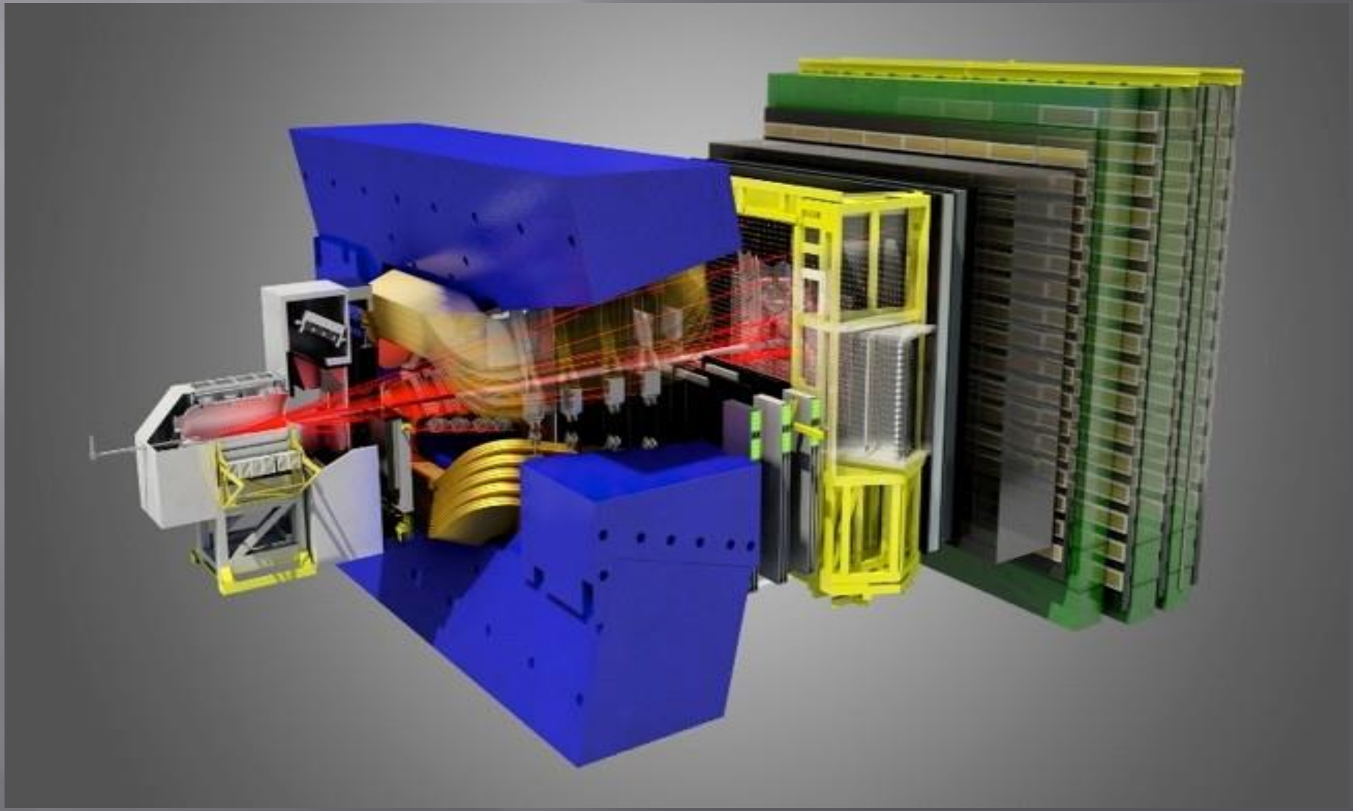
UNIVERSITY OF LIVERPOOL

LHCb and Silicon R&D

G. Casse

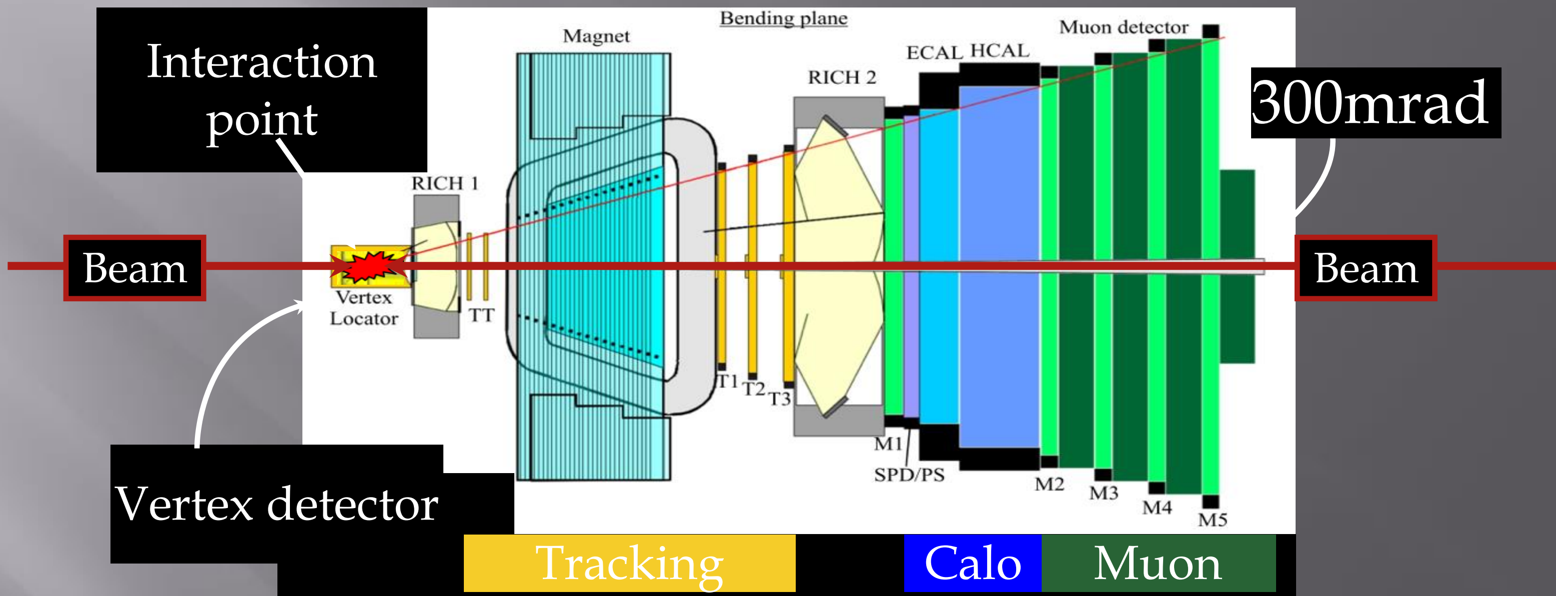
The LHCb experiment

LHCb is the LHC experiment dedicated to study the origin of the asymmetry that made antimatter disappearing from the Universe we observe. To this purpose, the LHCb is a forward single arm spectrometer at the heart of which is the most precise vertex detector of all the LHC experiments.

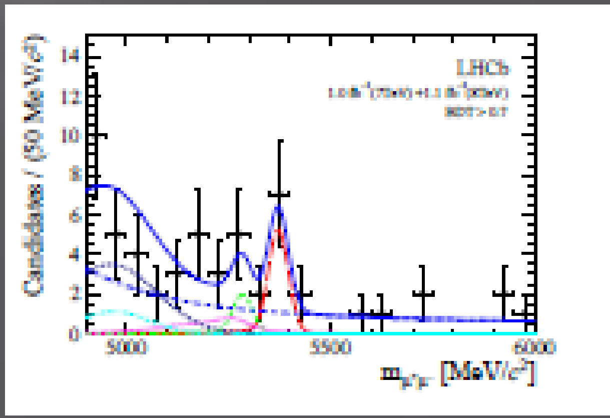


VELO: the most precise VERTEX detector system

0.8 cm from the interaction point (in radius). Highly sophisticated to spatially resolve the Vertices, sustain the occupancy and the radiation levels.



- Tony Affolder, Themis Bowcock, **Henry Brown**, John Carroll, Gianluigi Casse, Peter Cooke, Stephanie Donleavy, **Karlis Dreimanis**, **Stephen Farry**, Karol Hennessy, David Hutchcroft, Myfanwy Liles, Mike Lockwood, Ben McSkelly, Girish Patel, Adrian Pritchard, Kurt Rinnert, Tara Shears, Tony Smith, Peter Sutcliffe, Mark Whitley, Mike Wormald.



.... and, as one can expect from a detector set to measure Beauty, it is a beautiful piece of work.

VELO replacement:

- On display/in storage in LHCb exhibit (point 8)
- On display in LHC Collider exhibit (Science Museum)

Most precise detector in LHC experiments!
Prototype for the radiation hard technology (now the golden standard for the upgrades)
First use of advanced composites (TPG for heat & ZERO-CTE layups) at CERN.
It lead to two Industry awards in the UK (Micron Semiconductors and Stevenage Circuits)

Si R&D : enabling great science, and improving technologies for the public (applications).

… preparing for the coming challenges ….

- Future physics programmes are more and more demanding on detectors in terms of granularity, speed, radiation tolerance, (low) mass …
- Preeparing detectors for experiments cannot be performed in a responsive mode
- Research needs to anticipates the experimental needs
- Example: HL-LHC demands a factor of ten more granularity and radiation tolerance wrt LHC. Back a fe years it looked impossible ….

The RD50 Collaboration

- RD50: *48 institutes and 290 members*

38 European and Asian institutes

Belarus (Minsk), Belgium (Louvain), Czech Republic (Prague (3x)), Finland (Helsinki, Lappeenranta), France (Paris), Germany (Dortmund, Erfurt, Freiburg, Hamburg (2x), Karlsruhe, Munich), Italy (Bari, Florence, Padova, Perugia, Pisa, Trento), Lithuania (Vilnius), Netherlands (NIKHEF), Poland (Krakow, Warsaw(2x)), Romania (Bucharest (2x)), Russia (Moscow, St.Petersburg), Slovenia (Ljubljana), Spain (Barcelona(2x), Santander, Valencia), Switzerland (CERN, PSI), Ukraine (Kiev), United Kingdom (Glasgow, Liverpool)

7 North-American institutes

Canada (Montreal), USA (BNL, Fermilab, New Mexico, Santa Cruz, Syracuse)

1 Middle East institute

Israel (Tel Aviv)

1 Asian institute

India (Delhi)

Detailed member list: http://cern.ch/rd50

RD50 Organizational Structure

Co-Spokespersons

Gianluigi Casse **and** ***Michael Moll***

(University of Liverpool) (CERN PH-DT)

Defect / Material Characterization

Mara Bruzzi

(INFN & Uni Florence)

- **Characterization of microscopic properties of standard-, defect engineered and new materials pre- and post-irradiation**
- **DLTS, TSC, ….**
- **SIMS, SR, …**
- **NIEL (calculations)**
- WODEAN: Workshop on Defect Analysis in Silicon Detectors (G.Lindstroem & M.Bruzzi)

Detector Characterization

Eckhart Fretwurst

(Hamburg University)

- **Characterization of test structures (IV, CV, CCE, TCT,.)**
- **Development and testing of defect engineered silicon devices**
- **EPI, MCZ and other materials**
- **NIEL (experimental)**
- **Device modeling**
- **Operational conditions**
- Common irradiations
- Wafer procurement (M.Moll)
- **Simulations**

New Structures

Giulio Pellegrini

(CNM Barcelona)

- **3D detectors**
- **Thin detectors**
- **Cost effective solutions**
- **Other new structures**
- **Detectors with internal gain (avalanche detectors)**
- **Slim Edges**
- 3D (R.Bates)
- Semi 3D (Z.Li)
- Slim Edges (H.Sadrozinski)

Full Detector Systems

Gregor Kramberger

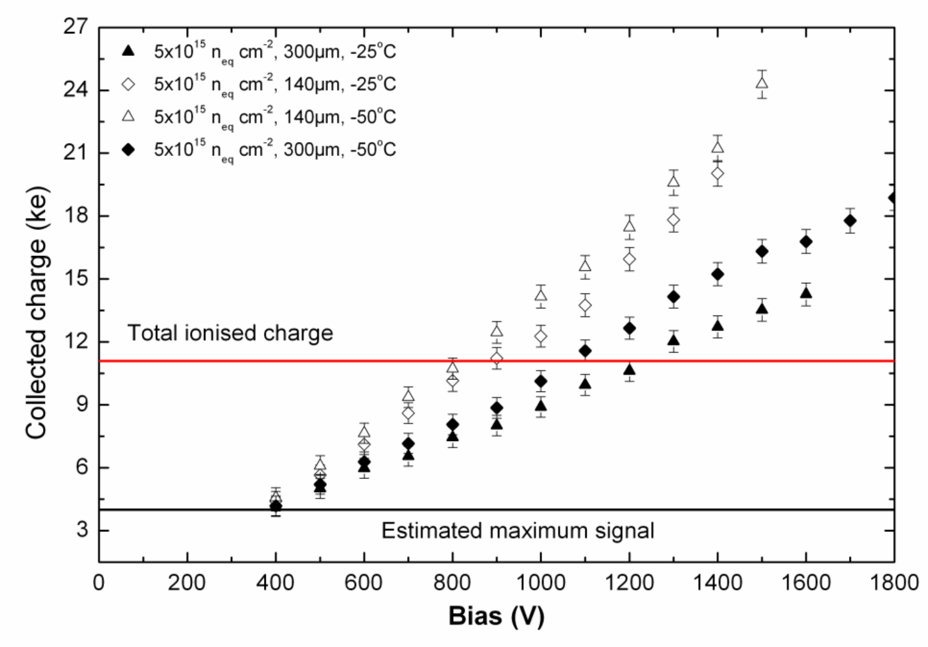
(Ljubljana University)

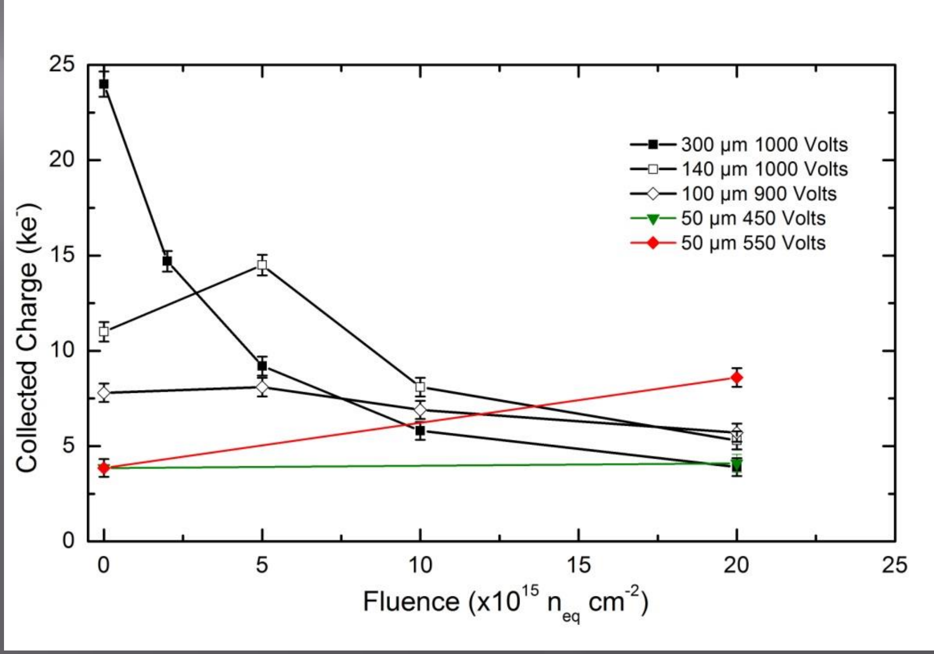
- **LHC-like tests**
- **Links to HEP**
- **Links electronics R&D**
- **Low rho strips**
- **Sensor readout (Alibava)**
- **Comparison:**
  - **- pad-mini-full detectors**
  - **- different producers**
- **Radiation Damage in HEP detectors**
- Test beams (G.Casse)

Collaboration Board Chair & Deputy: G.Kramberger (Ljubljana) & J.Vaitkus (Vilnius), Conference committee: U.Parzefall (Freiburg)
CERN contact: M.Moll (PH-DT), Secretary: V.Wedlake (PH-DT), Budget holder & GLIMOS: M.Glaser (PH-DT)

Solving the problem …

- <u>Charge Multiplication</u> observed and characterized after high levels of irradiation
- We proved that detectors capable to operate at the HL-LHC are possible in term of radiation tolerance requirements.





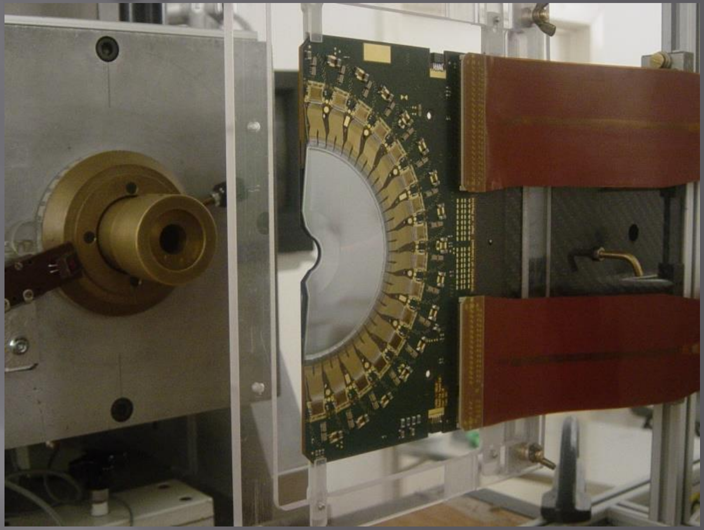
<u>Strip sensors</u> (Φ_{eq}=5 × 10^{15} cm^{-2}, 26 MeV p)
Charge Collection (Beta source, Alibava)

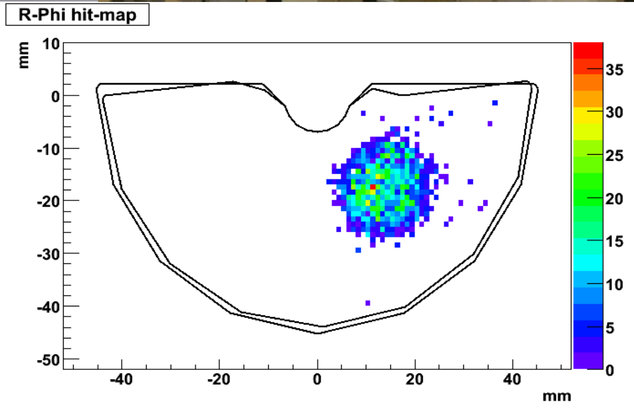
Si R&D activity outline

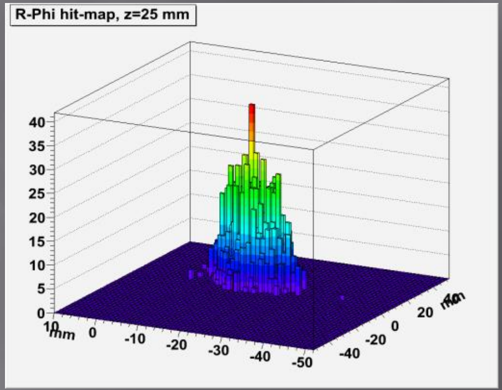
- Silicon (Strip and Pixel) sensors: RD50 and HEP
- Radiation facilities (AIDA-FP7, ATLAS-UK, CERN-PS)
- New sensor concepts: HV-CMOS ......
- Neutron detectors (for medical and security surveillance)
- Medical physics

- Promote novel ideas.
- Research pushing boundaries of current knowledge.
- Research for applying HEP science, instruments and technologies to different fields.
- Keep the scientific excellence of the Laboratory at an international level.
- Research is aligned with national and international priorities
- Training next generation of scientists

Instruments suitable for Medical physics (hadron-therapy) applications. Example of LHCb VeLo sensors as beam monitor at the Clatterbridge Centre for Oncology





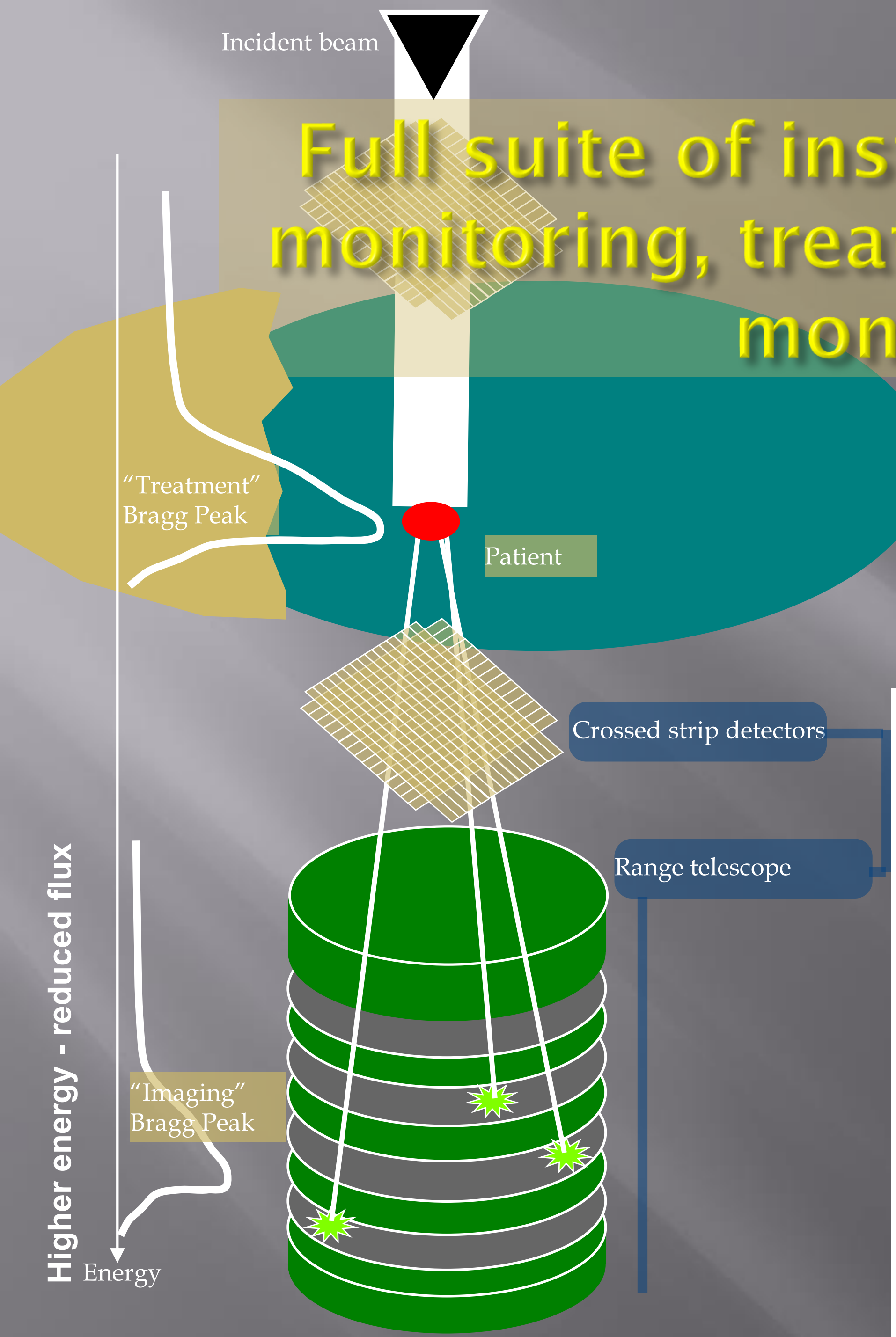


LHCb module positioned in front of the extraction collimator of the Cyclotron beam.

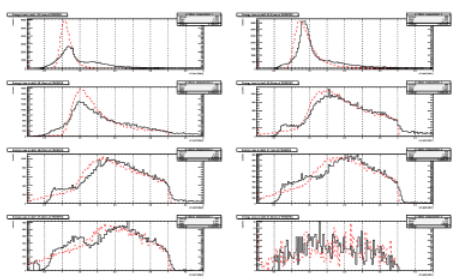
The module was put at different distances and positions to measure the beam halo e the profile of the beam spot.

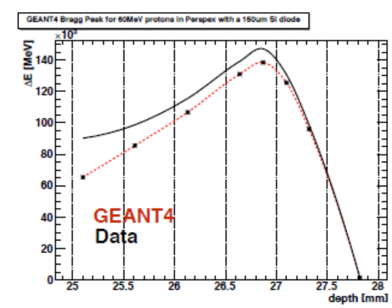
In medical Physics we have a grant for developing a novel concept of tissue equivalent phantom.

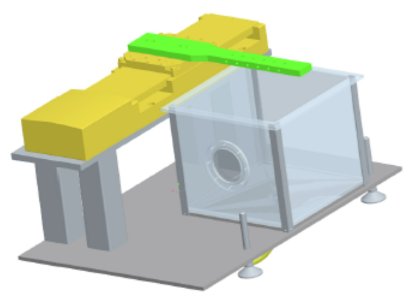
Full suite of instruments for beam monitoring, treatment planning and monitoring.

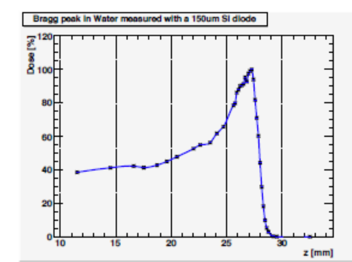


dE/dx plots of 60 MeV protons in Perspex









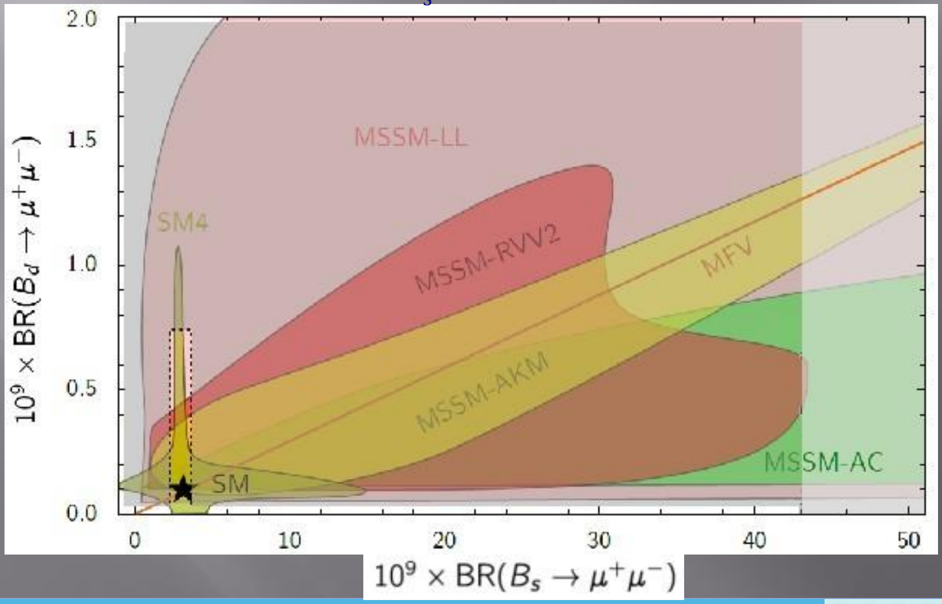
New detectors including strip detectors sent for parylene coating in the New Year

Summary

- Silicon R&D key to the success of the Liverpool PP group
- Leading the detector development for experiments (ATLAS μstrip and pixel upgrades, VELO pixels)
- Always in the research frontier to anticipate more demanding requirements (steering the R&D effort and directions, internationally)
- Exporting and adapting the advanced detector technologies to other applications (medical, security)
- Thinking of novel solutions

New Physics in Rare Decays

- $B_s^0 \to \mu^+\mu^-$ is a golden channel to search for virtual new physics particles
  - rate is highly suppressed in the SM
  - easily modified by new physics
- First evidence for the decay from LHCb recently confirmed (LHCb & CMS)
- Goals for upgrade:
  - precise measurement of $B(B^0 \to \mu^+\mu^-)/B(B_s^0 \to \mu^+\mu^-)$
  - measure lifetime of $B_s^0 \to \mu^+\mu^-$



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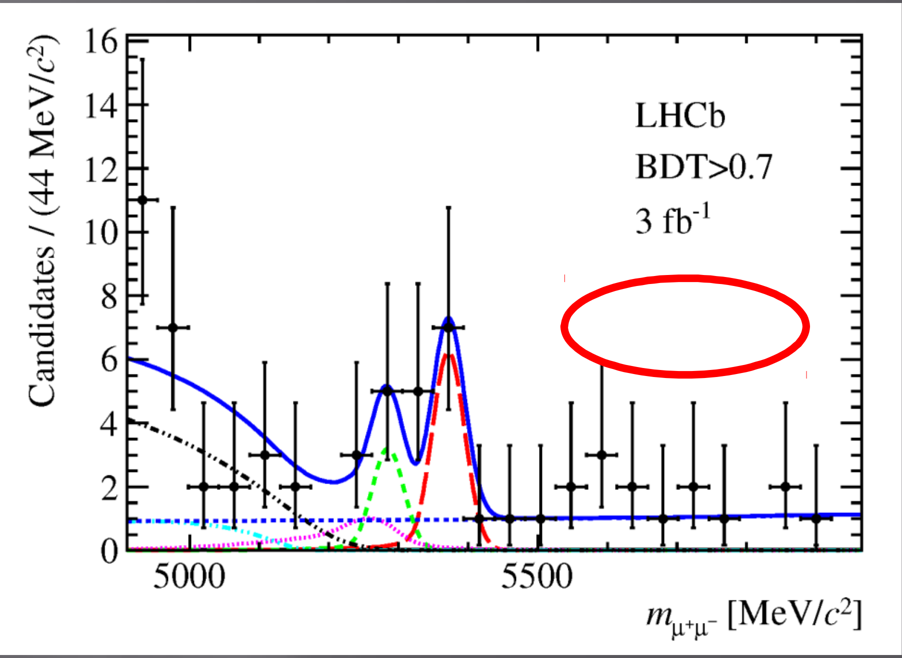

LHCb upgrade will also measure
- photon polarisation in $b \to s\gamma$ transitions (e.g. $B_s^0 \to \varphi\gamma$)
- angular distributions and asymmetries in $B^0 \to K^{*0}\mu^+\mu^-$ decays
- pure annihilation B decays (e.g. $B^+ \to D_s^+\varphi$, $B_c^+ \to K^+K^-\pi^+$)

New Physics in CP Violation

- Neutral mesons (e.g. B_s^0) can oscillate into their antimatter partners and back
- Recent precise measurement from LHCb
  - excellent decay-time resolution (VELO)
  - excellent flavour-tagging (RICH)

- With a final state (e.g. J/ψφ) common to both B_s^0 and $\bar{B}_s^0$ states, the decay time distribution acts as an interferometer
  - can measure relative CP violating phase ϕ_s
  - cleanly predicted in the SM

- Upgrade will improve measurement to level of theoretical uncertainty, and – importantly – add other channels (e.g. φφ, K(*)$\bar{K}$(*))

- Many other essential CP violation measurements (e.g. CKM phase γ)

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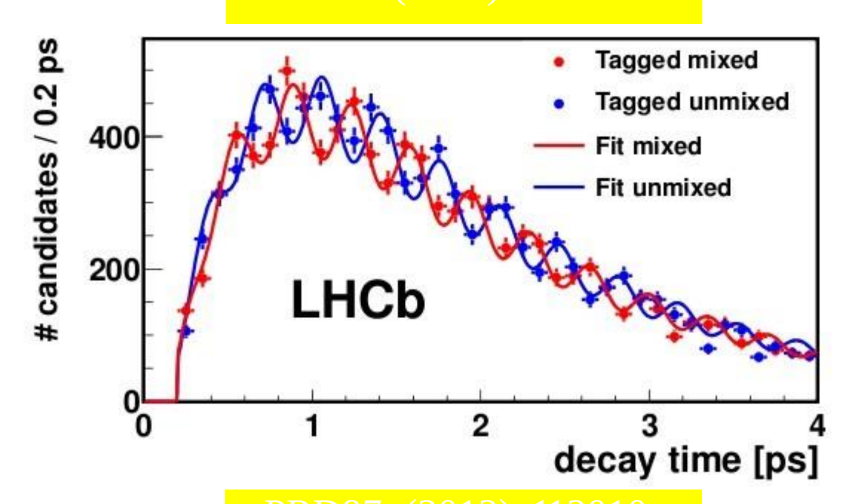

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