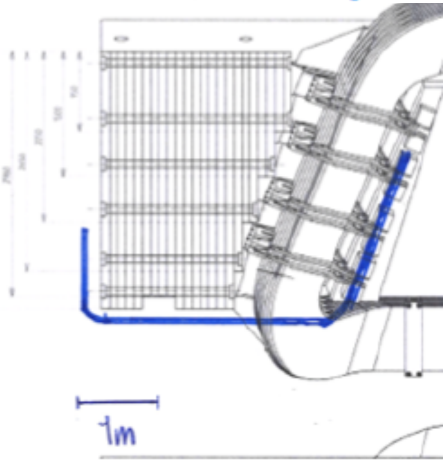
$\Sigma_b \to \Lambda_b \pi$

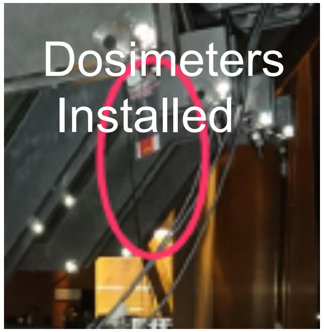
Gluon PDF

Spectroscopy

- Extruded Scintillator
  - Route with clear fibres
  - Prototype to be tested







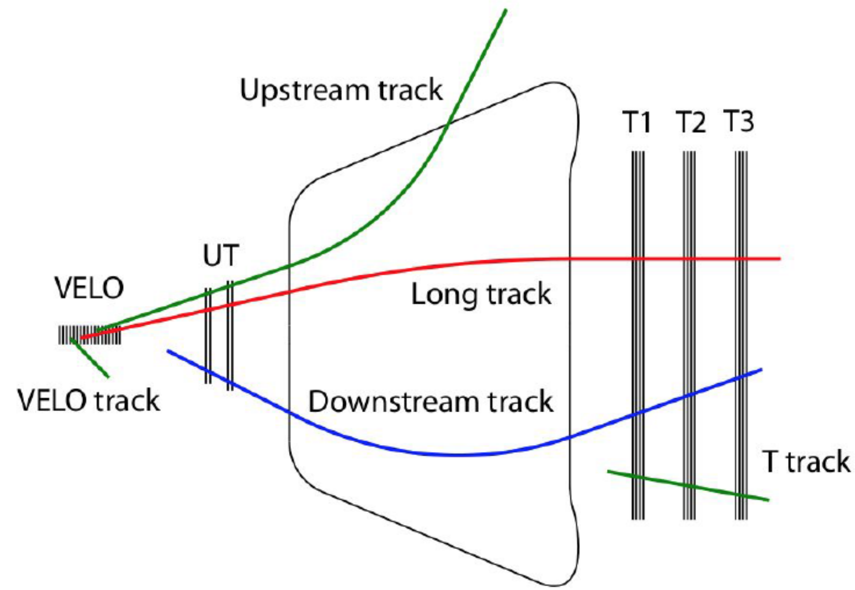
- Tracking & Simulation in development

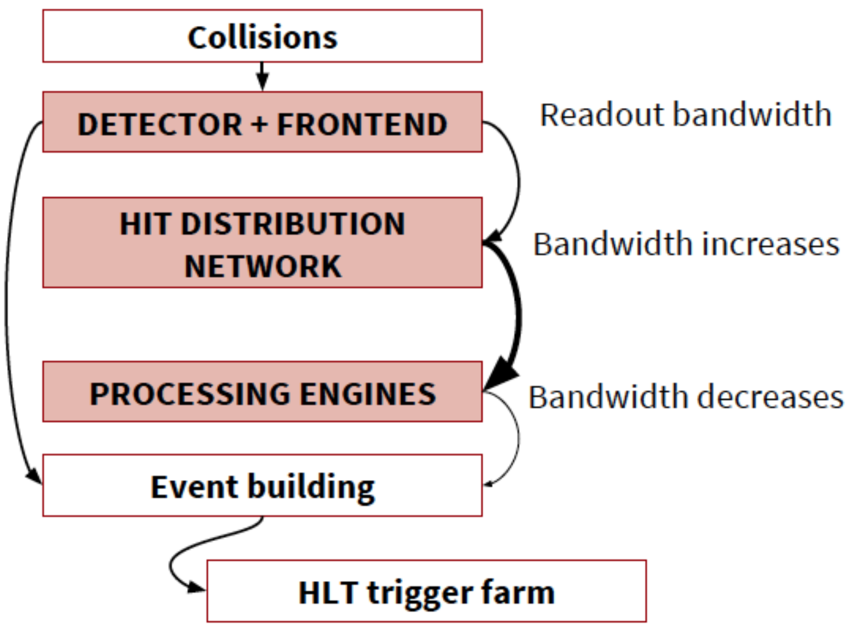
Downstream Tracking Unit

Simone Stracka

For Phase 1b

Without T- and downstream tracks, LHCb is only 50 cm long





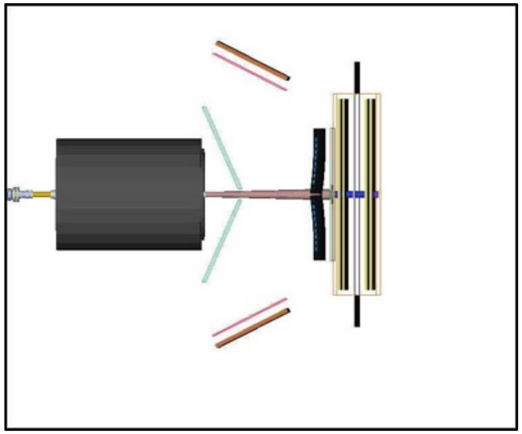
- Embedded Tracker Unit
- Algorithms implemented on commercial FPGA boards

9

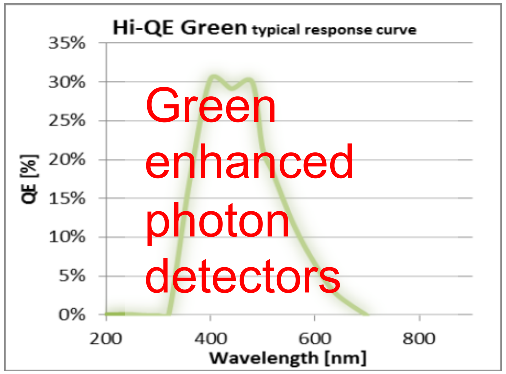
RICH

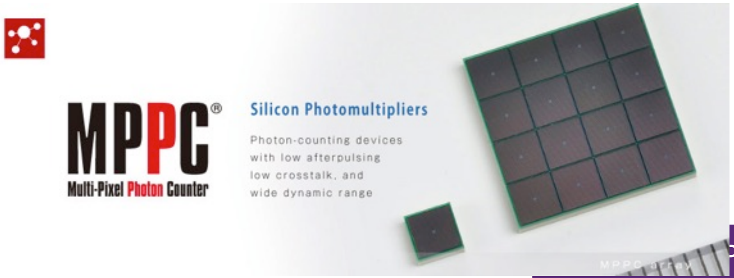
Carmelo d'Ambrosio
Sajan Easo
Gianluigi Pessina
Rok Pestotnik

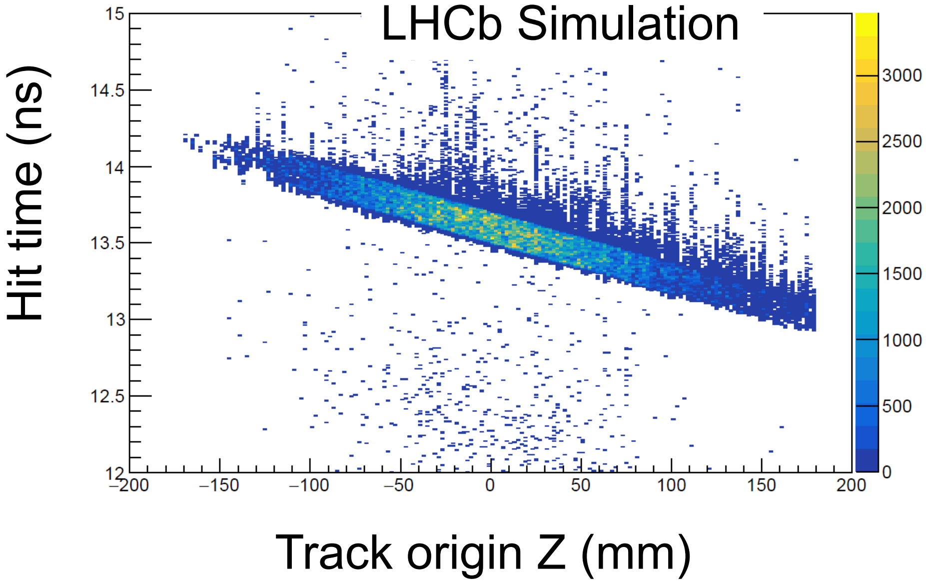
The recipe ☺



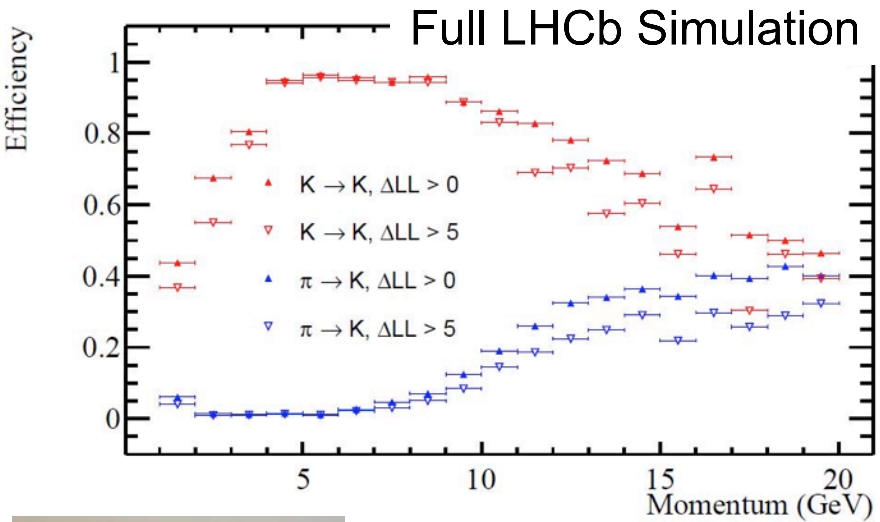
Increase granularity
Improve optical error,
Further reduce chromatic error
Provide the system with time resolution
Work on new and specific pattern recognition algorithms
Perhaps get rid of the magnetic shielding by using B-insensitive photodetectors

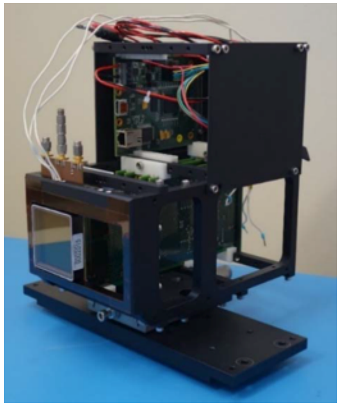






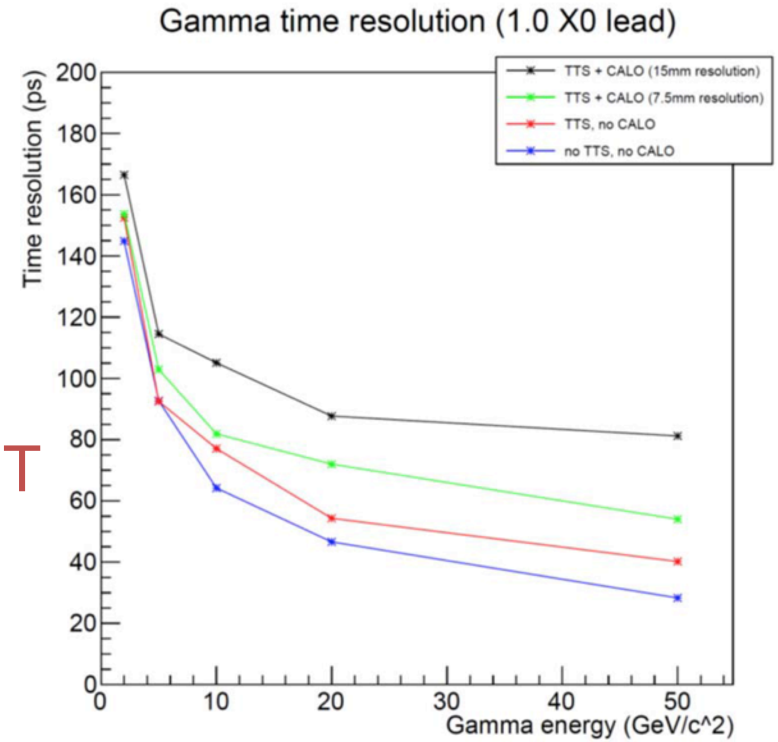
- Low p PID (K <10 GeV)





Technology:
Quartz radiator, MCP-PMT
Demonstrator tested
Full-scale in construction

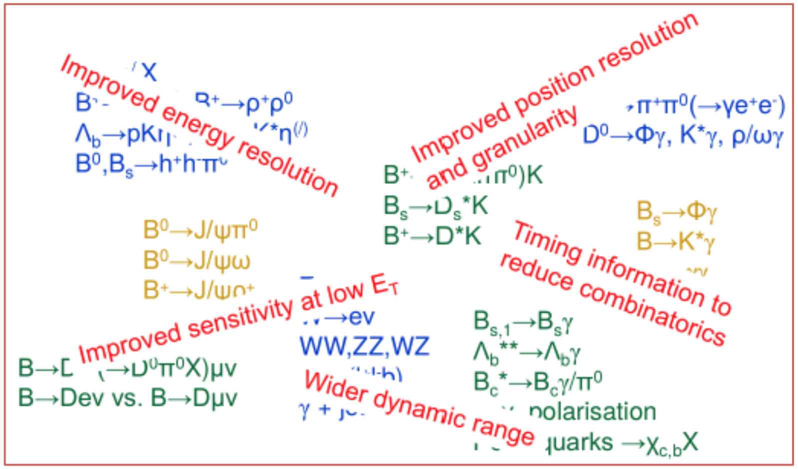
- Timing for photons
  – Convert, time-tag, associate to vertex

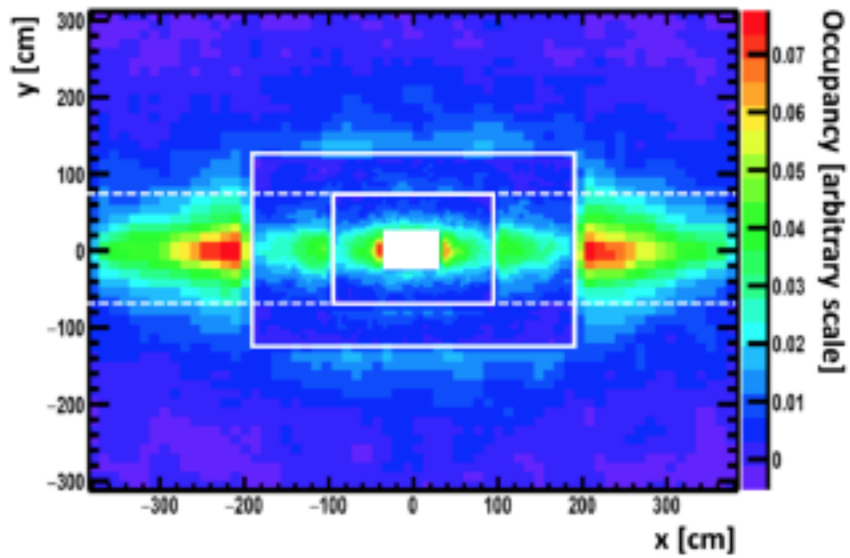


- 85ps timing achieved, near to aimed 70ps
- Proposal to mount module in LHCb in 17/18 shutdown

ECAL

Frederic Machefert Alexander Ledovskoy
Yury Guz Tommaso Tabarelli De Fatis

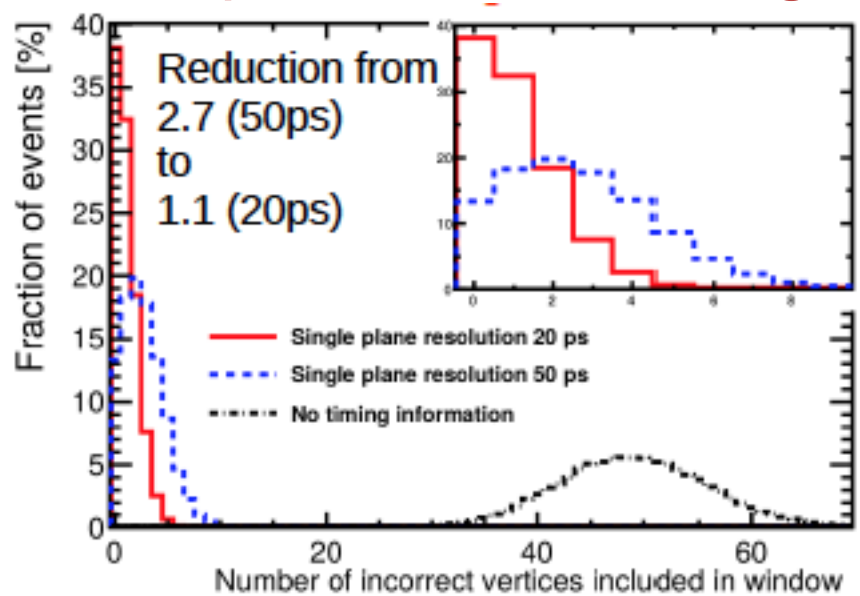




One of many options:

- 2x2 cm^2 cells
- Tungsten
- Hybrid of scintillator/PMT & Silicon
- Replace inner region LS3
  - Cascade replaced modules outwards

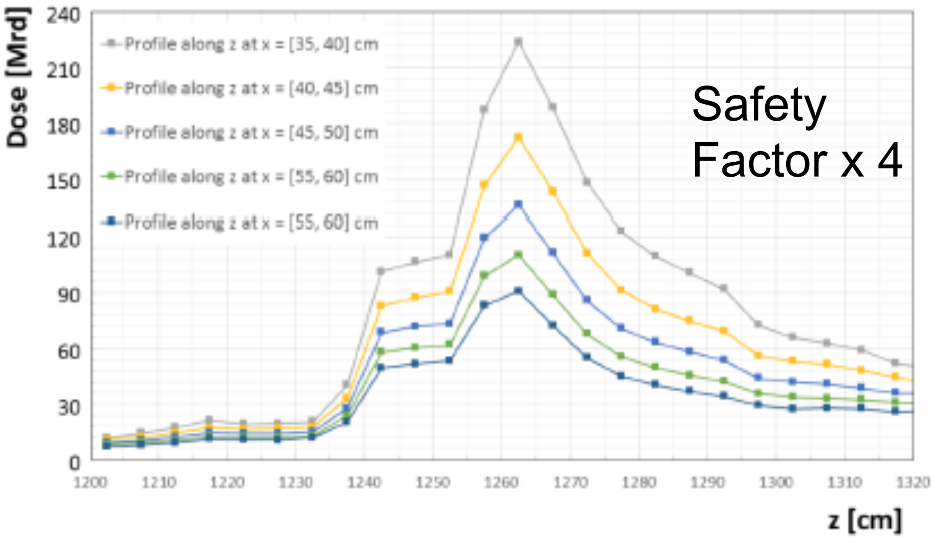
Importance of timing



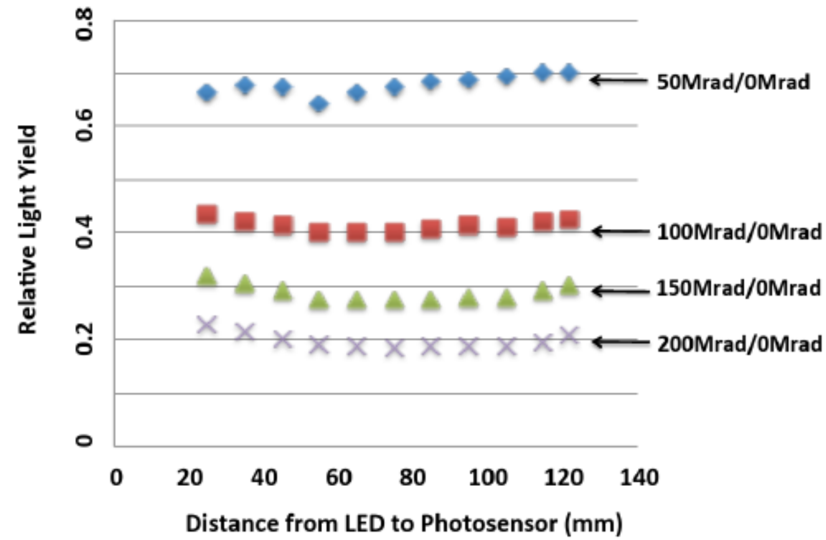
ECAL

Frederic Machefert Alexander Ledovskoy
Yury Guz Tommaso Tabarelli De Fatis

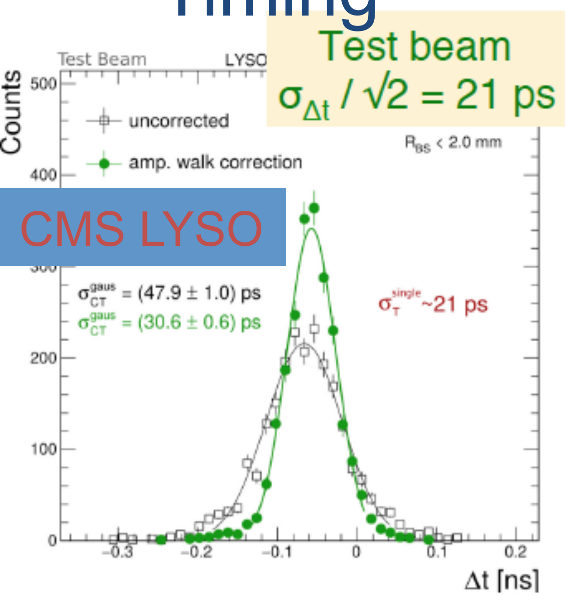
- Radiation hardness



CMS achieve radiation tolerance



- Timing



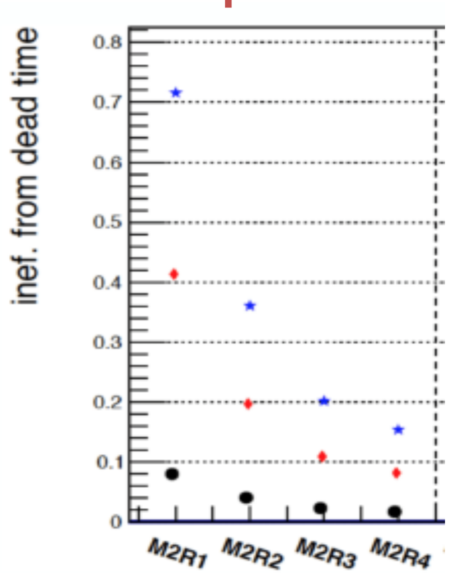
LHCb has unique challenges and finance limits

But existing solutions to inspire

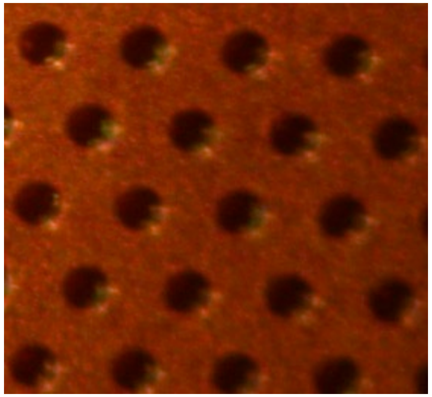
Muons

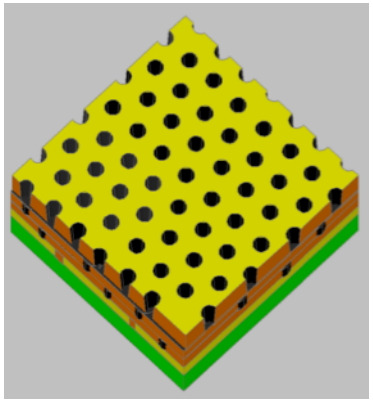
Peter Griffiths
Giovanni Bencivenni

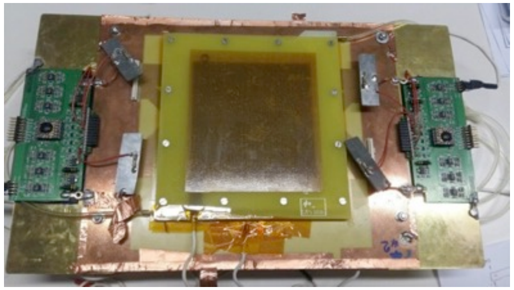
At 10^{34} $cm^{-2}s^{-1}$
The problem…



- μ-RWELL
  - Meet radiation specifications
  - Ease of assembly
  - Low Cost
  - Ease of Operation

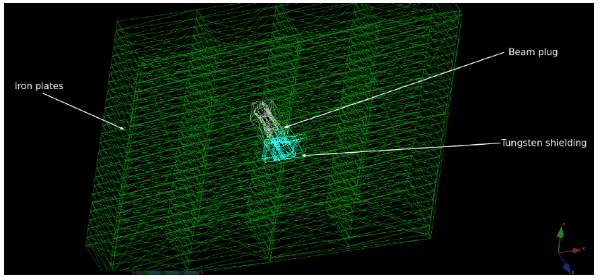






Prototypes Tested

- Iron shielding
- Effect on Muon ID small



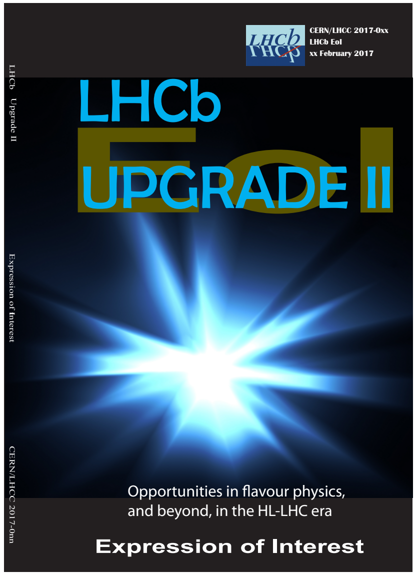
very promising performance:

- ✓ gas gain > 10^4
- ✓ safe operation
- ✓ rate capability > 1 MHz/cm^2
- ✓ time resolution ~ 5.7 ns
- ✓ efficiency/25 ns ~ 90- 95 % (single gap)

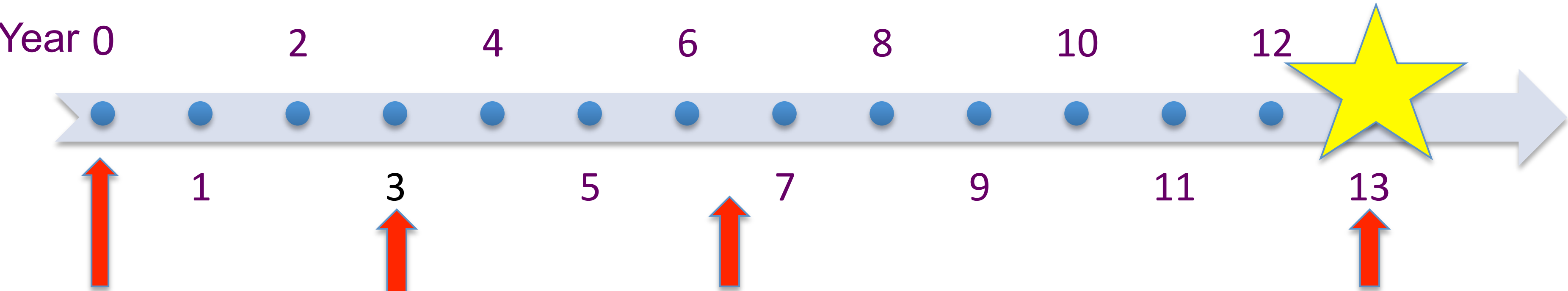
LHCC response to EOI

From LHCC minutes:

- The **LHCC notes** the submission of the EoI for LHCb upgrades beyond Phase-I, and **encourages** LHCb to pursue the physics studies and collaboration with the LHC experts to motivate these upgrades with a solid physics case, taking into account the expected results from LHCb Phase-I and Belle II, and establish feasible running conditions that do not interfere with other LHC experiments. The **LHCC urges** the LHCb management to ensure that these activities have no impact on the on-going Phase-I upgrades, which must take priority.



LHCb

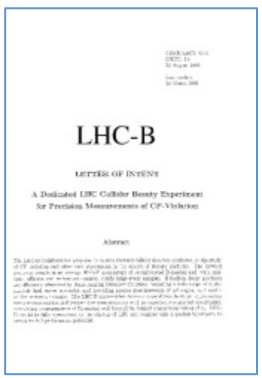


1995

1998

2000-2002

2008

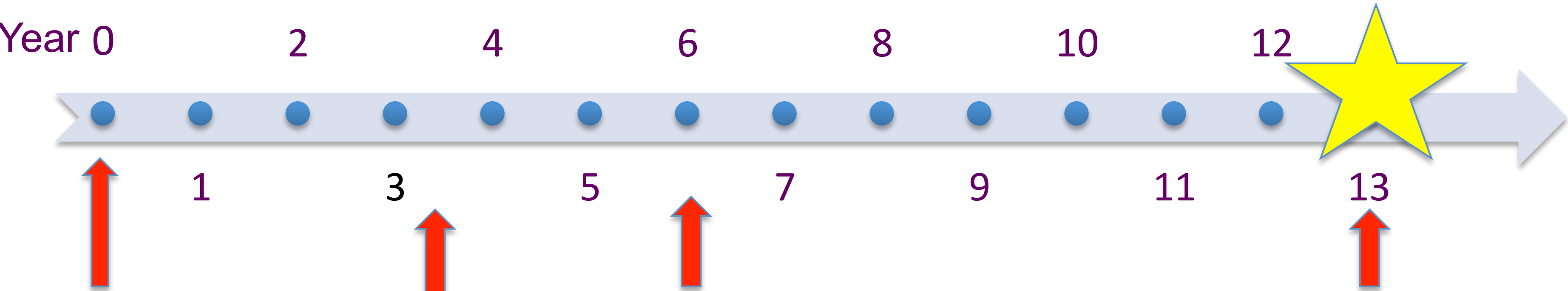


Letter Of Intent

Technical Proposal

Technical Design Reports

LHCb Phase I Upgrade



2008

2011/2012

2013-2014

2021

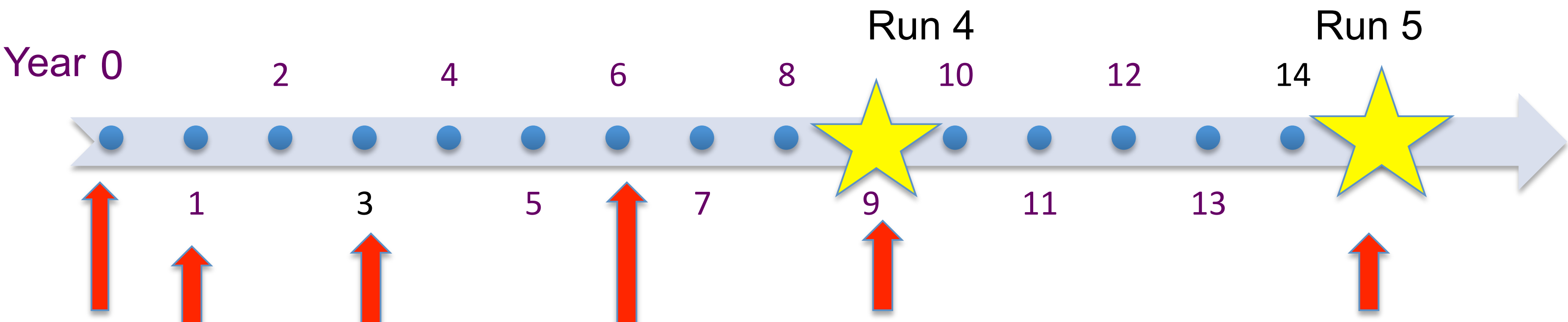
Expression Of Interest

LOI / Framework Technical Design Report

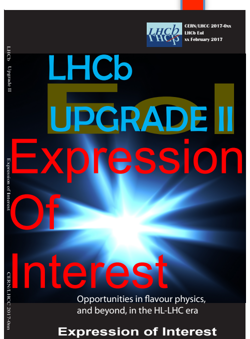
Technical Design Reports

LHCb Phase II Upgrade

"The history book on the shelf, is always repeating itself"



2017



2018

Physics Case

2020

Phase II Technical Design Report

Run4 PID Technical Design Report

Run4 Tracking Technical Design Report

2023

?

?

?

?

Phase II Detector TDRs

2026

2031

To consider:
HL-LHC Studies
European Strategy Group

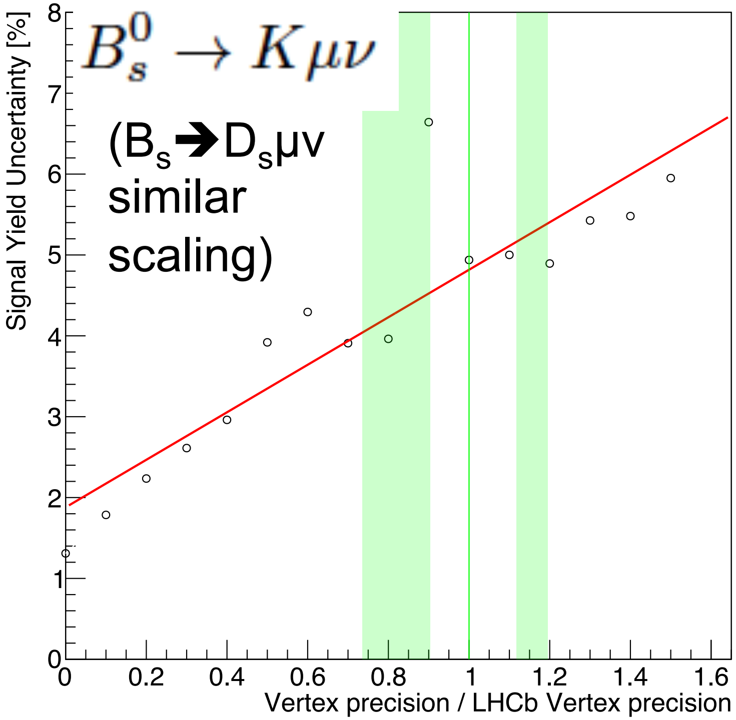
Studies for 2018 Physics Case

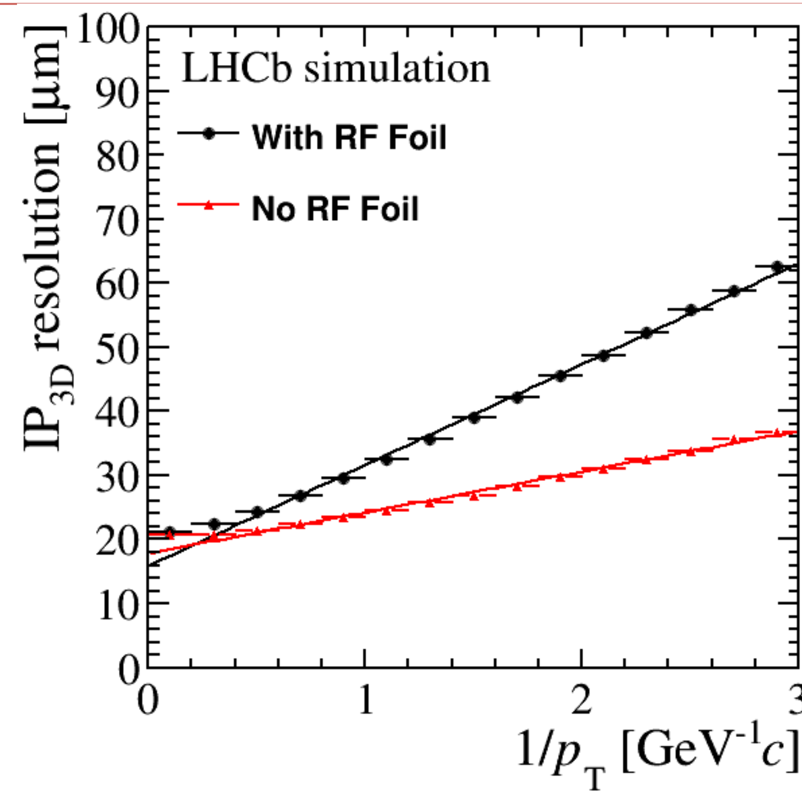
- At this meeting - tremendous progress on:
  – Cataloguing channels for Phase II programme
  – Scaling statistical uncertainties, considering theoretical limits
  – Qualitative statements on detector improvements
- Next we should look to move beyond this:
  – Quantifying alternative detector improvements
    - Parameterized “Fast” **simulations**
  – Allow us to prioritise (see costs slides) improvements in sub-detectors / between sub-detectors

Vertex Resolution

Iwan Smith
Mark Williams

Important Example Study for 2018 Physics Case Document





- Uncertainty on signal yield scales linearly with vertex precision

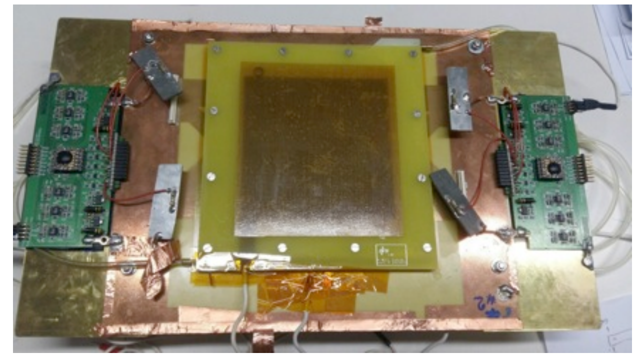
If secondary vertex resolution scaled like primary:

- Removing RF foil equivalent of increasing dataset by factor two!

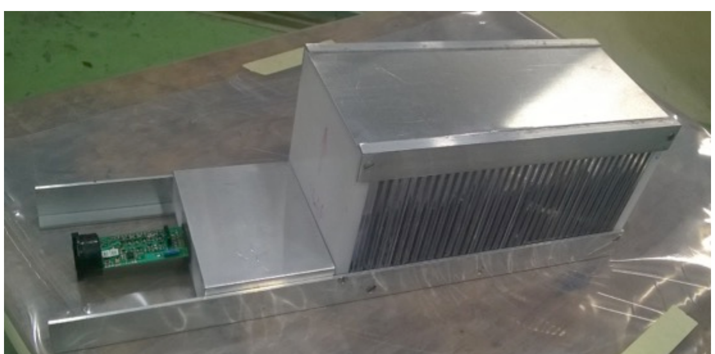
Prototypes

- Great to see hardware under construction/test
  - TORCH

  - μ-RWELL



  - ECAL



  - Inner Tracker

Phase II Next Meetings

"Knowing my fate is to be with you"

- Lake Placid, LHCb week
  - Dedicated session on Phase II Upgrade
    - Please register
  - May become a regular feature of LHCb weeks

- 3rd Meeting in this sequence for 2018
  - Proposals to host welcome
  - Voulez-vous ?

"My My, at Waterloo Napoleon did Surrender"

There are always rocky patches
but have to take a long view of history

160 years later….

“Waterloo...won the war”

The twenty two Member States of CERN

Member States (date of accession)

- Austria (1959)
- Belgium (1953)
- Bulgaria (1999)
- Czech Republic (1993)
- Denmark (1953)
- Finland (1991)
- France (1953)
- Germany (1953)
- Greece (1953)
- Hungary (1992)
- Israel (2014)
- Italy (1953)
- Netherlands (1953)
- Norway (1953)
- Poland (1991)
- Portugal (1986)
- Romania (2016)
- Slovakia (1993)
- Spain (1961-1968, 1983-)
- Sweden (1953)
- Switzerland (1953)
- United Kingdom (1953)

Thanks to Organisers

"I couldn't escape if I wanted to"

INFN-Pisa Staff

- Lucia Lilli
- Claudia Tofani
- Mauro Giannini
- Luca Barraco

plus of course our CERN LHCb secretary

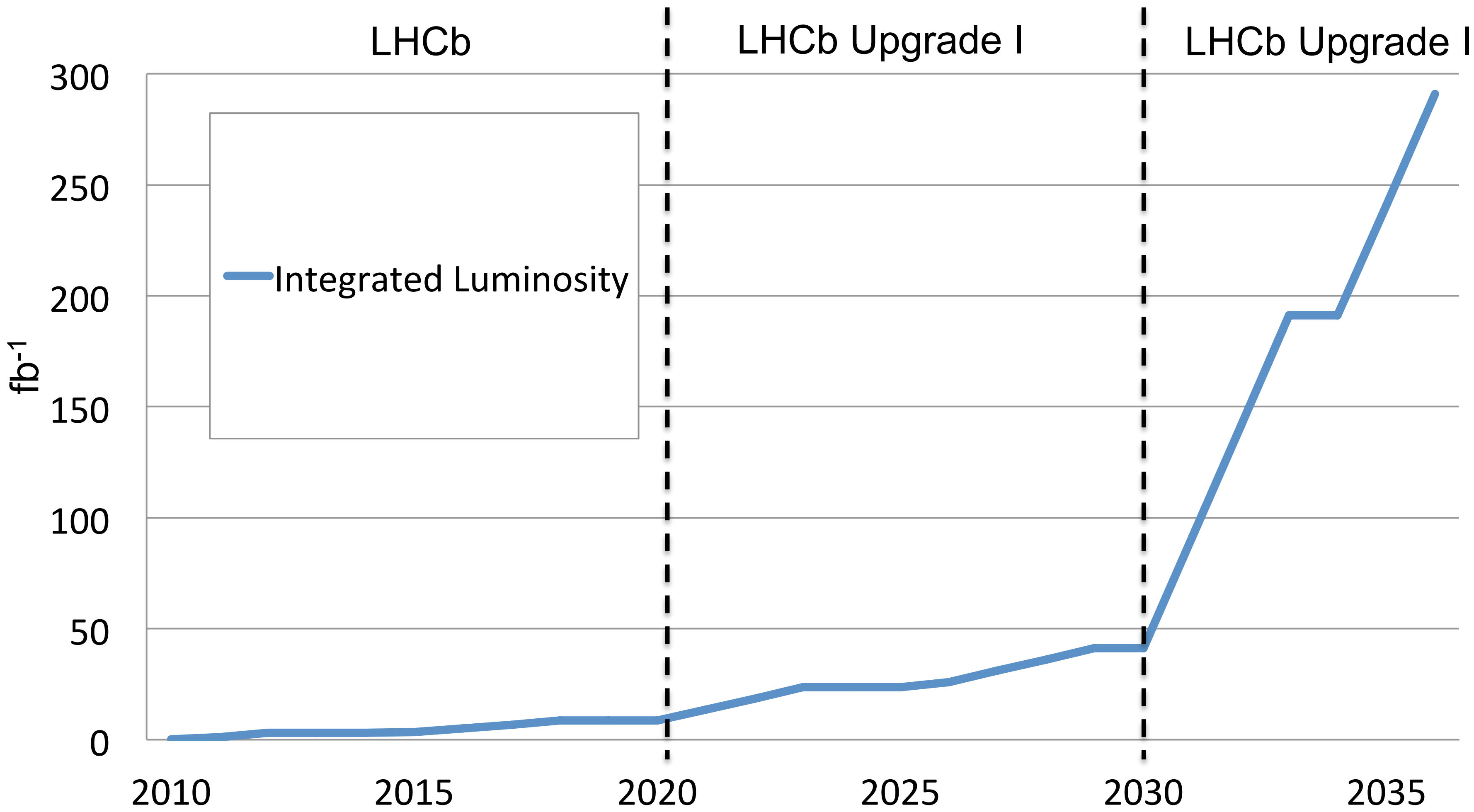
- Cindy Denis

"Promise to love you forever more"

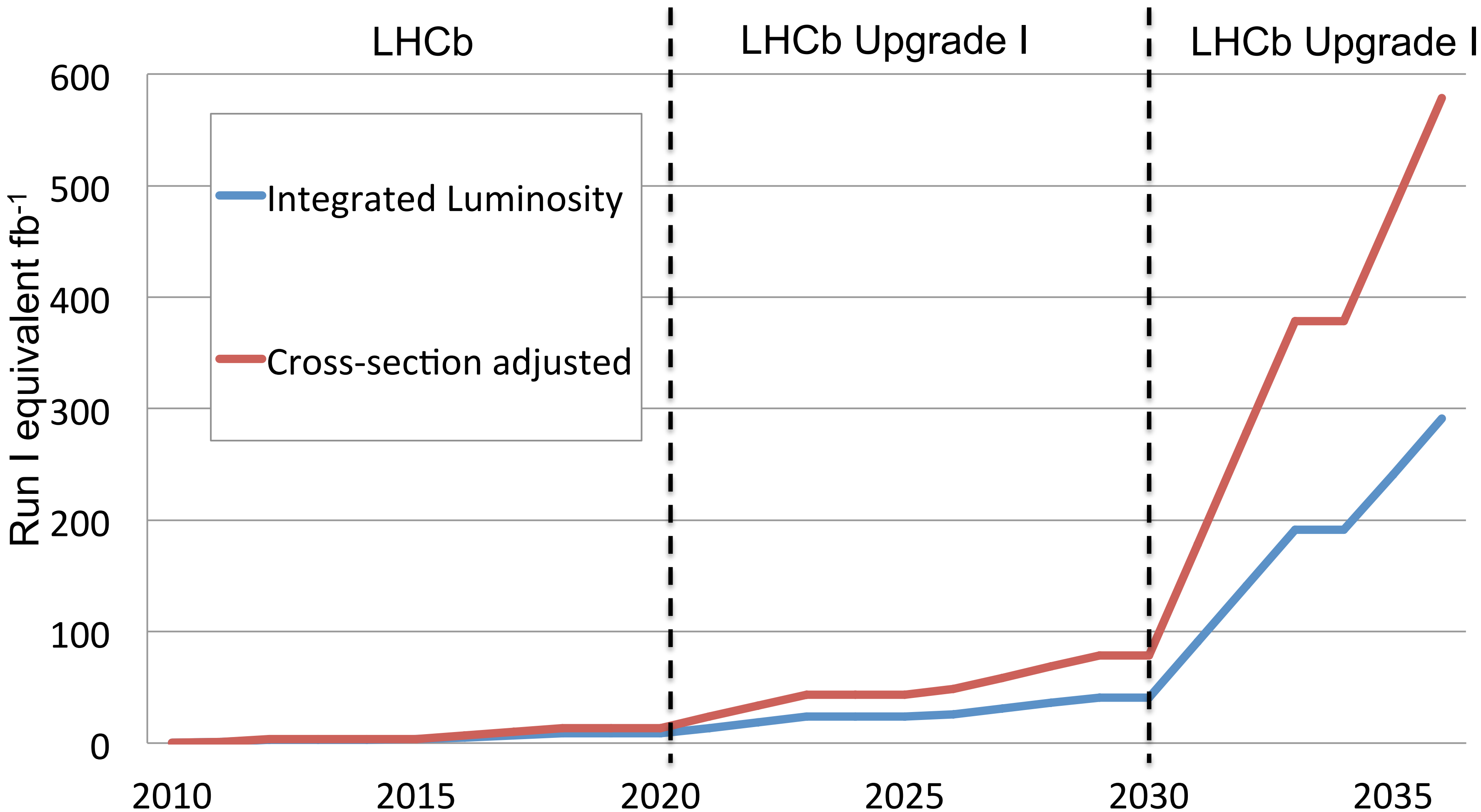
Thanks to all our friends old and new for your participation

Backup

LHCb Statistics- Timeline

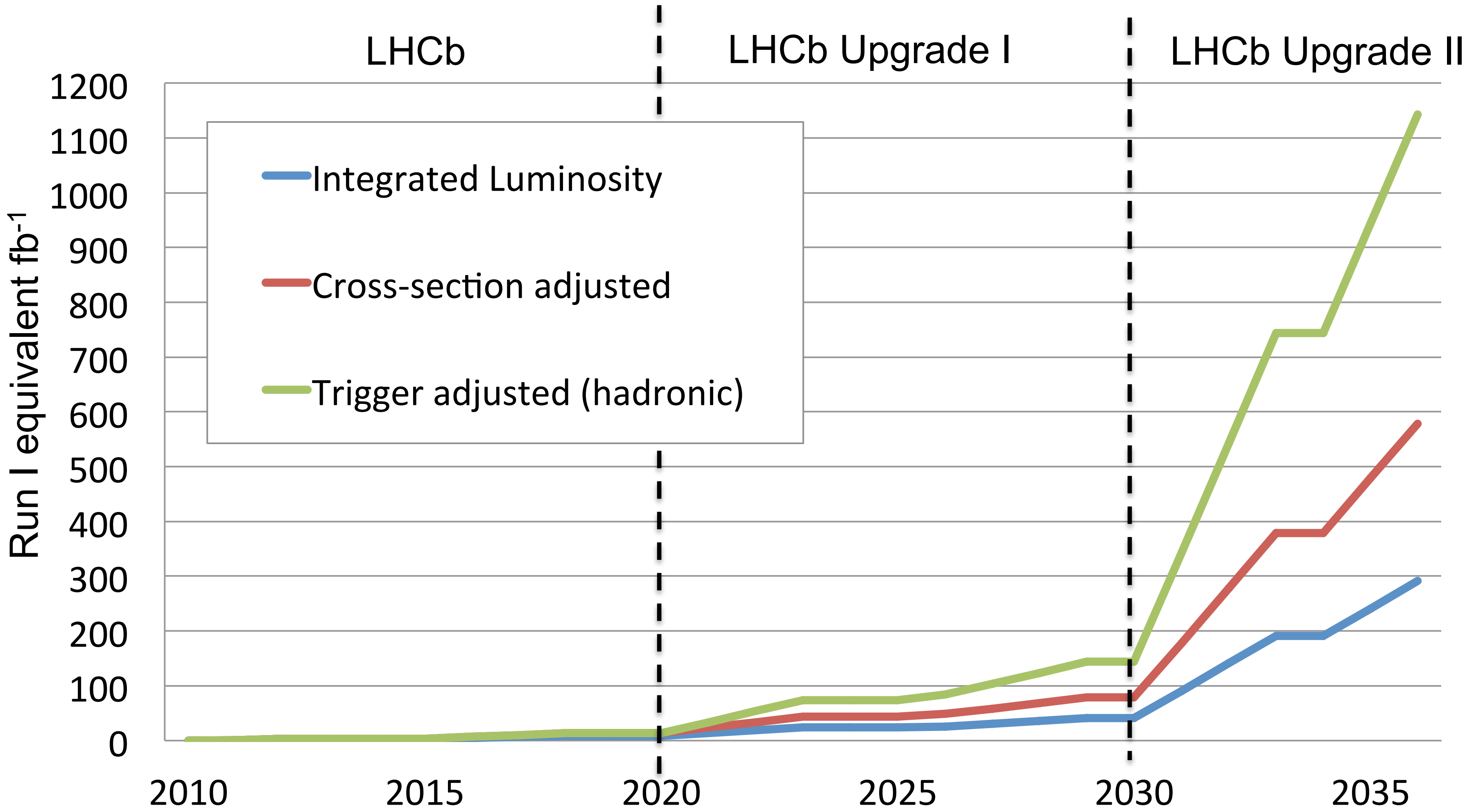


LHCb Statistics- Timeline



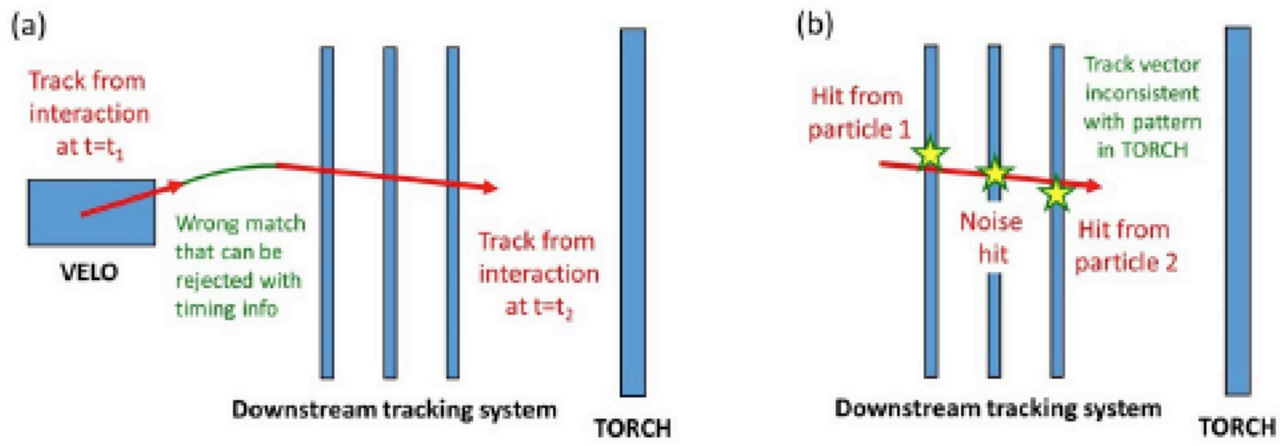
- Adjustment for 7/8/13/14 TeV cross-sections

LHCb Statistics- Timeline



- Indicative of potential only
- Assumptions made on relative trigger efficiencies have significant uncertainty

Matching: Timing Planes in Tracking

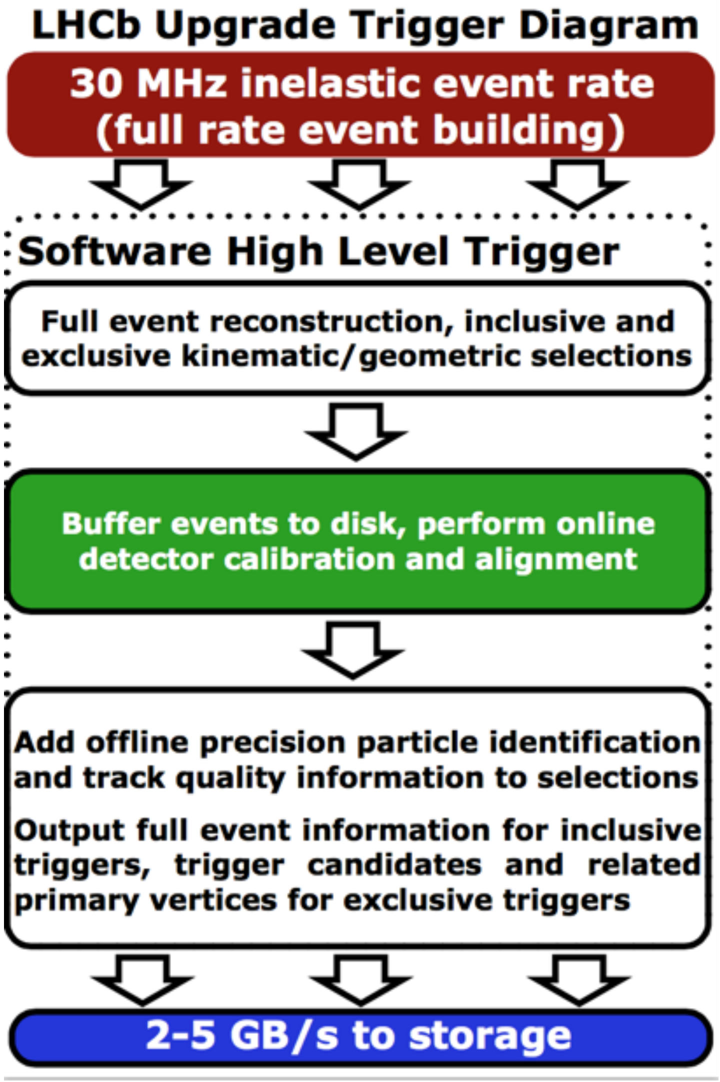


- Distance from VELO to main Tracker is ~ 7m
  - Intermediate station before magnet
- VELO will add timing
- Is timing needed in tracker region also to obtain correct matching of track stubs in Phase II?
  - TORCH would be a candidate technology

Trigger & Data Processing

- Fully software based trigger
  - Efficiency & Flexibility
  - No fundamental change in architecture foreseen
- Software & Computing
  - Strategy will develop from Upgrade I
  - Use of multicore processors, possibly GPUs, accelerators
  - Data volume growth clearly a challenge
  - Beneficial impact of fast timing information in speeding-up reconstruction ?

Upgrade Phase-I Trigger



Detector System Summary

Detector	LS3	Phase-II
VELO	Deployment of prototype modules	New detector with fast timing
Tracking	Insert Silicon IT, modify SciFi; install MS	Silicon UT and IT, SciFi OT
RICH	New photodetectors for selected regions; use of timing information	New optics; full replacement of photodetectors
TORCH	Installation	Higher granularity photodetectors
CALO	Tungsten sampling modules installed in inner region	New modules in middle and outer regions
Muon	Replace HCAL with iron shielding; installation of high-rate chambers	Complete chamber installation
Trigger and data processing	Adiabatic software improvements; review of offline processing; installation of downstream track-finding processor	Expansion/replacement of links, readout boards and servers and servers

- We will not be able to afford all items in LS3 column for LS3
- Prioritisation required but not in EoI