Scintillating Fibre Tracker
and
Lepton Universality in Λ_b decays

Jan de Boer

VSI meeting – 30th January 2023

Overview of this talk

1. Introduction of the Scintillating Fibre Tracker

2. Assembly to Operation

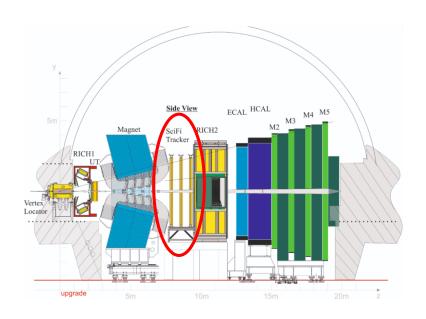3. Λ_b *decays*

Experimental Particle Physics

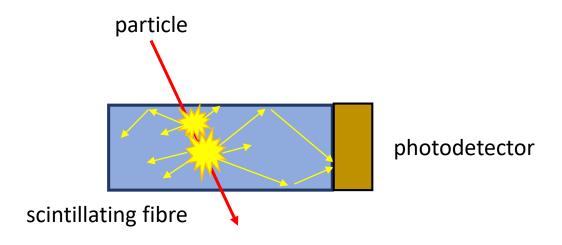# Scintillating Fibre Tracker (SciFi)
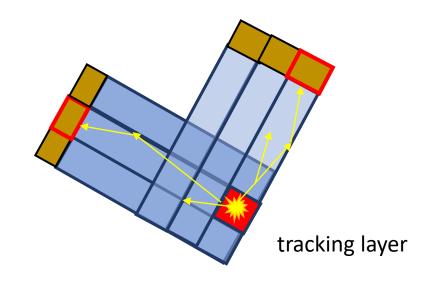
- Technology
- Construction
- Commissioning

The principle

- A scintillator converts deposited energy of an ionizing particle into light

- Polystyrene (= plastic) with organic scintillators :
  = **scintillating fibre**

- Detection of scintillating light with a photodetector:
  = **signal detection**

- Arranging a lot of fibres in a smart way to determine the particles location along its trajectory:
  = **tracking**

- Scintillating Fibres: **light -> signal -> tracking**

particle

photodetector

scintillating fibre

tracking layer

Why tracking? Why Scintillating Fibres?

- Tracking is an integral part of the event reconstruction and provides information on:

    - primary and secondary vertices (Vertex Locator)

    - momentum (Scintillating Fibre Tracker)

    - squared four-momentum transfer (TOTEM, ATLAS-ALFA)

- Three major technologies are used for this:

    - silicon (expensive)

    - gaseous (not fast enough)

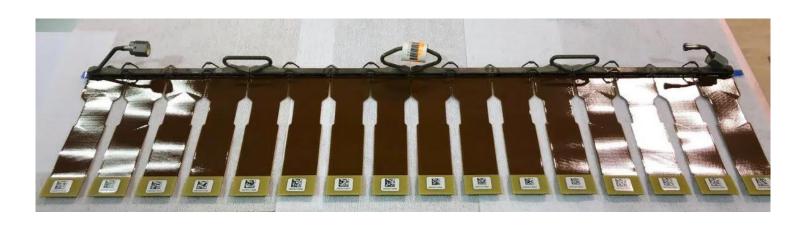   - scintillating fibre (inexpensive and fast!)

- Scintillating Fibres also come with a low material budget, and as such this technology has attractive properties for LHCb's next generation tracker: the Scintillating Fibre tracker
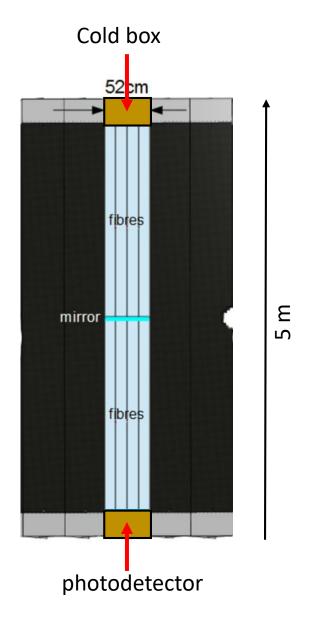
SciFi Tracker in numbers

- 12 layers divided over 3 tracking stations (T1-T3)

- Dimensions: 5x6 meter, total active area: 340 m^2

- Fibres are:

  -250 µm diameter

  -2.4 m long

  -put in a 6-layer honeycomb structure:

1.3 mm

- Clustered read-out at the far ends by silicon photomultipliers (SiPMs)

- Foreseen resolution: ~80 µm

11.000 km of fibre used!

$D_{fibre} = 250$ µm

mean position

signal amplitude

pos

pixel

channel

fired pixel

photon

fibre

particle

1.3 mm

524.000 channels

T1 T2 T3

readout

~6m

mirror

1 module with 8 mats

~5m

Cooling

- With a 2.4 m long fibre: limited light yield at the SiPMs

    + radiation impact on fibres and SiPMs

- SiPMs require cooling to -40 °C to mitigate dark current

    - limit cluster rates

- Cooling introduces a lot of infrastructure (services):

    vacuum, cooling, dry gas, condensation prevention,

    safety systems, …

Assembly of the detector

- Period from June 2019 – Febr 2022

- 12 C-frames to be assembled

- Services (SiPM Cooling, Vacuum, Dry Gas, Condensation Prevention System)

- Front-End Electronics (Front-End Cooling, power supplies, DAQ system)

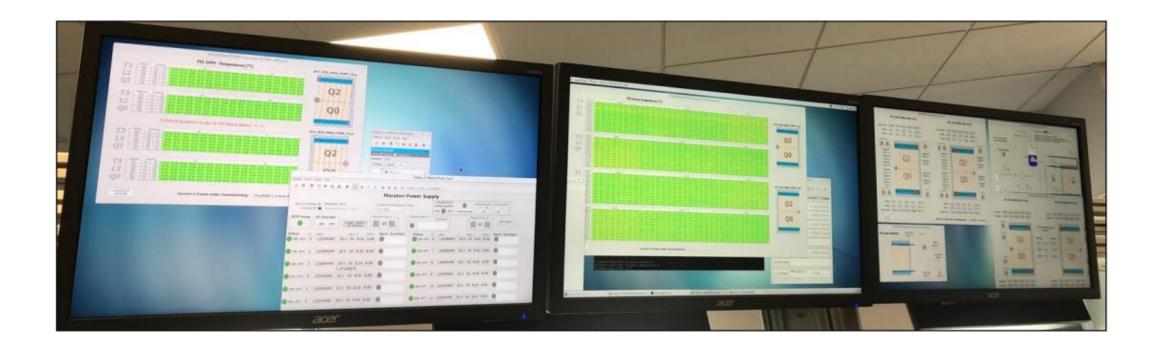**Full chain of checks and tests done, before a C-frame is allowed to be installed underground.**

Assembly of the detector

Example: check whether cooling liquid is circulated properly for the SiPM.

Installing temperature sensors, read-out plus mapping test via the Detector Control System
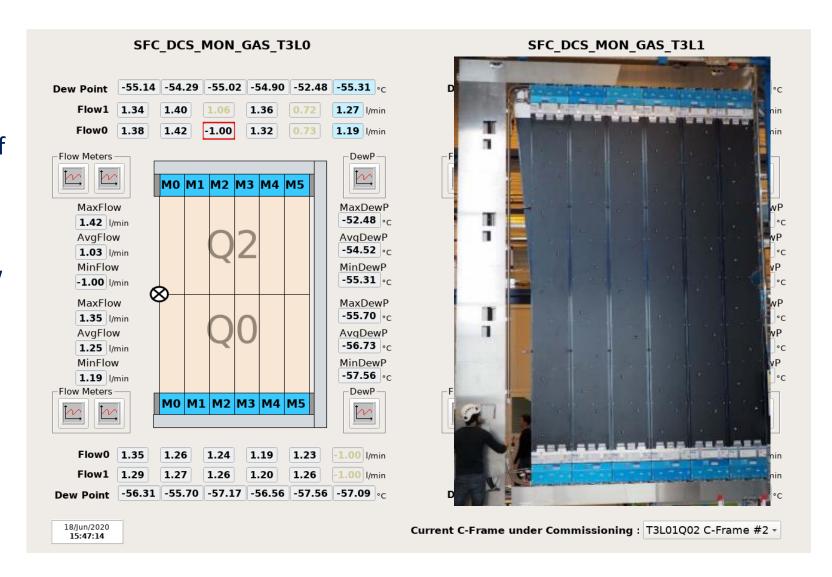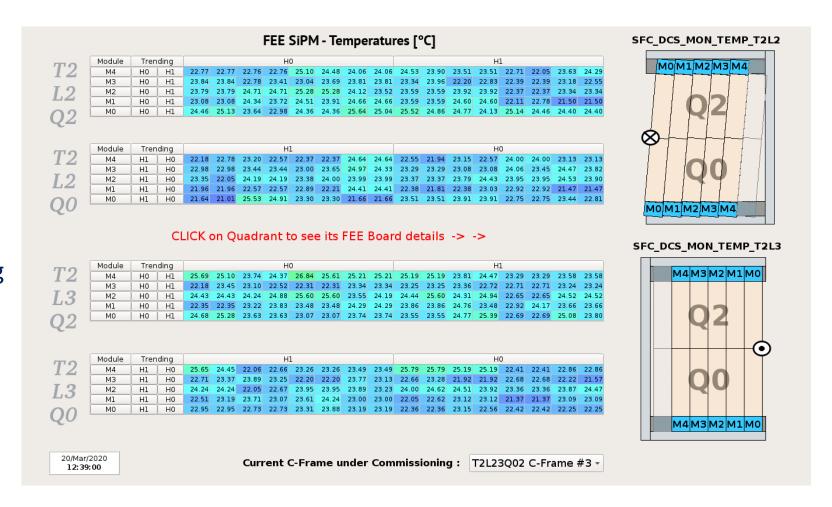
Detector Control System

Example: Dry Gas

- Monitoring of the dry gas system

- Humidity inside cold box needs to be kept low: risk of frost build up and condensation that can damage equipment

- The dew point and gas flow inside a cold box are measured and displayed

- Additional functionalities

Example: SiPM temperature

- Monitoring of SiPM temperature

- SiPM temperature is at the core of having an optimal performing tracking detector

- The panel provides direct feedback on the functioning of the cooling system
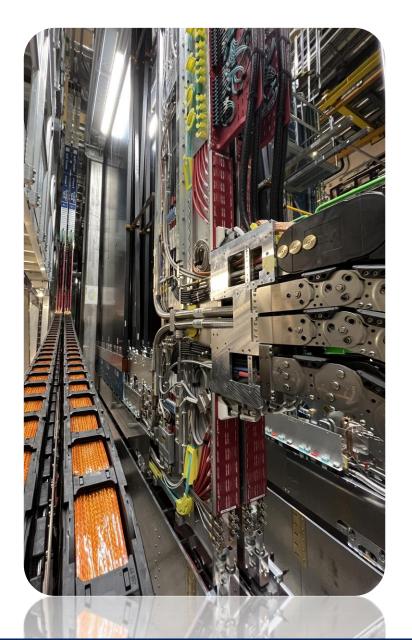
- Additional Functionalities

Installation of the detector

Serious amount of effort to install the detector in the cavern 100 meters below surface.

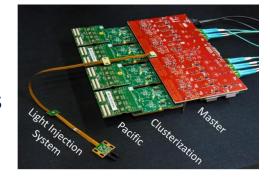Connect and fire it up!?

Commisioning of the detector

Experimental Control System:

Aim is to operate the detector and collect data in an almost fully automated manner.
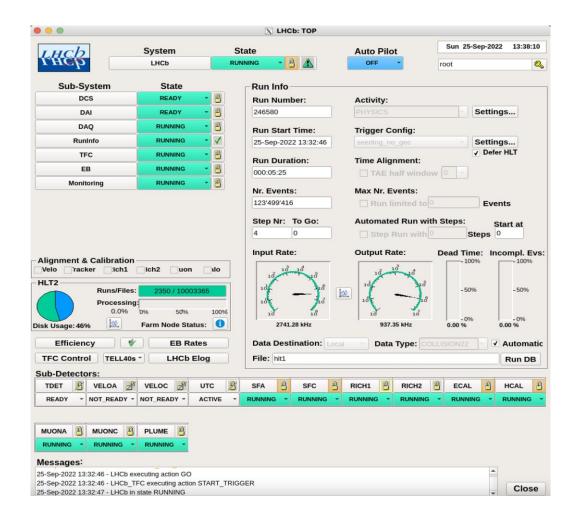
Ongoing efforts at this moment:

-threshold scans

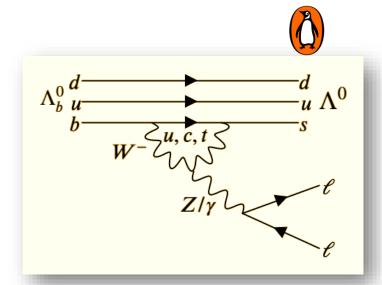-timing scans

-full read-out chain checks

-reconstruction

-...

Still takes months to get this done!

Λ_b decays

Lepton Flavour Universality in Λ_b decays

- Part of the anomalies of b→sℓℓ transitions (ℓ=lepton)

- Flavour Changing Neutral Current

- In SM forbidden at tree level, only possible via higher order diagrams and therefore highly suppressed

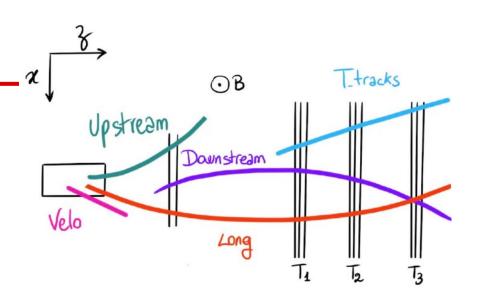- Experimentally measured as double ratio:

$$R_\Lambda = \frac{\mathscr{B}(\Lambda_b^0 \to \Lambda \mu^+ \mu^-)}{\mathscr{B}(\Lambda_b^0 \to \Lambda e^+ e^-)} \cdot \frac{\mathscr{B}(\Lambda_b^0 \to \Lambda J/\psi(\to e^+ e^-))}{\mathscr{B}(\Lambda_b^0 \to \Lambda J/\psi(\to \mu^+ \mu^-))}$$
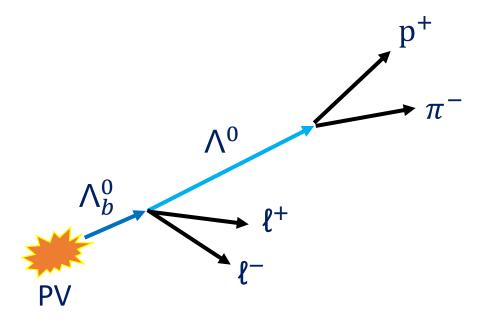
1 in SM!

Event reconstruction

decay length ≈ 1 m   (γ=15-25)

- Λ is **long lived**, decays into $p^+\pi^-$
  - ➢ Reconstruction split into Downstream/Long tracks
  - ➢ Downstream comes with lower mass resolution but does increase statistics by a factor 3

- Lepton pair created:
  - ➢ Dilepton invariant mass (q^2) measured
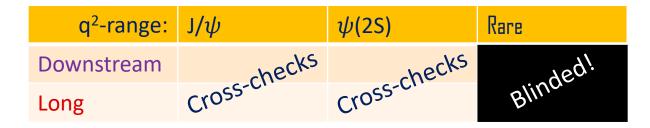 - ➢ Incl. two resonances: J/ψ and ψ(2S)

Analysis strategy

- $\Lambda_b^0 \to \Lambda \mu^+ \mu^-$ and $\Lambda_b^0 \to \Lambda e^+ e^-$ decays

- Cross-checks via resonances:
  $\Lambda_b^0 \to \Lambda J/\psi(\to\mu^+\mu^-)$ and $\Lambda_b^0 \to \Lambda \psi(2s)(\to\mu^+\mu^-)$
  $\Lambda_b^0 \to \Lambda J/\psi(\to e^+ e^-)$ and $\Lambda_b^0 \to \Lambda \psi(2s)(\to e^+ e^-)$

q^2-range:	J/ψ	$\psi(2S)$	Rare
Downstream	Cross-checks	Cross-checks	Blinded!
Long			

- Split over periods: LHC Run1, Run2

*Scintillating Fibre Tracker
and
Lepton Universality in Λ$_b$ decays*