The development of Strontium-90 Tile scanning table for TileCal at the ATLAS experiment

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INSTITUTE FOR COLLIDER PARTICLE PHYSICS

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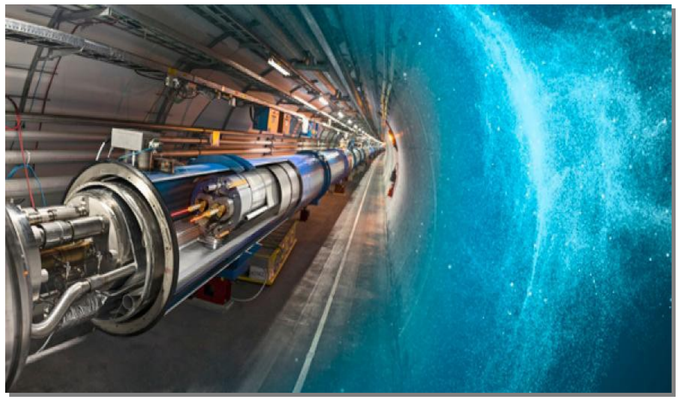

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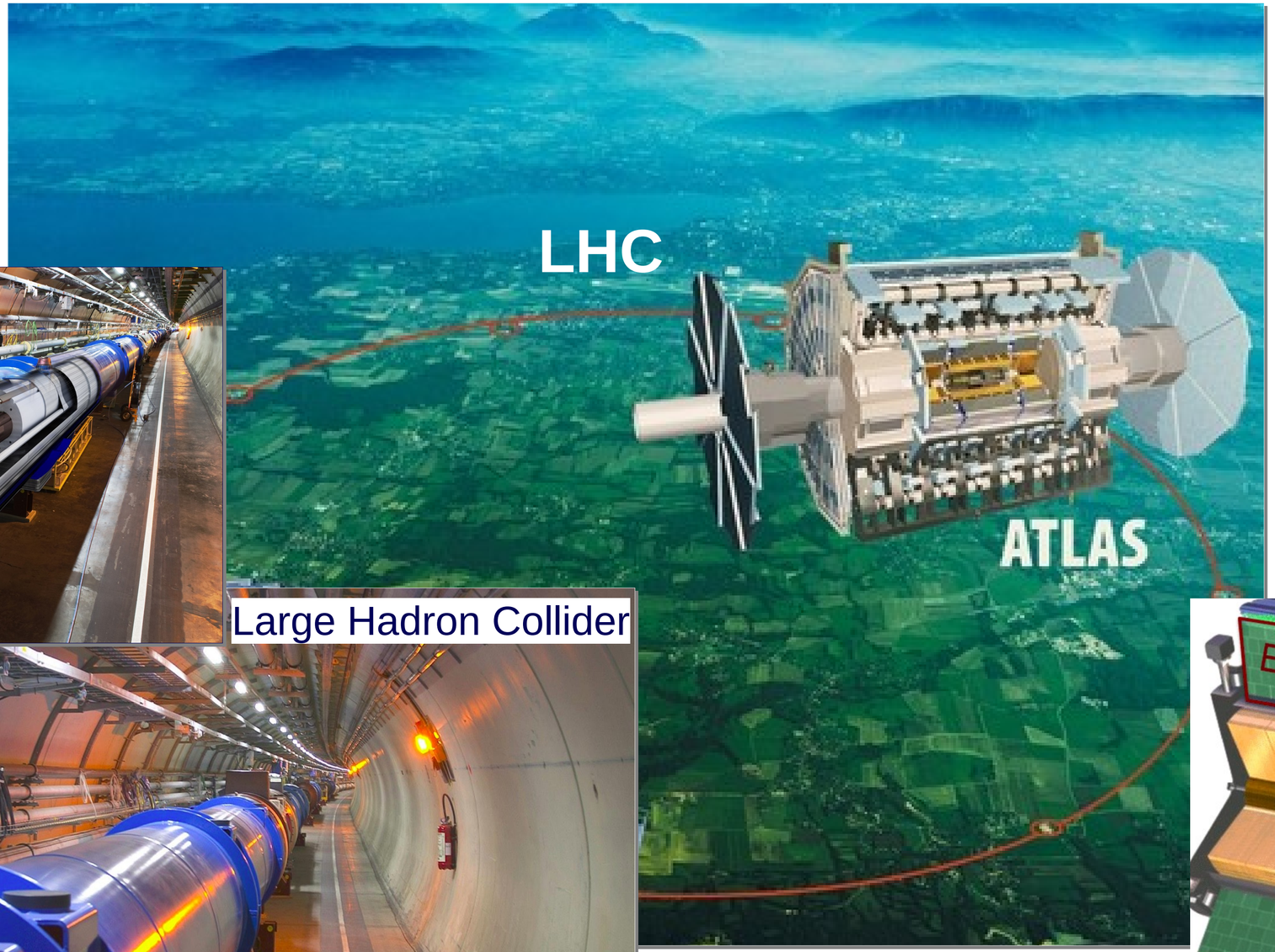
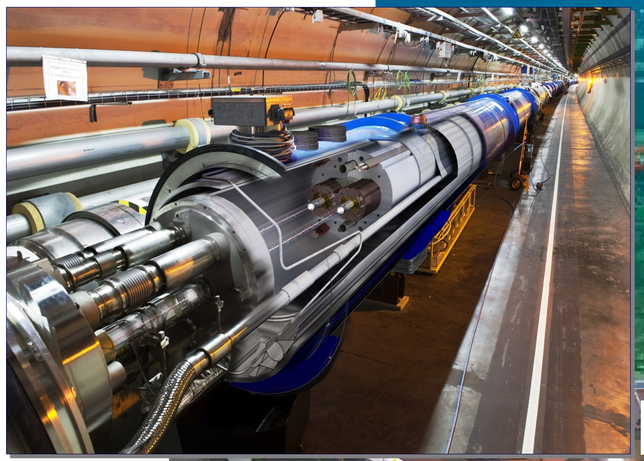
ATLAS EXPERIMENT

Overview

- The Large Hadron Collider, ATLAS detector & TileCal
- Motivation for developing a Sr90 scanning table:
    - E3 & E4 scintillator detector modules and the need for quality control (LHC Run 4)
- Overview of new Sr90 scanning table
- One-coordinate scanning mechanism
- Scanner control and data acquisition
- Summary

The Large Hadron Collider and ATLAS detector

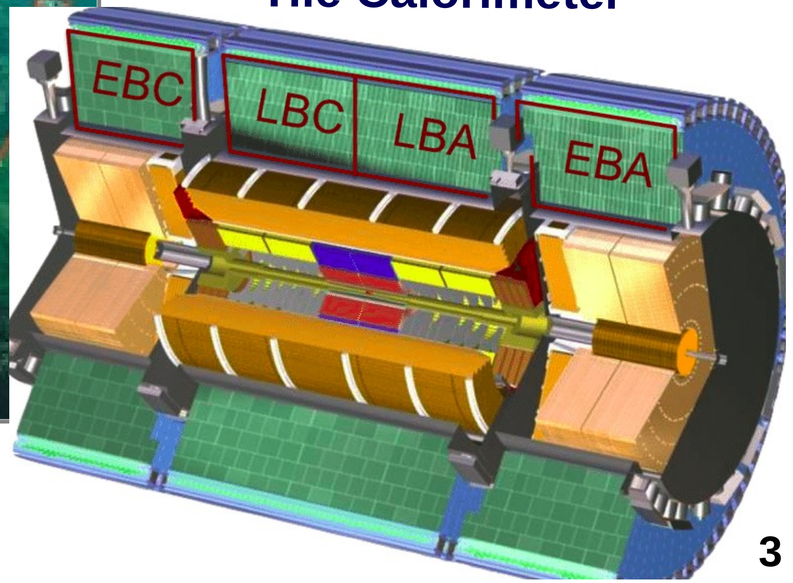




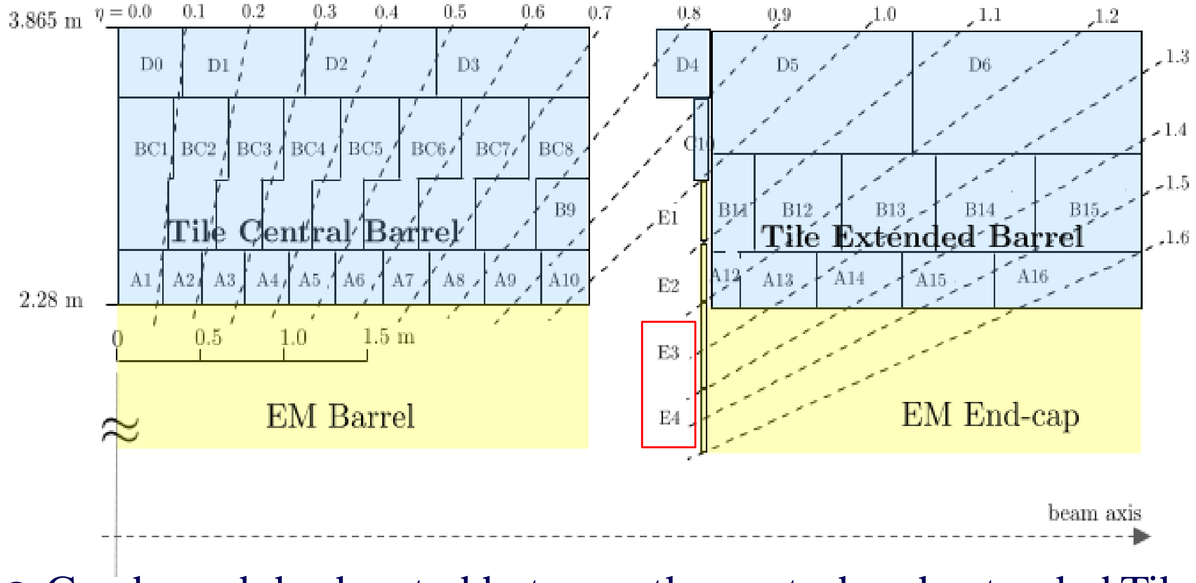
Large Hadron Collider

- 27 km circumference
- 1600 superconducting magnets at -271.3°C
- 120 tonnes liquid helium
- Protons at 99.9999991% the speed of light
- 40 million collisions per sec.
- at main interaction points: CMS, ALICE, LHCb & ATLAS

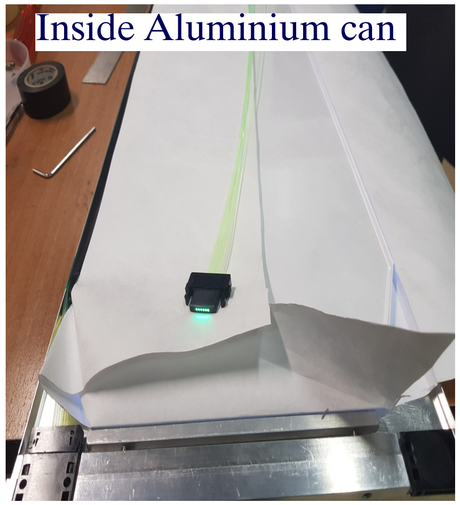
Tile Calorimeter



E3 & E4 Scintillator Detector Modules

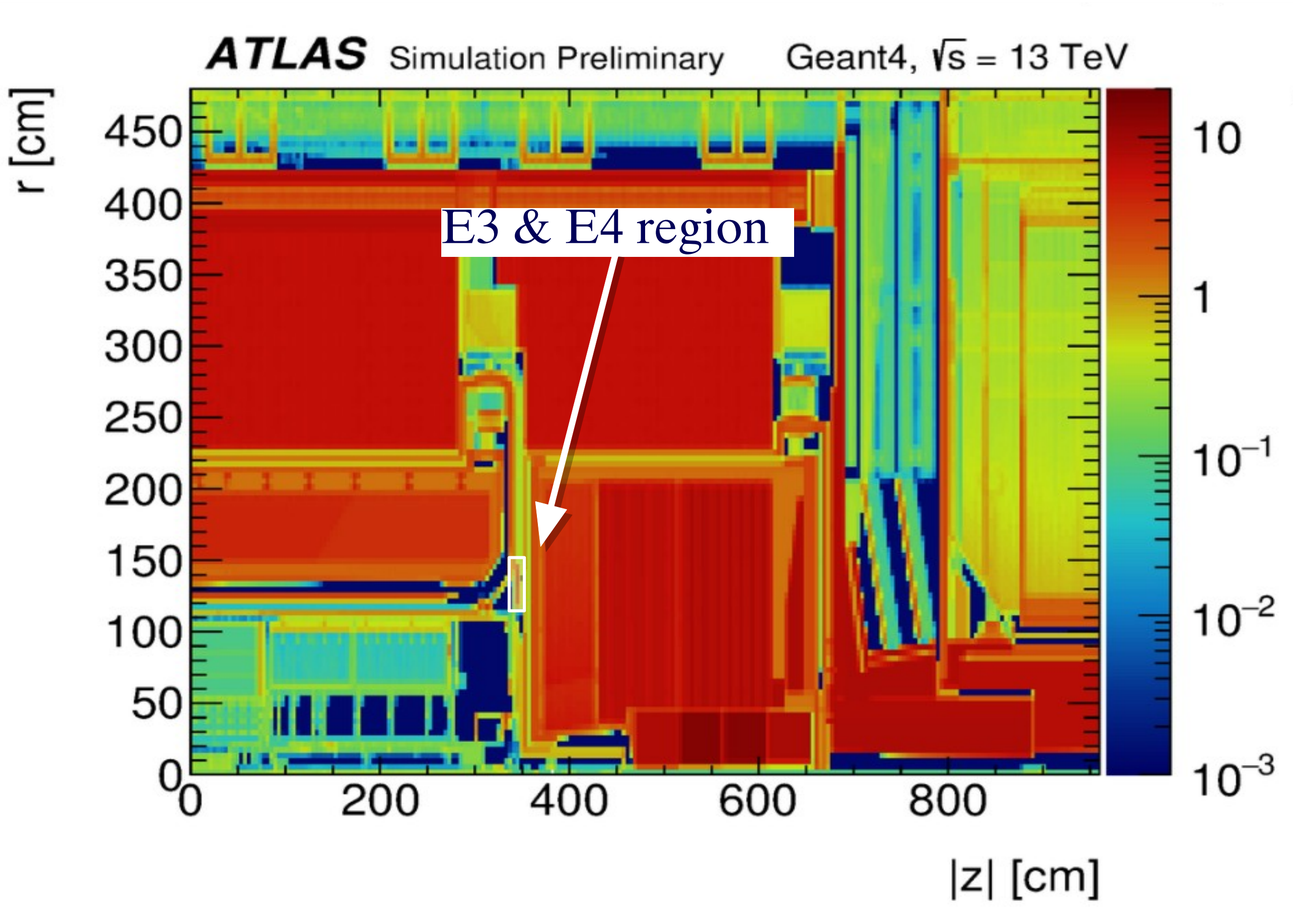


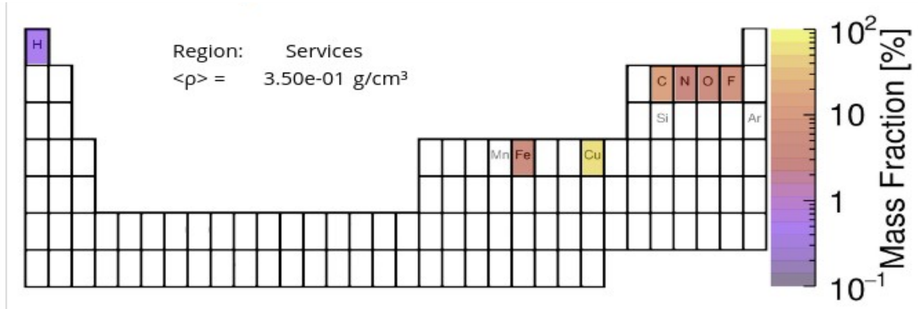
- Crack modules located between the central and extended Tile Calorimeter barrels, are used for correcting the electromagnetic energy responses.
- They are situated in close proximity to the beam axis.

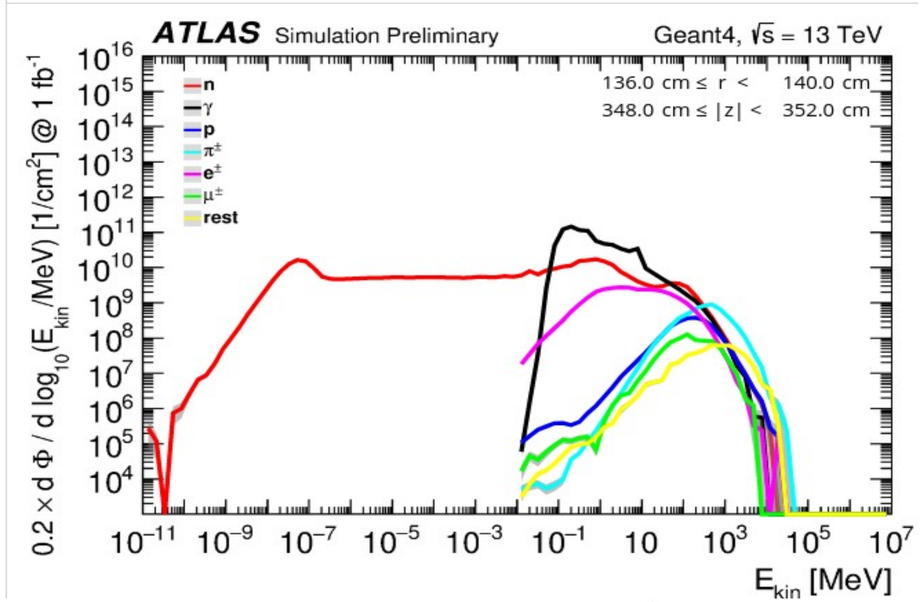


- During Run-2 (2015-2018) data-taking period of the LHC energy $\sqrt{}$ = 13 TeV and integrated luminosity of 139 fb^{-1}, E3 & E4 scintillators were degraded by radiation and had to be replaced. (loss of up to **95%** of the light at the inner radius)
- The radiation dose at the inner radius was of the order of 20 MRad
- In 2019 during LS2 of the LHC, Tile Calorimeter team completely replaced the E3 & E4 scintillators for LHC Run 3.

Radiation environment during the LHC Run 3







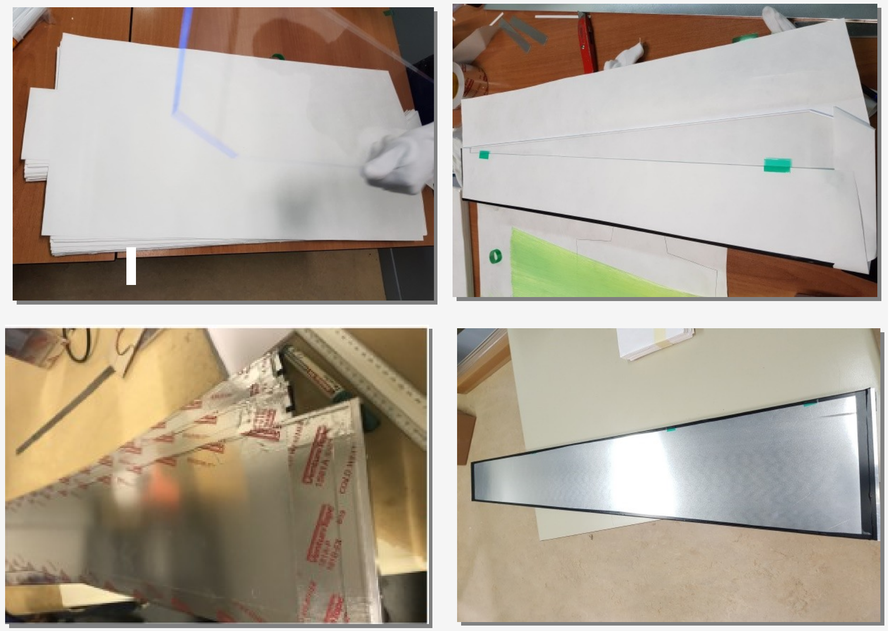
|z|_min (cm)	|z|_max (cm)	r_min (cm)	r_max (cm)	density (g/cm^3)	TID (Gy)	NIEL (n_eq/cm^2)	SEE (h_>20MeV/cm^2)	NEUT (n_>100keV/cm^2)	CHAD (h_chgd/cm^2)
348.0	352.0	136.0	140.0	3.50e-01	1.52e+01+/-9.42e-02	1.48e+11+/-7.39e+08	2.61e+10+/-1.50e+08	1.44e+11+/-7.18e+08	8.08e+09+/-5.87e+07

- At an integrated luminosity of 500 fb^{-1} for Run 3 (Run 2 was 139 fb^{-1}) the E3 & E4 are expected to undergo radiation damage.
- Need to replace E3 & E4 scintillators during HL-LHC era

Quality control of E3 & E4 scintillators

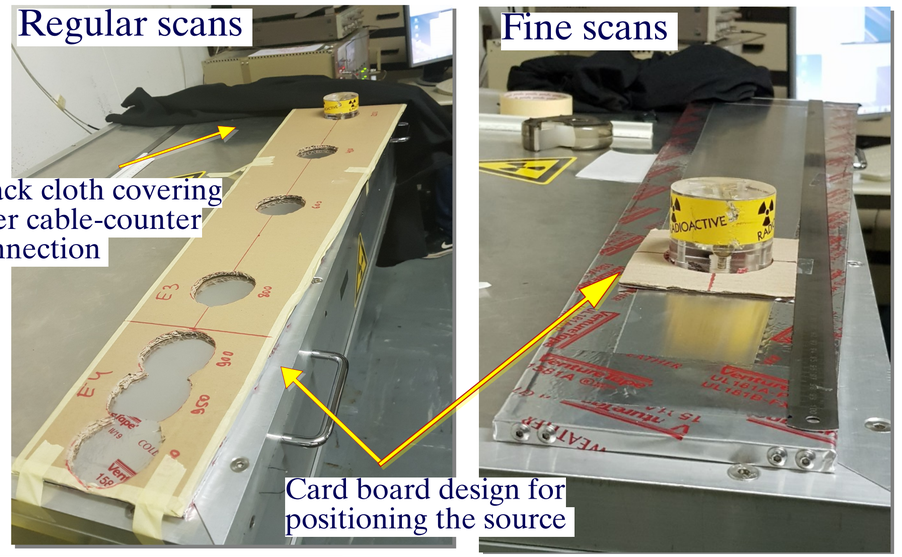
- The quality of E3 and E4 needs to be ensured prior to installation on the ATLAS detector
- Previoulsy, the characterization and qualification of assembled E3 and E4 scintillator counters was conducted through manual scans using Sr90 source & a small box containing PMT.

Assembly of E3 & E4 scintillator modules

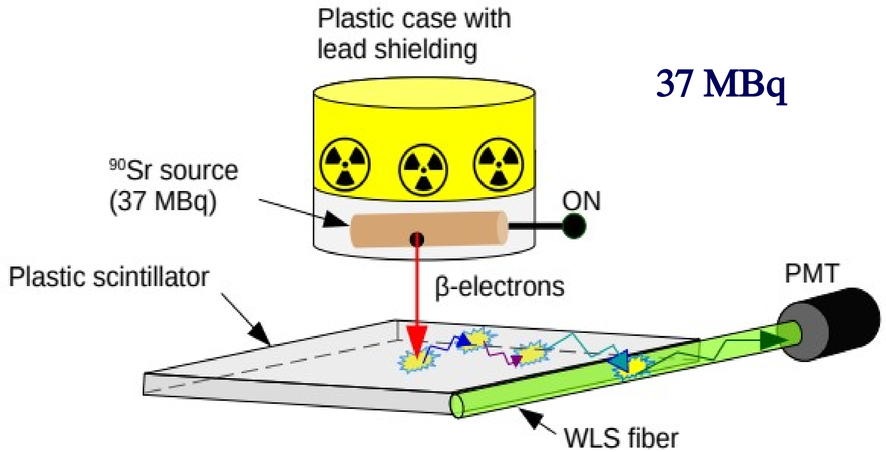


- The performance of assembled E3 and E4 scintillator counters must be checked.
- Need to assess the light-tightness of each counter; check for light leaks from connections & aluminium cover ends.
- Check if each slab is coupled to WLS fibers.
- All counters must show consistent response to Sr90 source.

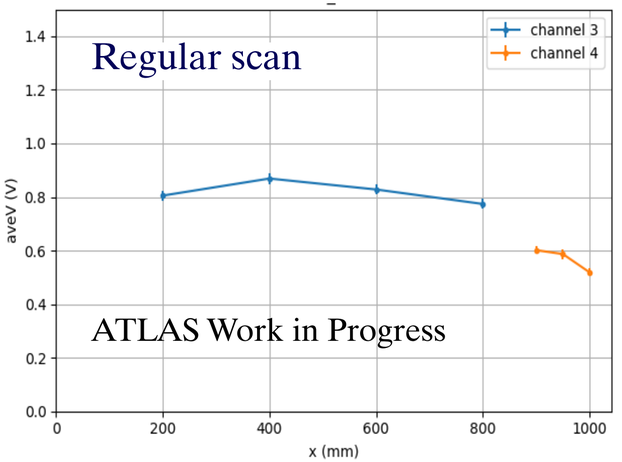
Manual Sr90 scans

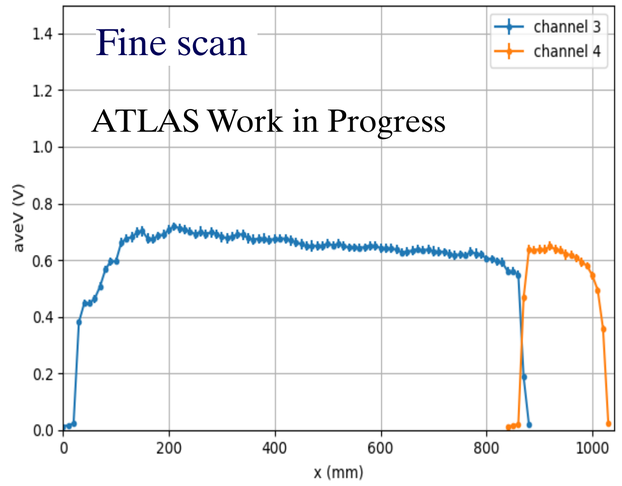


Light collection



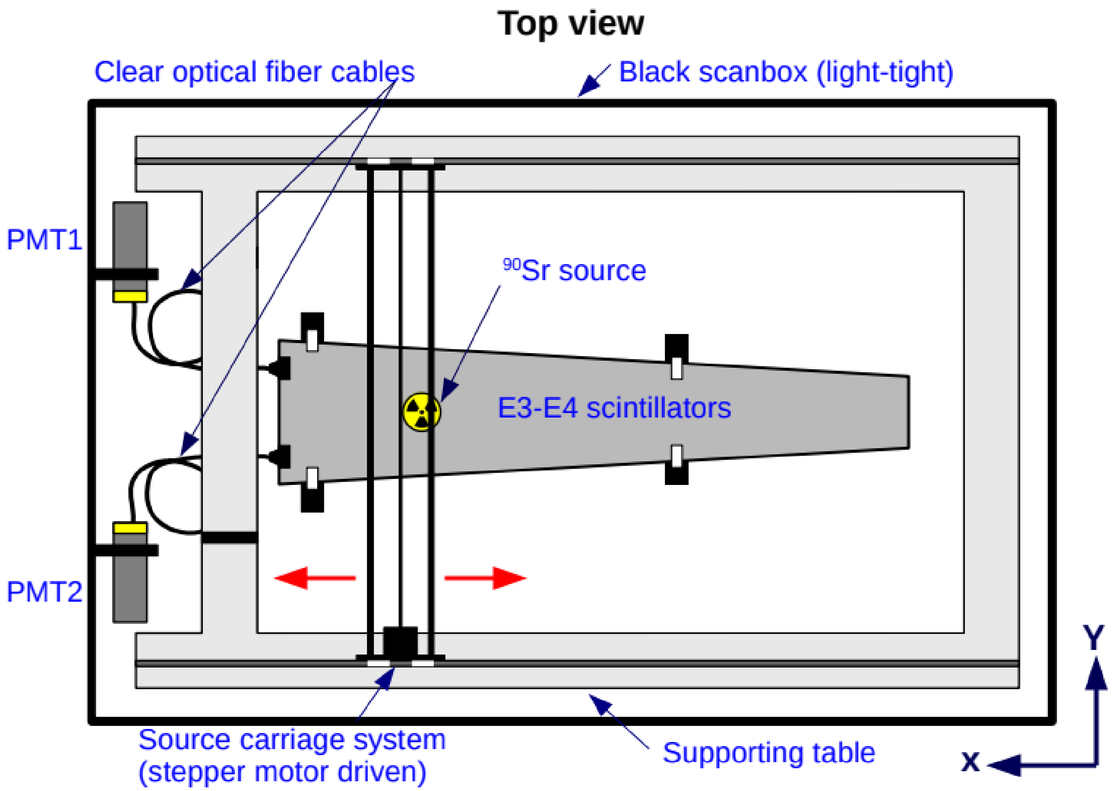
Response to Sr90 source

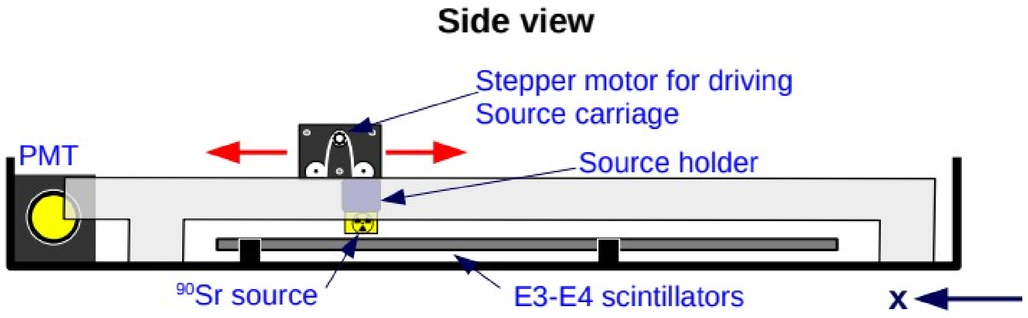




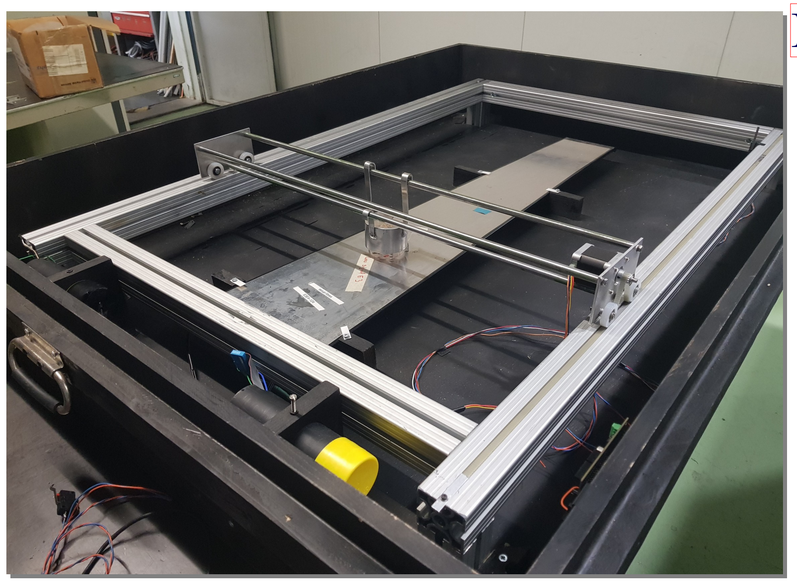
- The scanbox was too small to house all components. Need to develop a big automated Sr90 scanbox

Overview of a new Sr90 scanning table

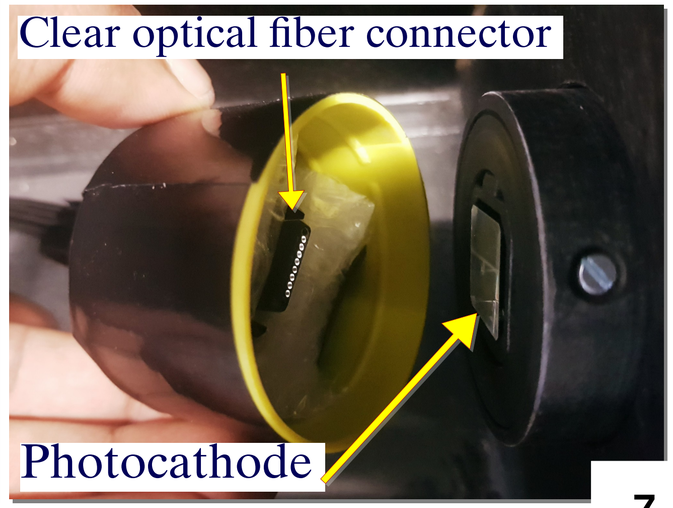




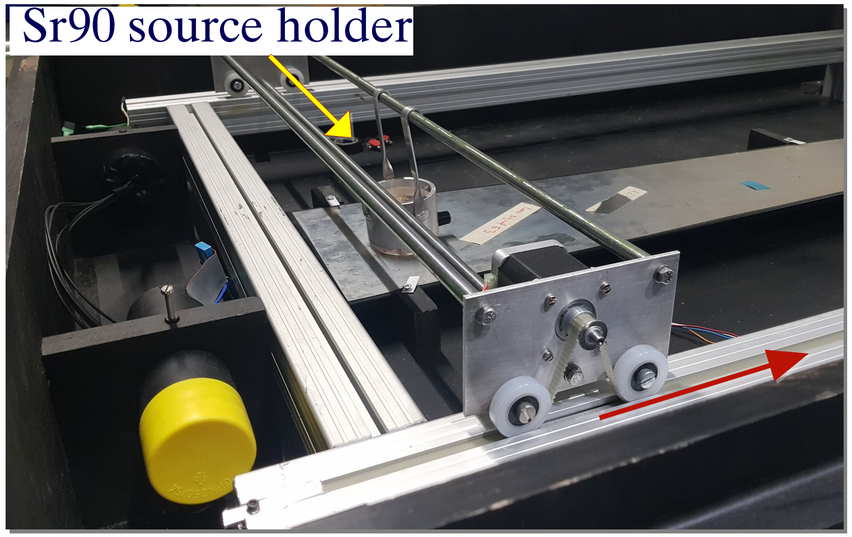
- The new scanbox is automated and big enough to house all components and guard against external light.
- The light-tight scanning box contains the following componets:
  1. 1D scanning mechanism
  2. 37 MBq Strontium-90 radioactive β source (β energy 546 keV, half life 28.8 years)
  3. 2 photomultipliers (Hamamatsu R7877)
  4. 2 clear optical fiber cables (for light transmission)



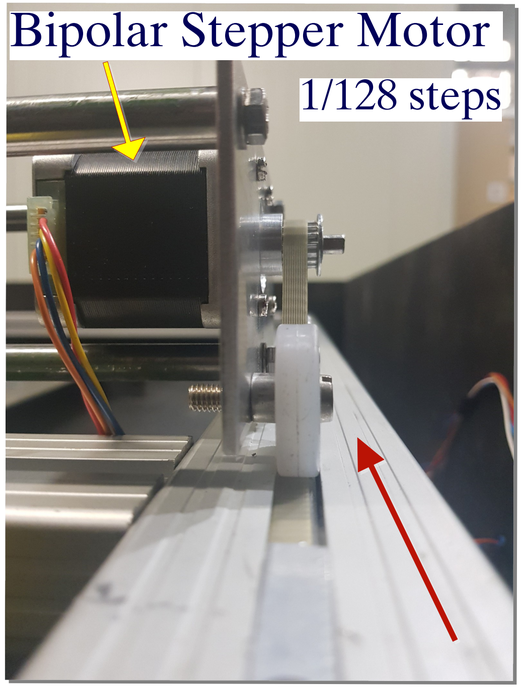
Fiber cable & PMT connection



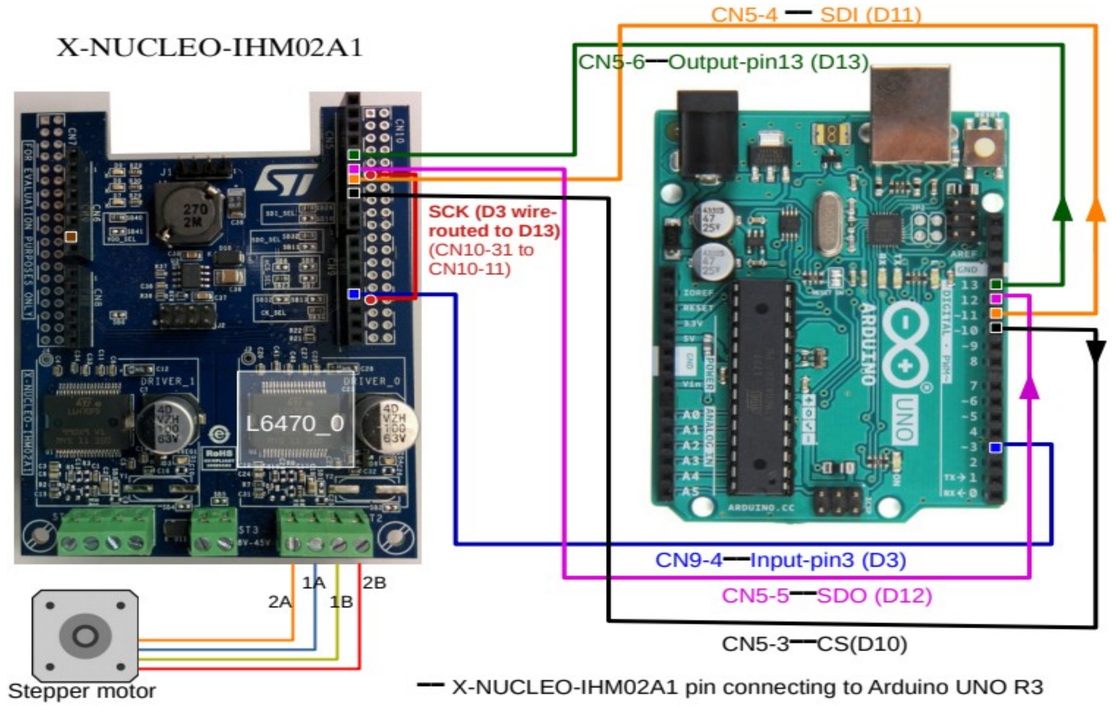
One-coordinate scanning mechanism

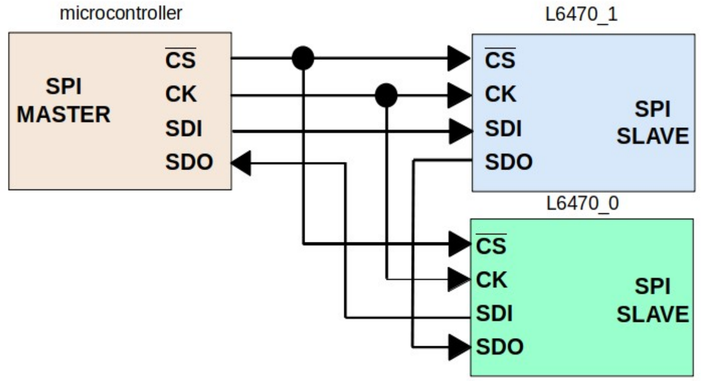


- The one-coordinate positioning system of the scanner is driven by a powerful 103H5210-5240 Bipolar Stepper Motor (good positioning accuracy).
- The scan length (x-axis) is restricted by the limit switches.
- The motor is controlled by an X-NUCLEO-IHM02A1 two-axis stepper motor driver expansion board (L6470), which is plugged onto the Arduino Uno R3 microcontroller (mounted in the scanbox).
- Arduino microcontroller uses a sychronous serial data protocol (Serial Peripheral Interface) to communicate with the L6470 stepper driver
- The config. comprises four digital lines of SPI: chip select (CS), serial clock (SCK), Serial Data Input (SDI) and Serial Data Output (SDO).



Nucleo board and Arduino connected in daisy chain configuration



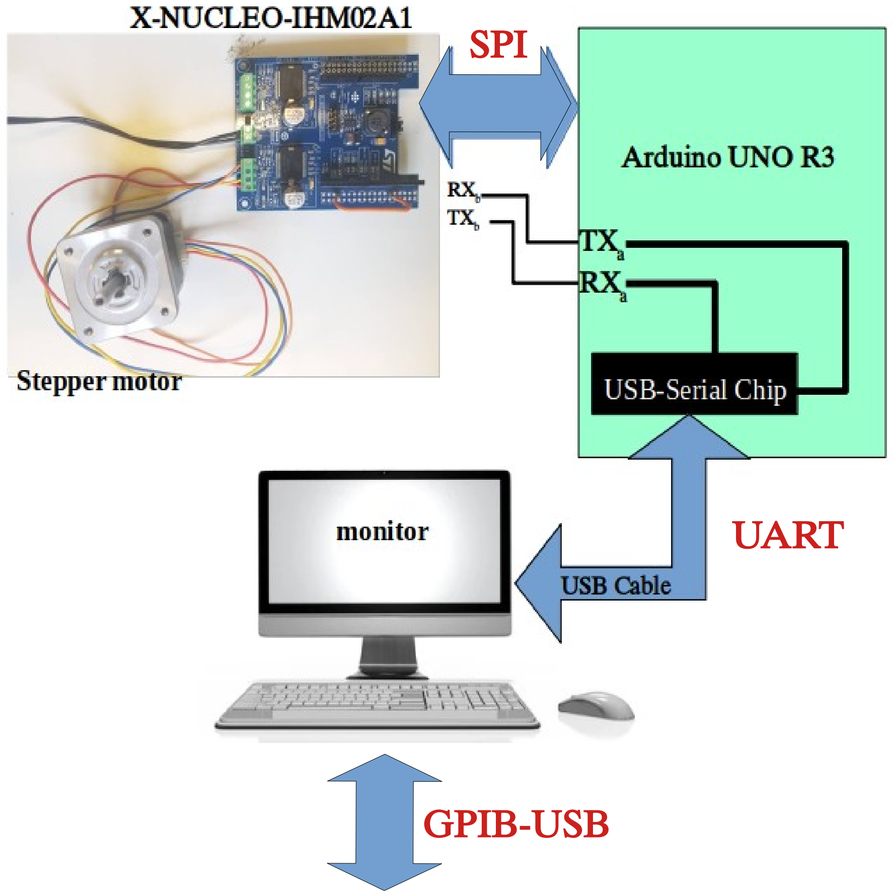


File Edit Sketch Tools Help

stspin6470 § SparkFunAutoDriver.h

```
pinMode(3, INPUT);      // D3 = SPI SCK, wired-routed to D13(SCK),
pinMode(4, OUTPUT);     // D4 = nReset
pinMode(SDI, OUTPUT); // Serial IN
pinMode(SDO, INPUT);  // Serial OUT
pinMode(13, OUTPUT);    // serial clock -> routed to D3 by wire
pinMode(A2, OUTPUT);    // CS signal
pinMode(homeSwitchPin, INPUT_PULLUP);
pinMode(led, OUTPUT);
//pinMode(limitButton, INPUT_PULLUP);
```

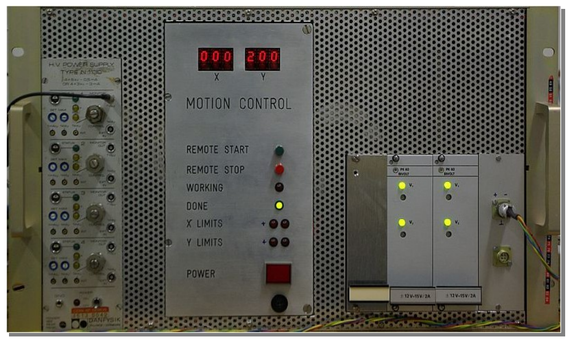
Scanner control and data acquisition



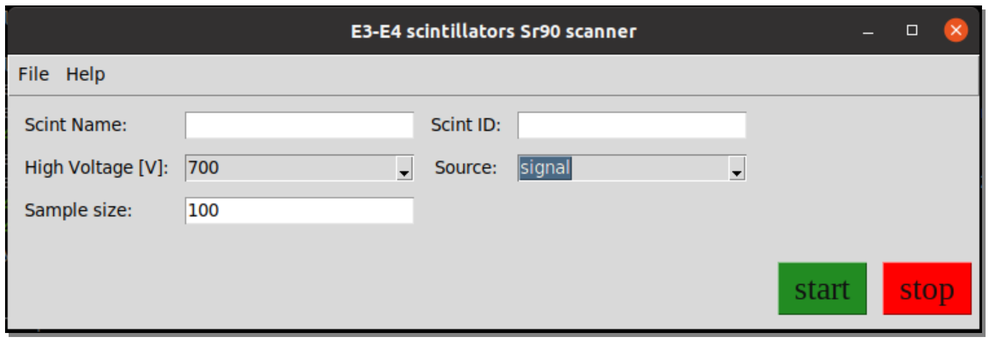
- The scanning mechanism is accessible via serial port using a Universal Serial Bus (USB) cable connection -UART protocol .
- The main control program (GUI) allows for scintillator counter naming, selecting the voltage, signal/pedestal source and the sample size.
- The movement commands are sent to the microcontroller via pySerial.
- The HV power supply unit is used to supply R7877 PMT.
- The signal generated by the R7877 PMT is measured as a function of radiation source position using a special integrator card and Keithley-2000 multimeter with scan card, interfaced by GPIB-USB.

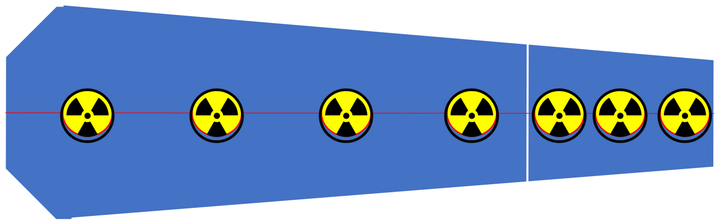
Digital multimeter fo readout

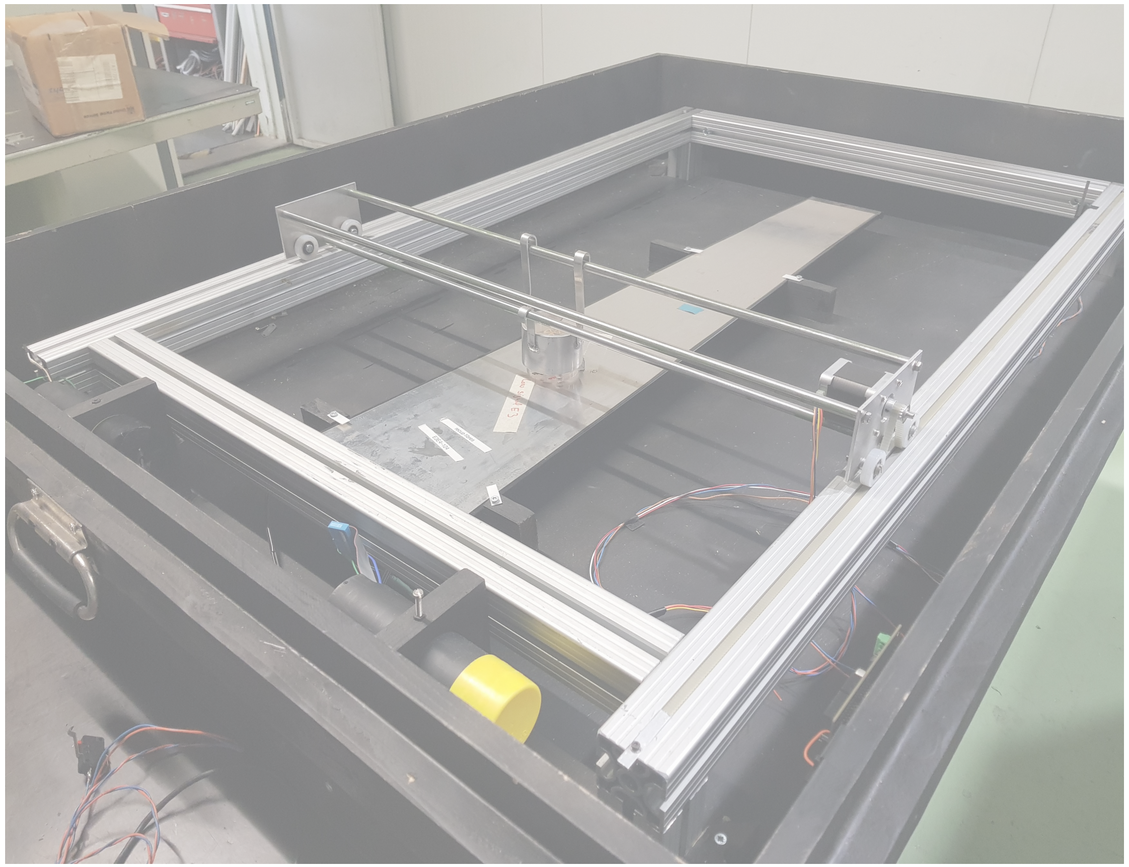
HV power supply unit



GUI for exercuting the main control program







Summary

- The strontium-90 scanning table for quality control of assembled E3 and E4 scintillator detector modules has been developed at the ATLAS experiment.
- A detector module, clear optical fiber cables, and connections can all be housed in the scanbox; contaminations from the external light is no longer worrisome.
- An automated 1D carriage mechanism allows for good Sr90 source positioning accuracy during scanning.
- The scanning table will be employed after LHC Run 3 during the replacement of E3 and E4 scintillators as radiation damage demands.

Thank you!