STATUS OF THE BDX EXPERIMENT

MARIANGELA BONDÌ

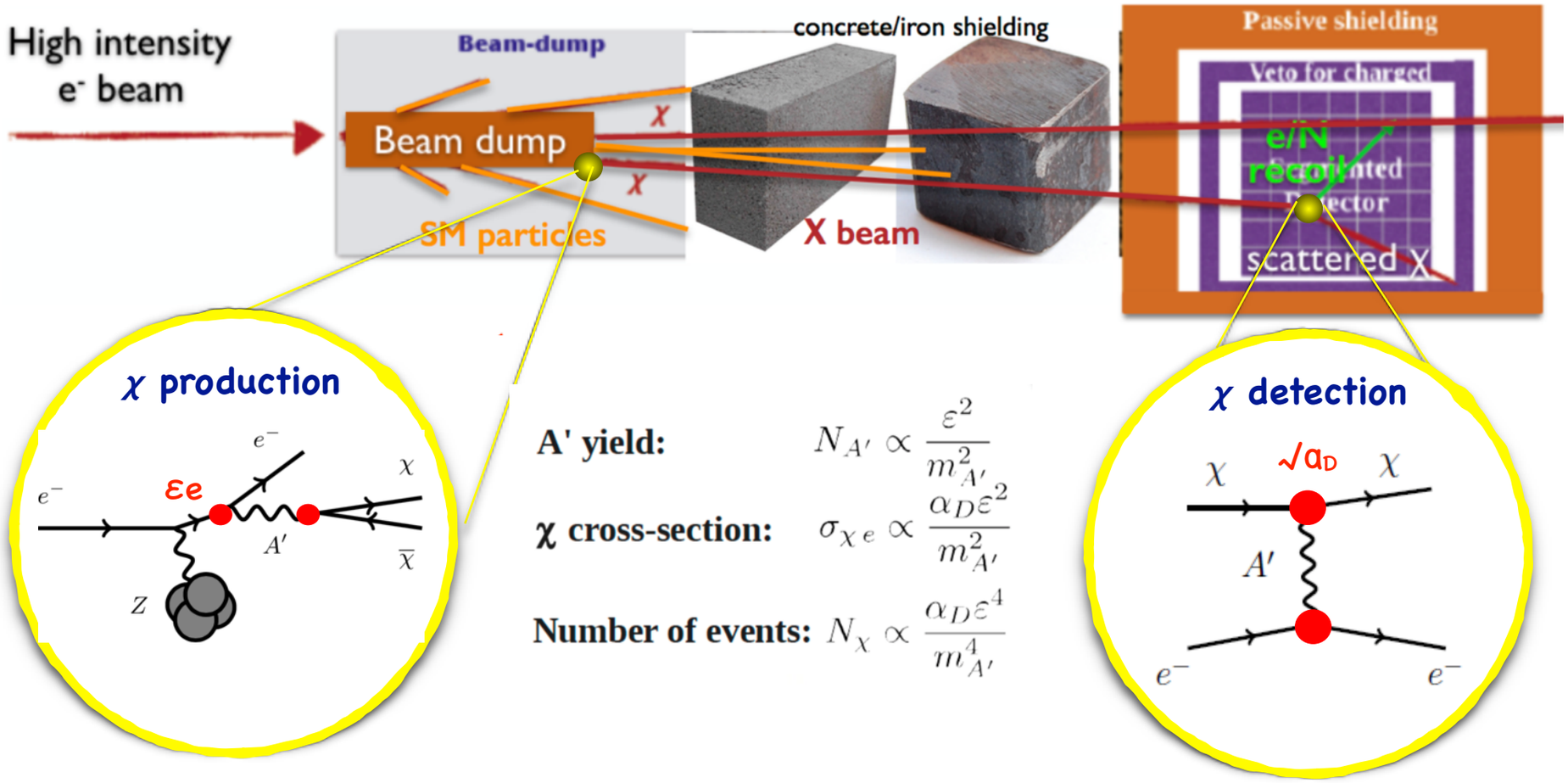
FOR THE BDX COLLABORATION

- **BDX EXPERIMENT OVERVIEW:**
- GOAL
- BDX @ JLAB
- DETECTOR
- BACKGROUNDS
- **BDX STATUS**
- **BDX UPDATE**
- MUON FLUX MEASUREMENTS

HPS COLLABORATION MEETING - JLAB, MAY 22-24, 2018

BDX EXPERIMENT

GOAL : LIGHT DARK MATTER SEARCH IN A BEAM DUMP EXPERIMENT



1 STEP: LDM PRODUCTION

An electron radiates an A' and the A' promptly decays to a X pair

GeV - high intensity e- beam

2 STEP : LDM DETECTION

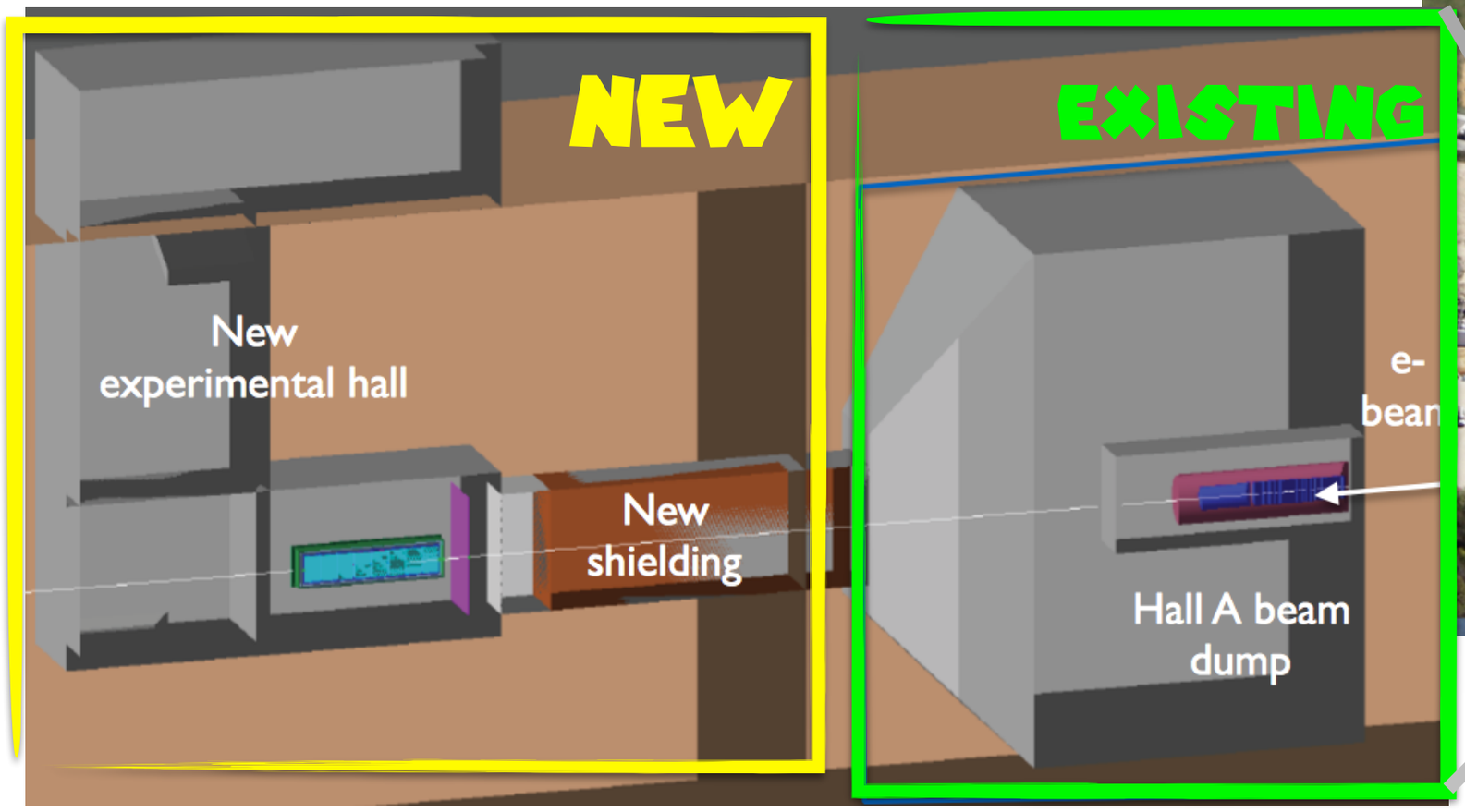
The X (in-)elastically scatters on a e-/nucleon in the detector producing a visible recoil

BDX @ JLAB

KEY POINTS:

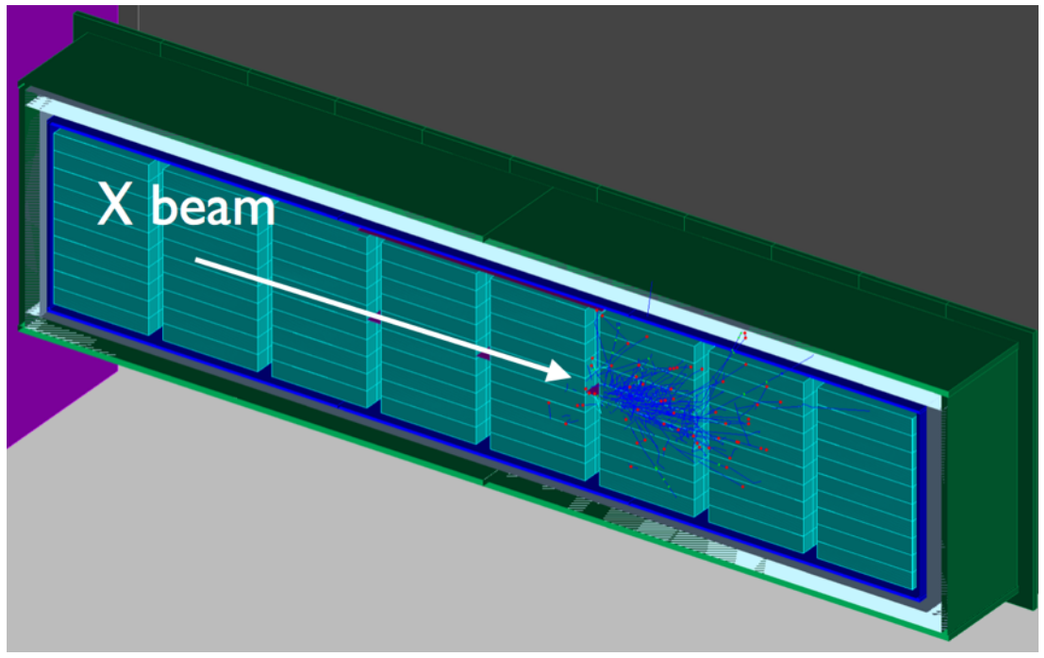
- **High energy** beam : 11 GeV
- the **Highest** available **beam current** ~ 65 μA
- Integrated charge: 10^{22} EOT in ~ 10 months

- BDX detector located underground, downstream of Hall-A beam-dump
- BDX beamtime fits the Hall-A experimental program (already-approved experiments with more than 10^{22} (11 GeV) EOT, e.g. Moeller exp.)
- New underground experimental hall



BDX DETECTOR

LDM SIGNAL IN THE DETECTOR : X-electron -> EM shower ~ GEV

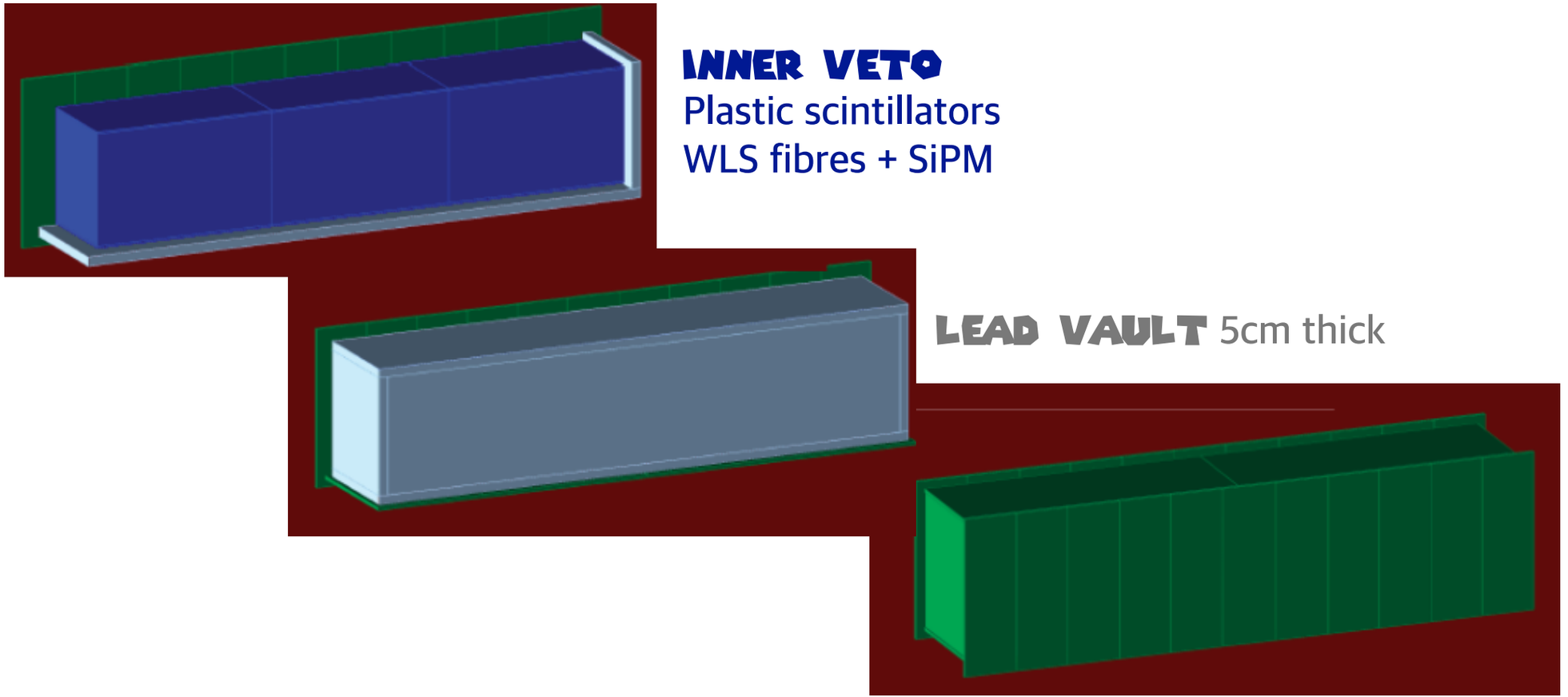


LDM DETECTION

MODULAR EM CALORIMETER

- 800 CsI(Tl) crystals (from BaBar EMCal)
- 8 modules 10x10 crystals each
- ~ 3 m long , ~ 50x50 cm^2 front face
- 6x6 mm^2 SiPM readout

BACKGROUND REJECTION

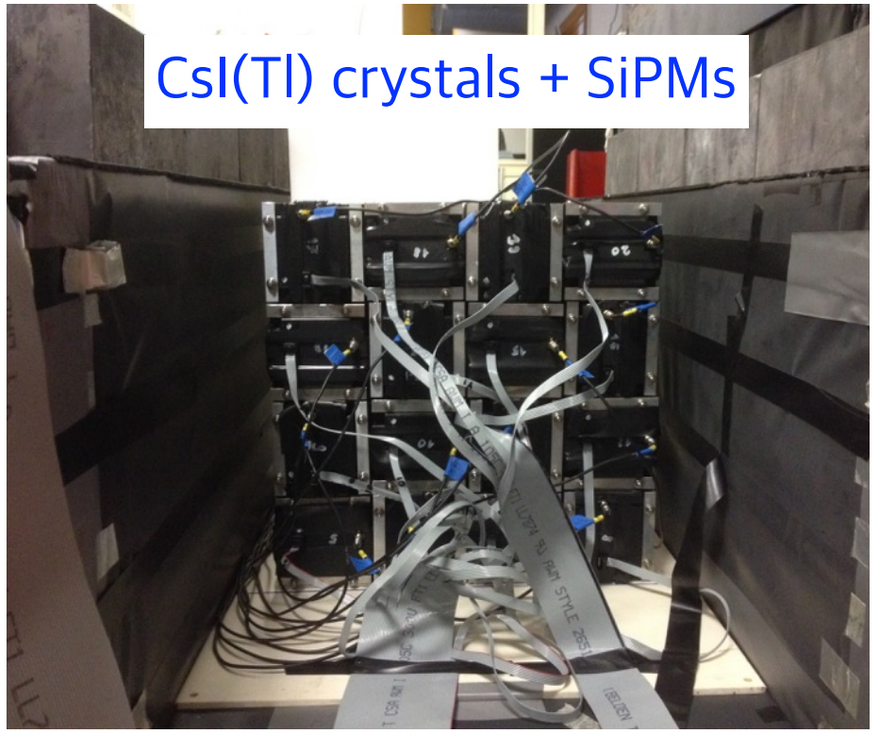


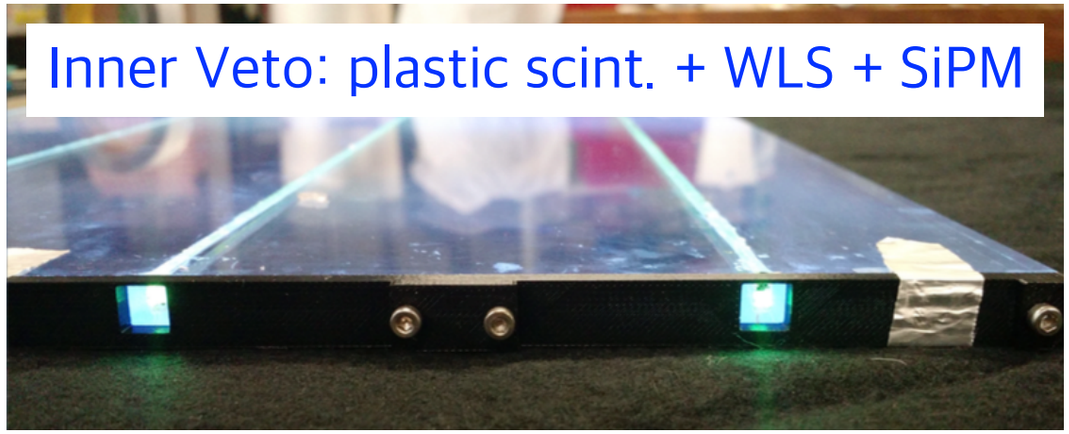
INNER VETO
Plastic scintillators
WLS fibres + SiPM

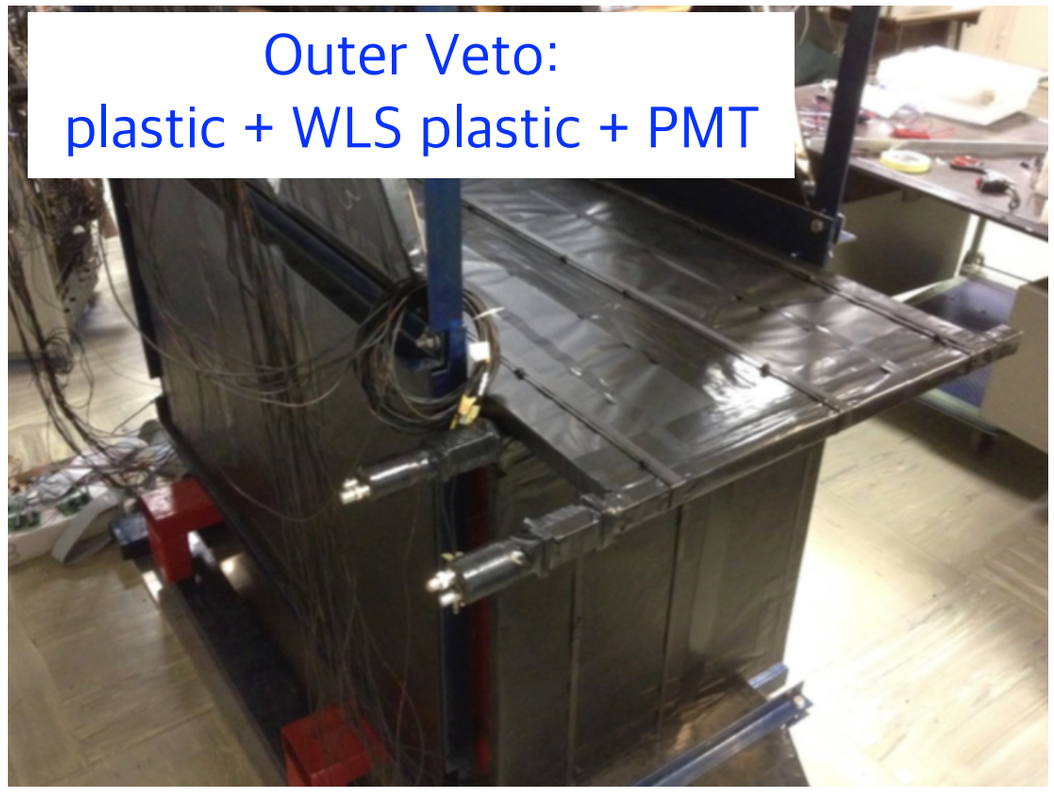
LEAD VAULT 5cm thick

OUTER VETO
Plastic scintillators
LightGuide/WLS scint.
PMTs/SiPM

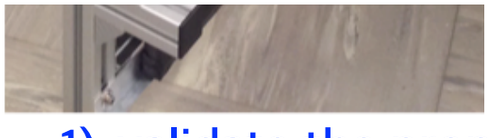
BDX PROTOTYPE







Outer Veto:
plastic scint. + Light guide + PMT

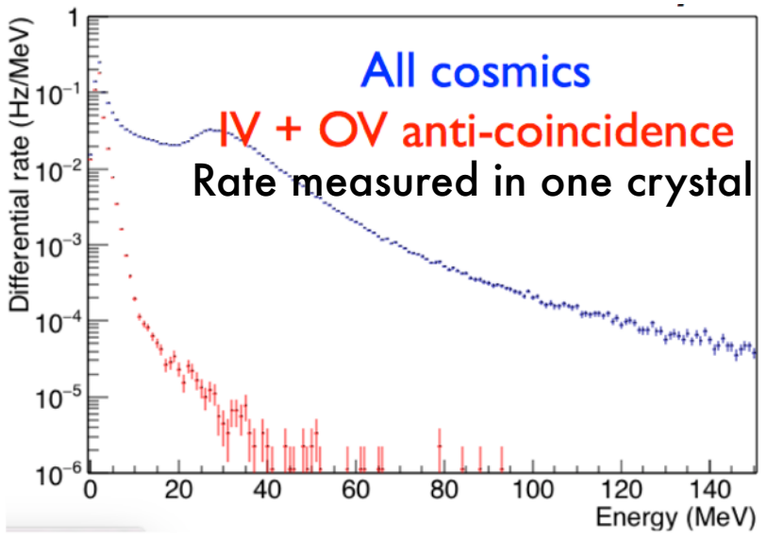


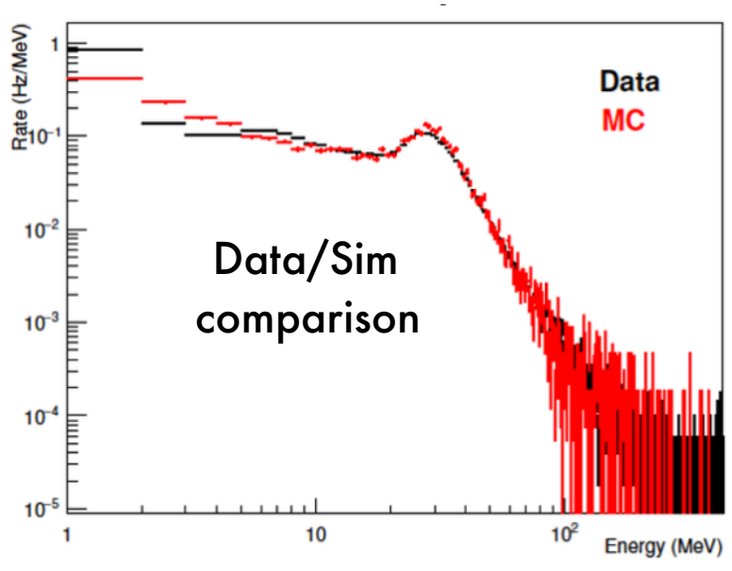
GOALS:

1) validate the proposed design and technical choices
2) measure the capability of rejecting cosmic background and project conservatively experimental data to full detector.

BACKGROUND

COSMIC BACKGROUND : MEASURED WITH THE BDX PROTOTYPE IN CATANIA/LNS



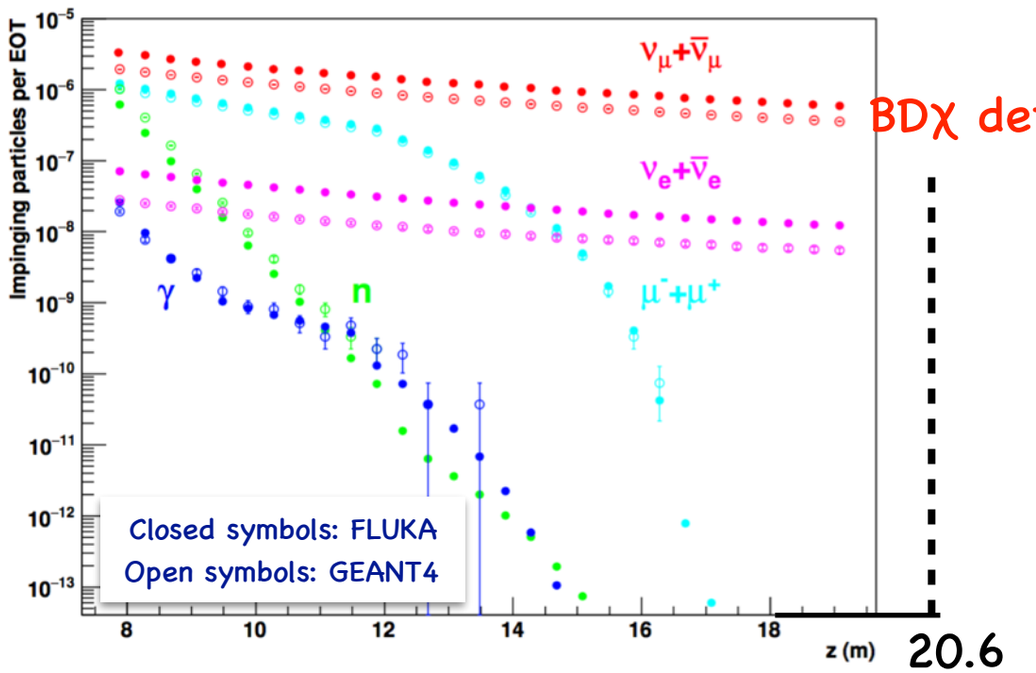


Using Vetos in anti-coincidence and high energy thresholds O(0.5GeV):

expected cosmic bg in the BDX lifetime < 2 counts

BEAM-RELATED BACKGROUND :

The interaction of the 11 GeV electron beam in the dump was simulated and the flux of secondaries was studied as a function of the distance from the dump



- No μ n and γ with E>500 MeV are found at detector location
- Neutrinos survives to the detector -> For a simulated statistics of 2.2×10^8 EOT we obtained, after all rejection cuts and extrapolation to 10^{22} EOT ~ 10 ν.

BDX STATUS

BDX Proposal to JLAB PAC 44 (2016)

- C2 - Conditionally Approval
- Main concern expressed by the PAC on beam-on background

From the report:
While simulations are an essential tool in understanding background conditions, they are not sufficient to design an experiment. The BDX collaboration is therefore encouraged to think more about **benchmarking their simulations with measurements on site**.

BDX Proposal Update to JLAB PAC 45 (2017)

Assessing the beam-related bg :

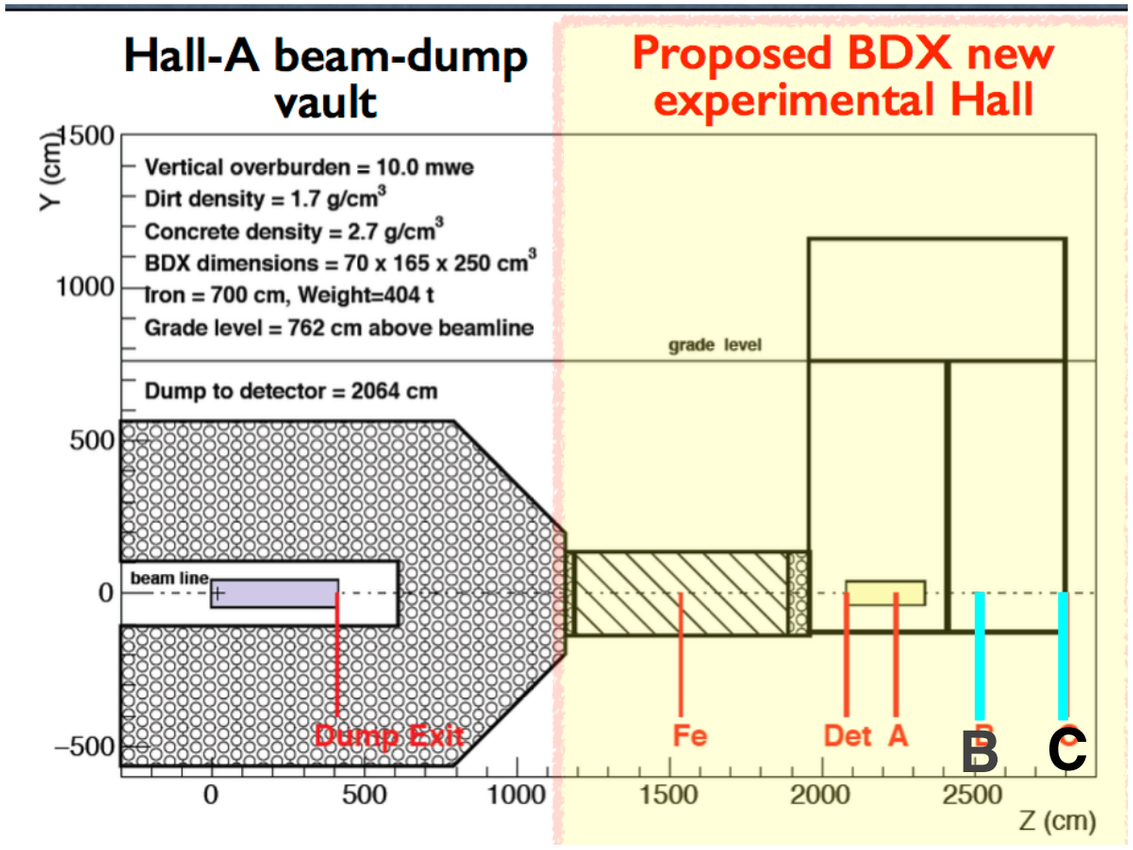
- measuring the muon flux behind the Hall-A dump with the **current shielding configuratio**
- compare MC results obtained in two frameworks: Geant4 and FLUKA (in col with RadCon

Summary: The collaboration should continue working with JLab to carry out the proposed tests, towards achieving full approval at a subsequent PAC.

BDX PROPOSAL TO JLAB PAC46 (2018)

report results/simulation of Muon test

BDX MUON TEST

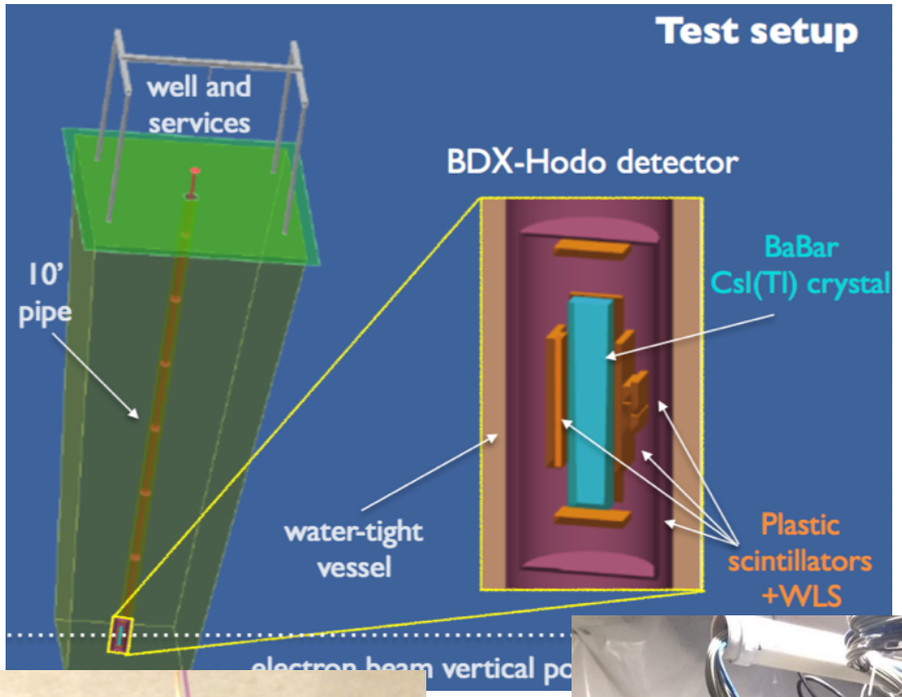


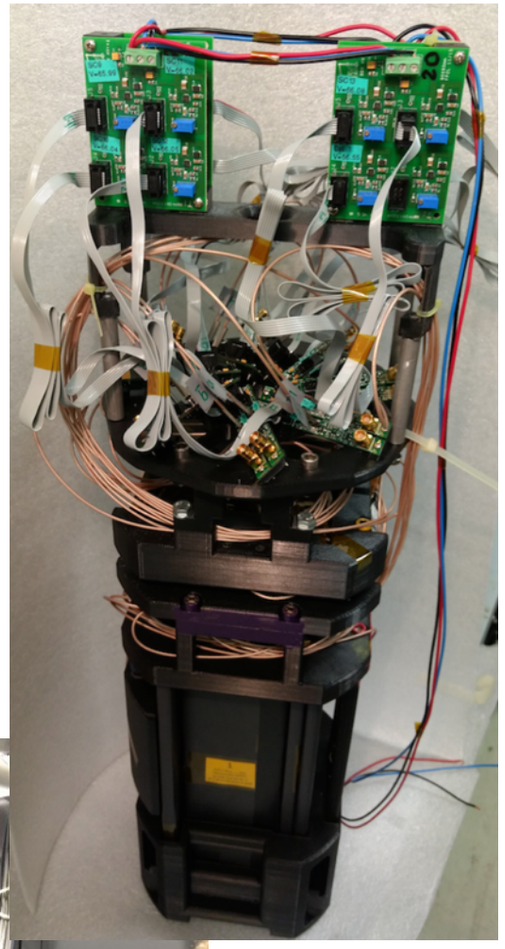
- We have measured the flux of high-energy muon behind the hall A beam-dump with the current shielding configuration when 11 GeV e- -beam is on
- The measurements is a benchmark for MC simulation and helping to understand background
- 2 10” pipes downstream of Hall-A beam-dump were drilled down to beam height (8 m) and aligned with the beam-line n 2 different positions B (25 m) and C (28 m)

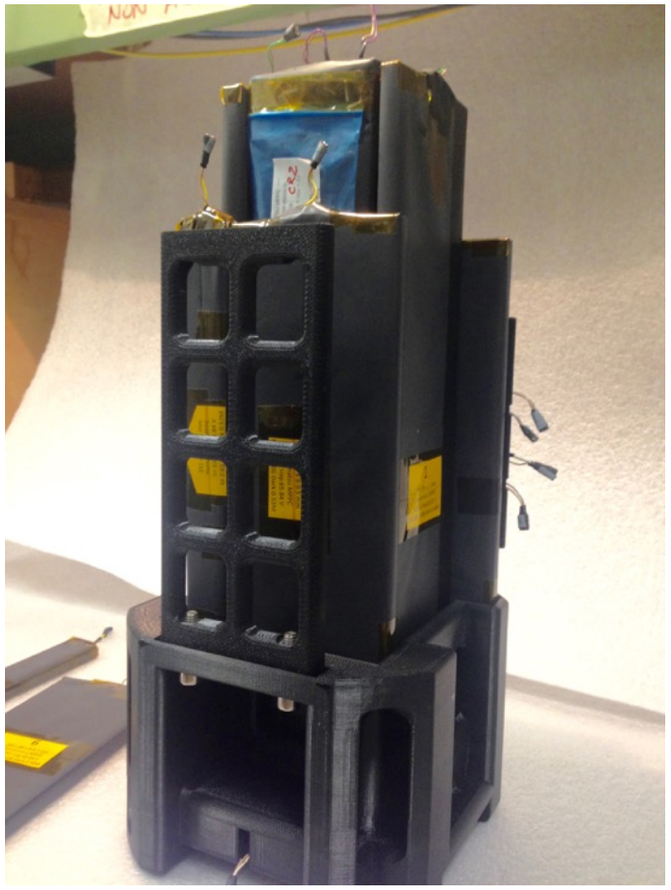
BDX MUON TEST : BDX-HODO DETECTOR

SAME TECHNOLOGIES PROPOSED IN THE FINAL EXPERIMENT

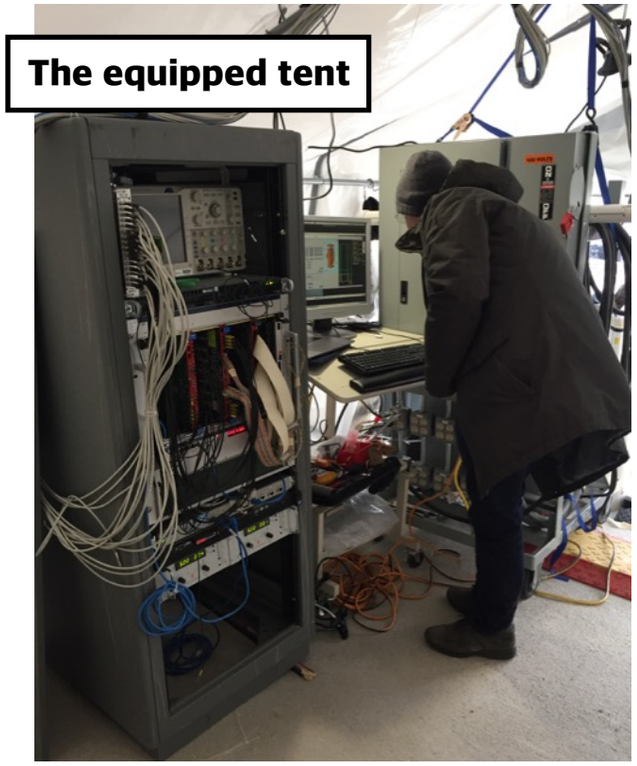
- CRISTAL
  - CsI(Tl) crystal (5x5 x 30 cm^2)
  - 6x6 mm2 Hamamatsu SiPMs
- SCINTILLATORS
  - 13 plastic scintillator paddles 1 cm thick
  - 3x3 mm2 SIPM coupled via WLS fibers
- CONTAINER
  - Cylindrical vessel (d=20cm, h=52cm)
  - Stainless steel, water-tight







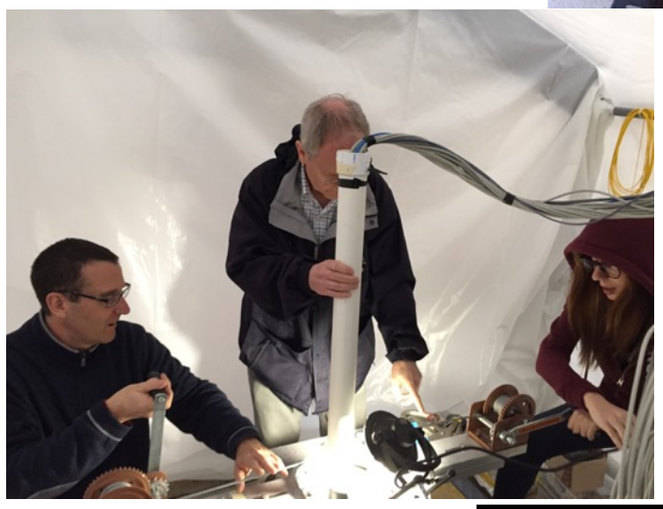
BDX MUON TEST
NEW HALL-TENT


The equipped tent


DETECTOR 8 M DOWN

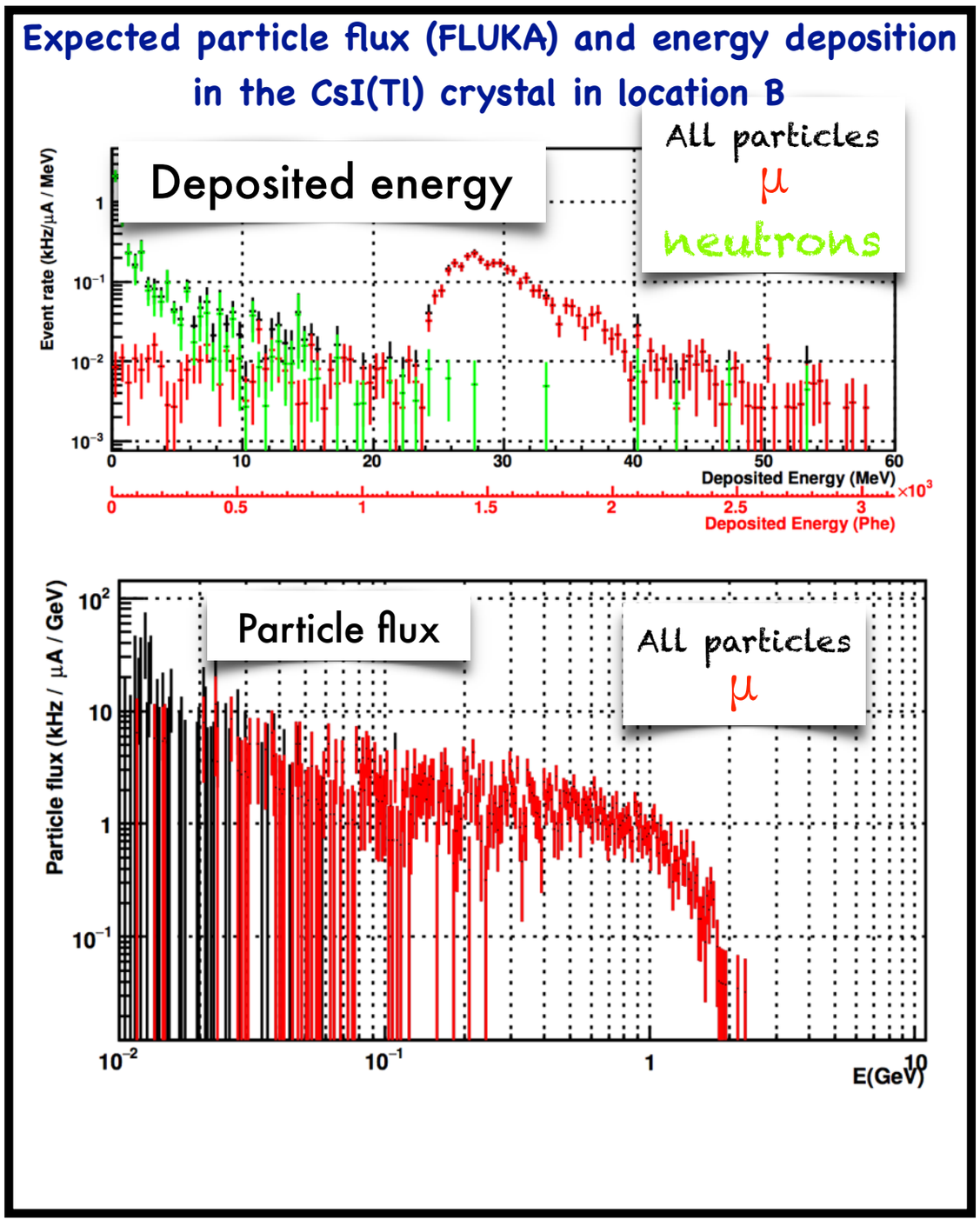

The BDX-HODO inside well B


Connecting the extension sections




DATA taking

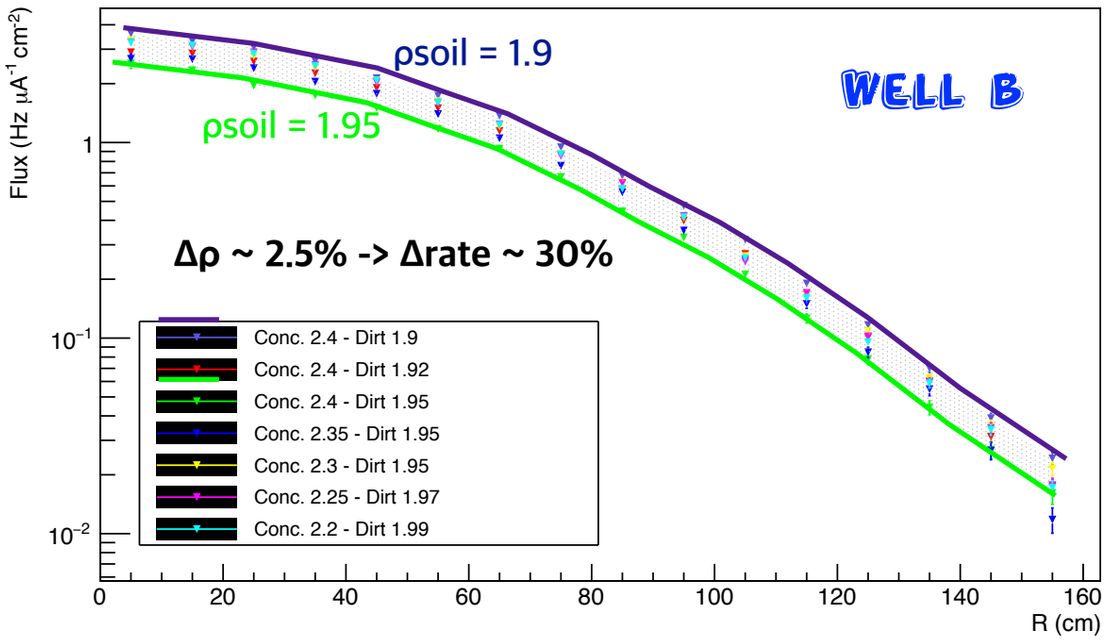
BDX MUON TEST
EXPECTED RESULTS: MC SIMULATION

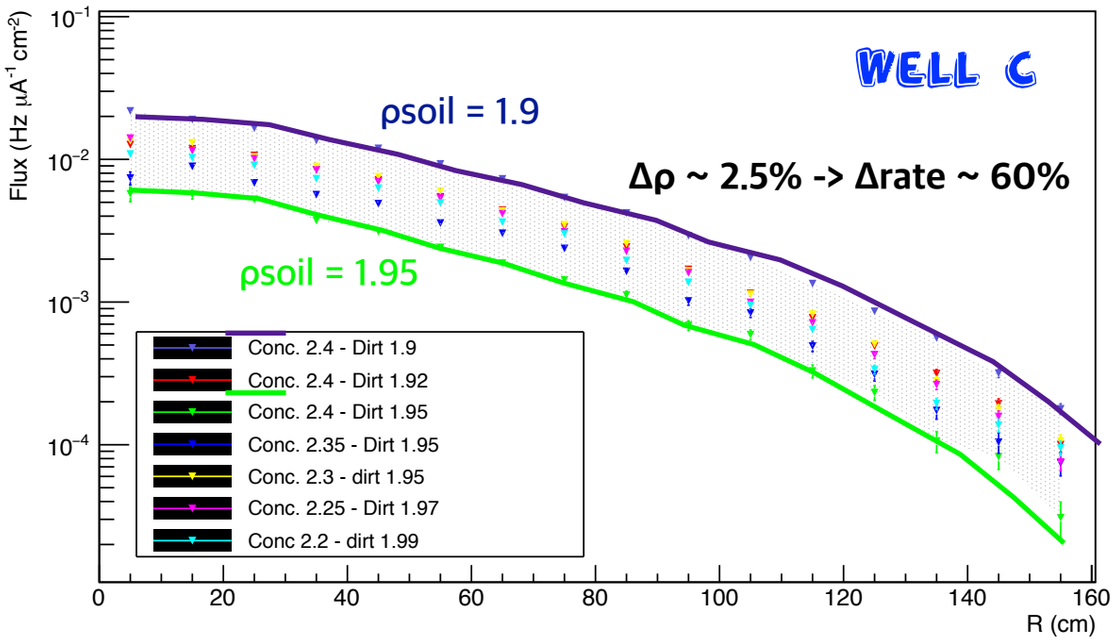


- Simulation performed using FLUKA/GEANT4 framework
  - generating muons by primary electron interaction on Hall-A beam dump (FLUKA)
  - propagating muons to the pipe positions using GEANT4
  - BDX-HODO response with GEANT4
- Only muons and neutrons reach the area of interest
- Rate from cosmic muons is negligible (and measurable !)

BDX MUON TEST
EXPECTED RESULTS: MC SIMULATION

Flux vs vertical position





- ✦ Simulation performed using FLUKA/GEANT4 framework
  - generating muons by primary electron interaction on Hall-A beam dump (FLUKA)
  - propagating muons to the pipe positions using GEANT4
  - BDX-HODO response with GEANT4
- ✦ **Only muons** and low-energy neutrons **reach the area of interest**
- ✦ Rate from cosmic muons is negligible (and measurable !)
- ✦ **Significant dependence on soil density** :
  - **soil density measured** in correspondence of the two wells : **1.93 - 1.95 g/cm3**
  - soil density along the muon flight path unknown : constant ??
  - concrete density: no measurement available
- ✦ Expected Rate :
  - Rate Well B: order of magnitude of kHz
  - Rate Well C: order of magnitude of Hz
  - Rate_WellB/Rate_WellC ~ 200-400

BDX MUON TEST
EXPERIMENTAL CAMPAIGN

★ Positions scan: the muon flux sampled at different heights with respect to nominal beam height (8 m underground).

◉ Beam: CEBAF e- beam @ **10.6 GeV** and current of 22 uA

➡ Well B : 22 positions (ranged between -110 cm and 150 cm). Each measurement was repeated at least 2 times

➡ Well C: 14 positions (ranged between -80 cm and 80 cm). Each measurement was repeated at least 2 times

★ Currents scan: the muon flux sampled at nominal beam height (8 m underground) changing the current .

◉ Beam: CEBAF e- beam @ **10.6 GeV**

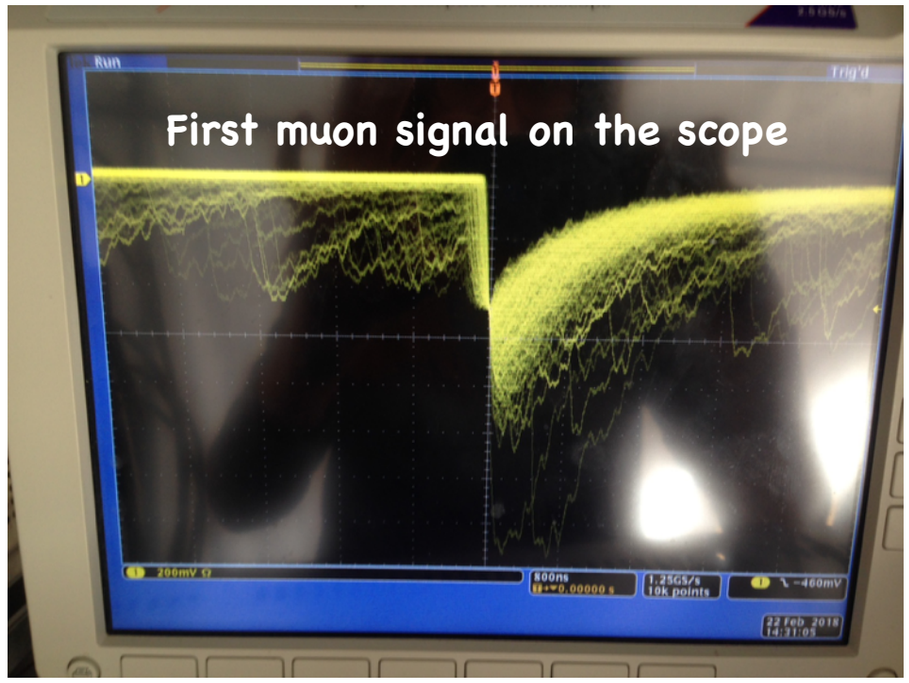
➡ Current = 2.2uA, 5uA, 10uA, 22uA

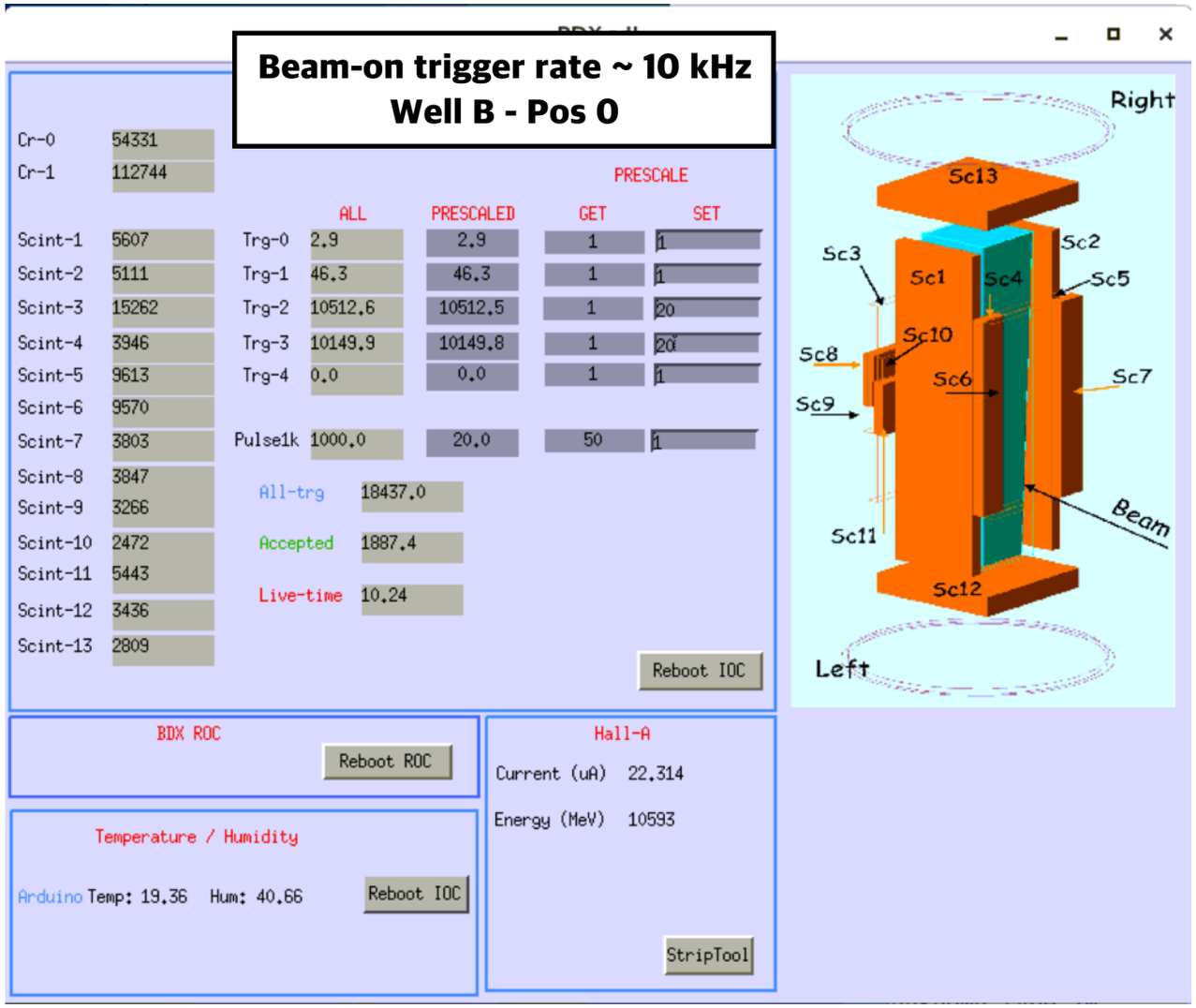
➡ Well1 : 1 position (position 0)

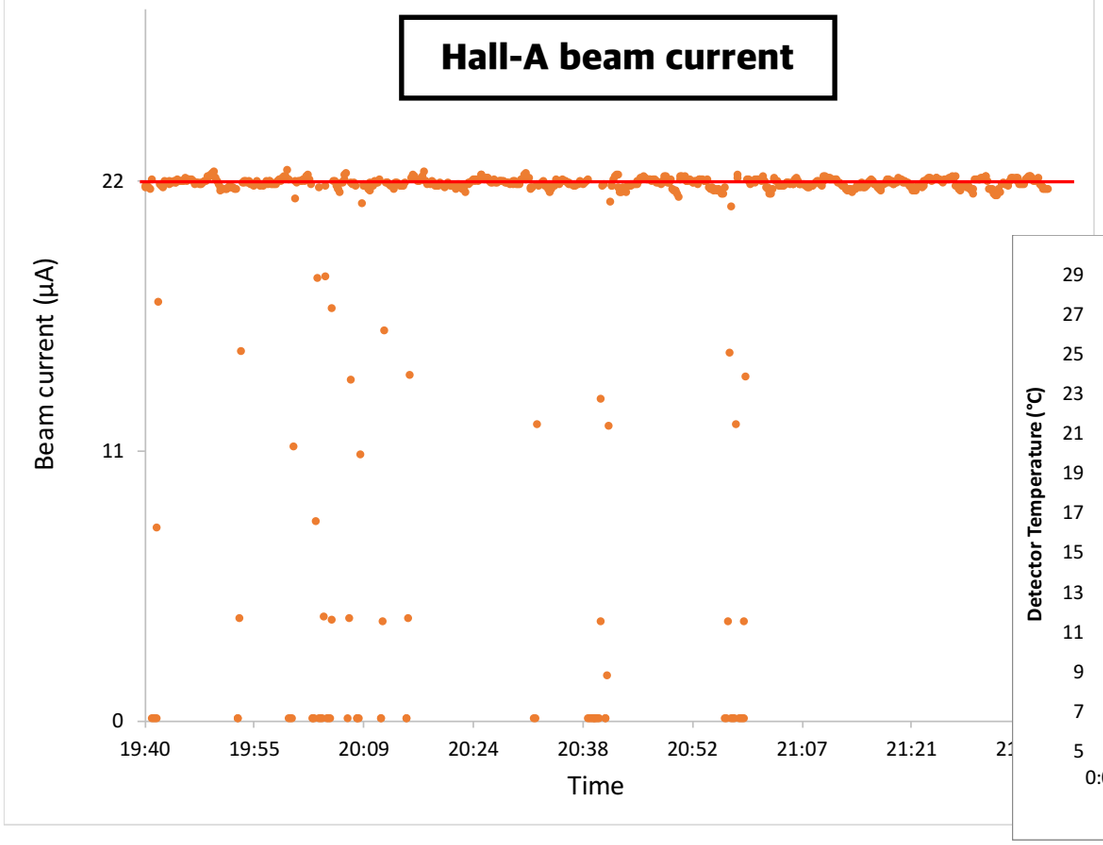
★ Cosmic Background

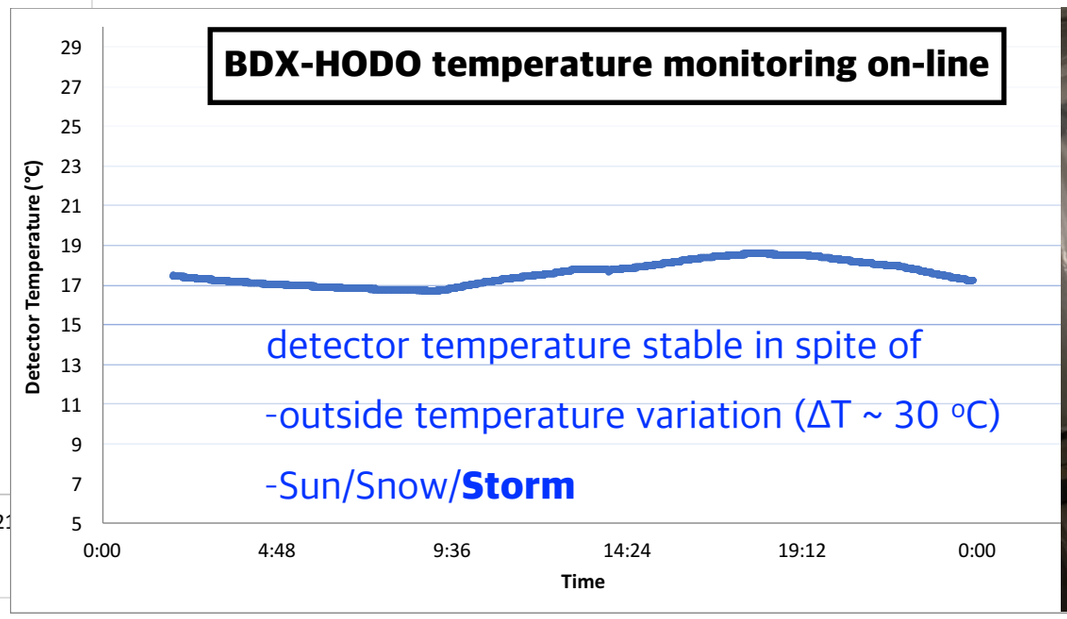
◉ Long run taken with BDX-HODO inside Well C

BDX MUON TEST
RUNNING THE EXPERIMENT

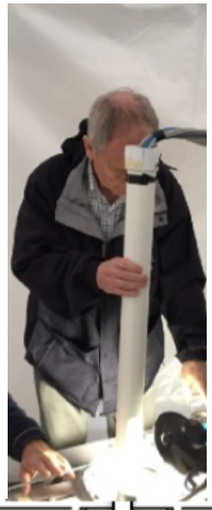


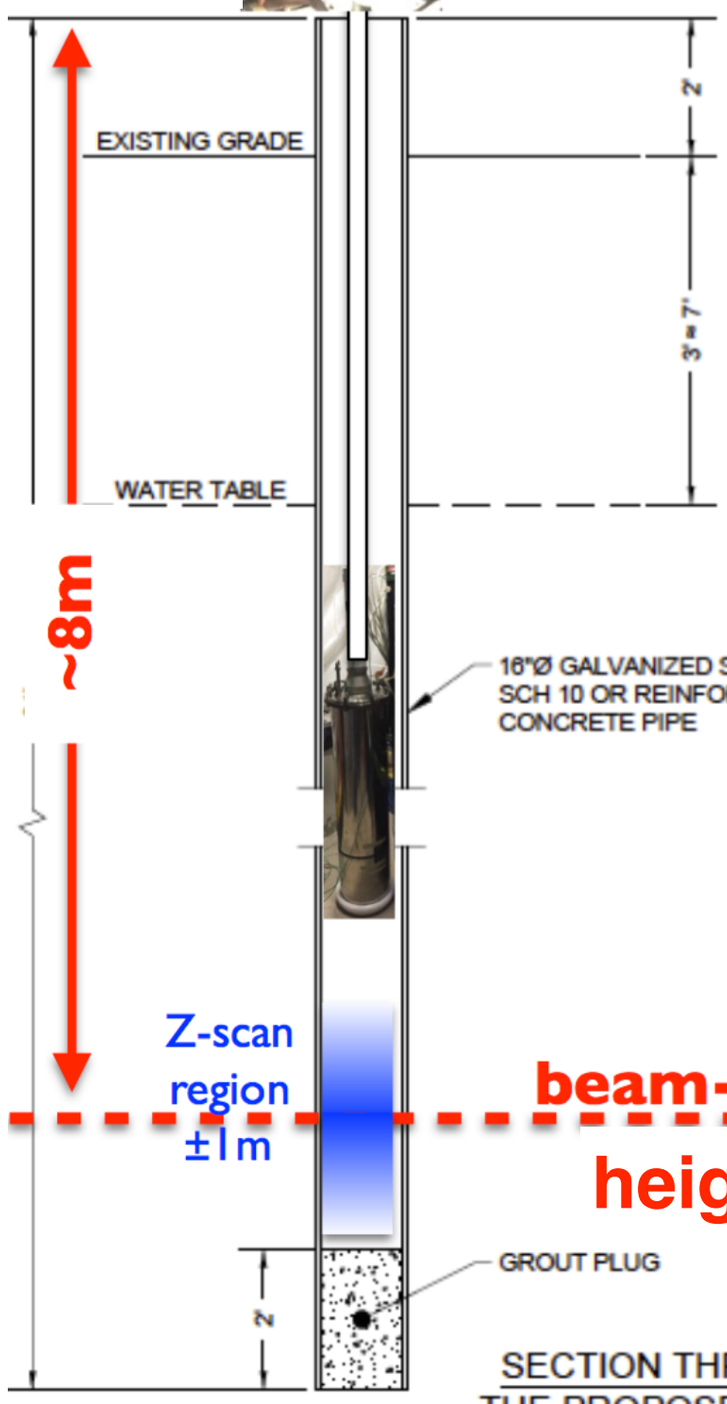






BDX MUON TEST
RUNNING THE EXPERIMENT

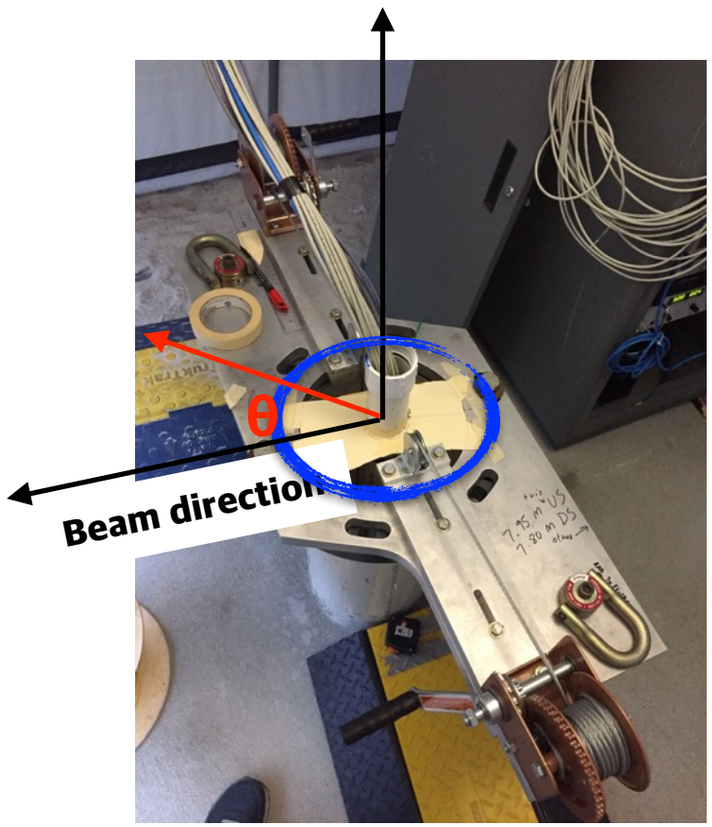


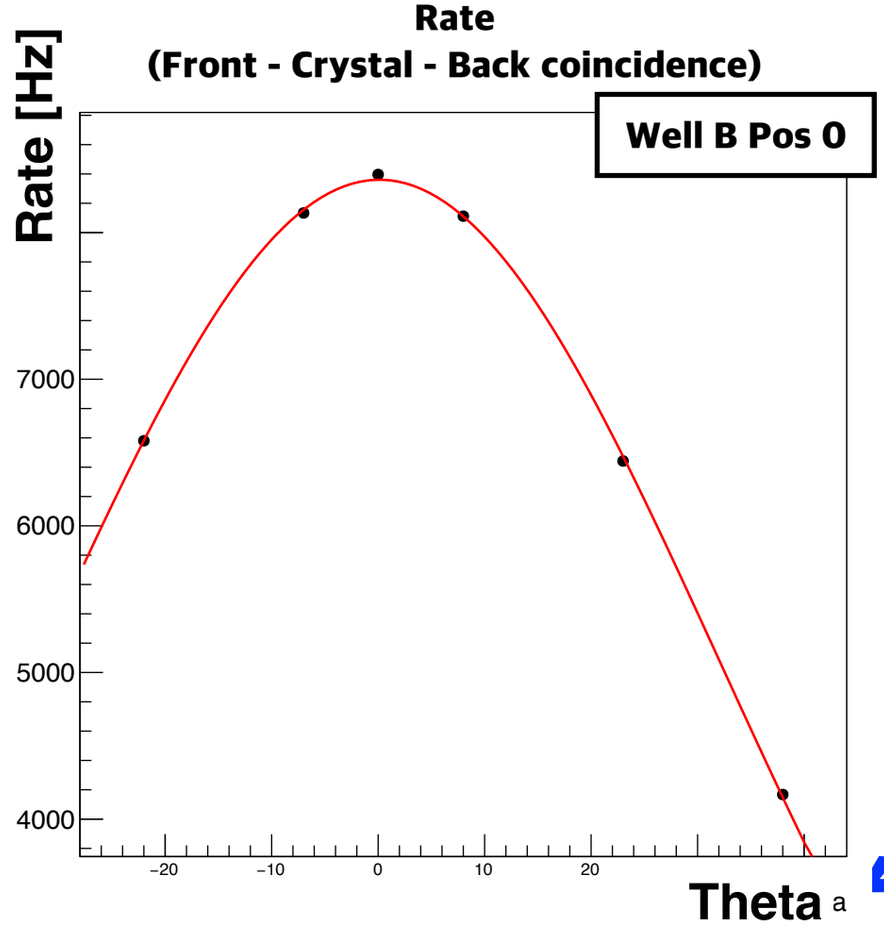


SECTION THROUGH
THE PROPOSED WELL

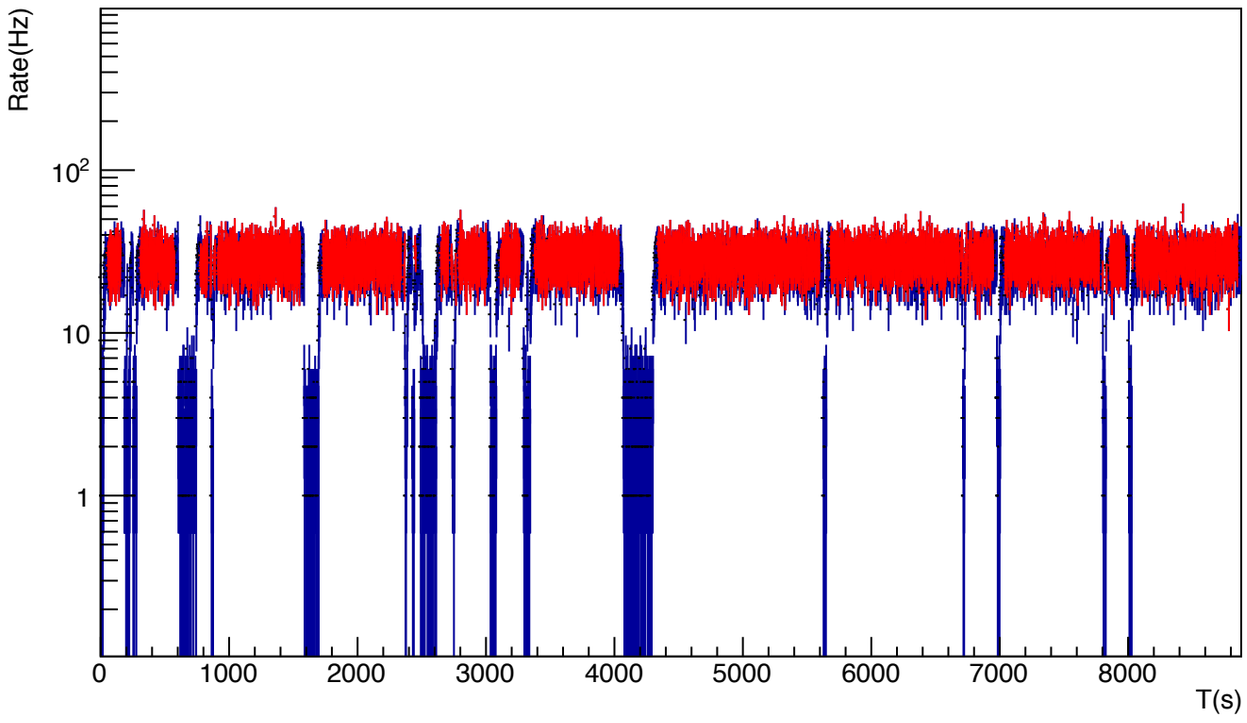
- **Vertical position** inside the pipe measured by a marked tape attached on the PVC extinction

- **Angular alignment** performed looking at the rate as a function of rotating angle θ

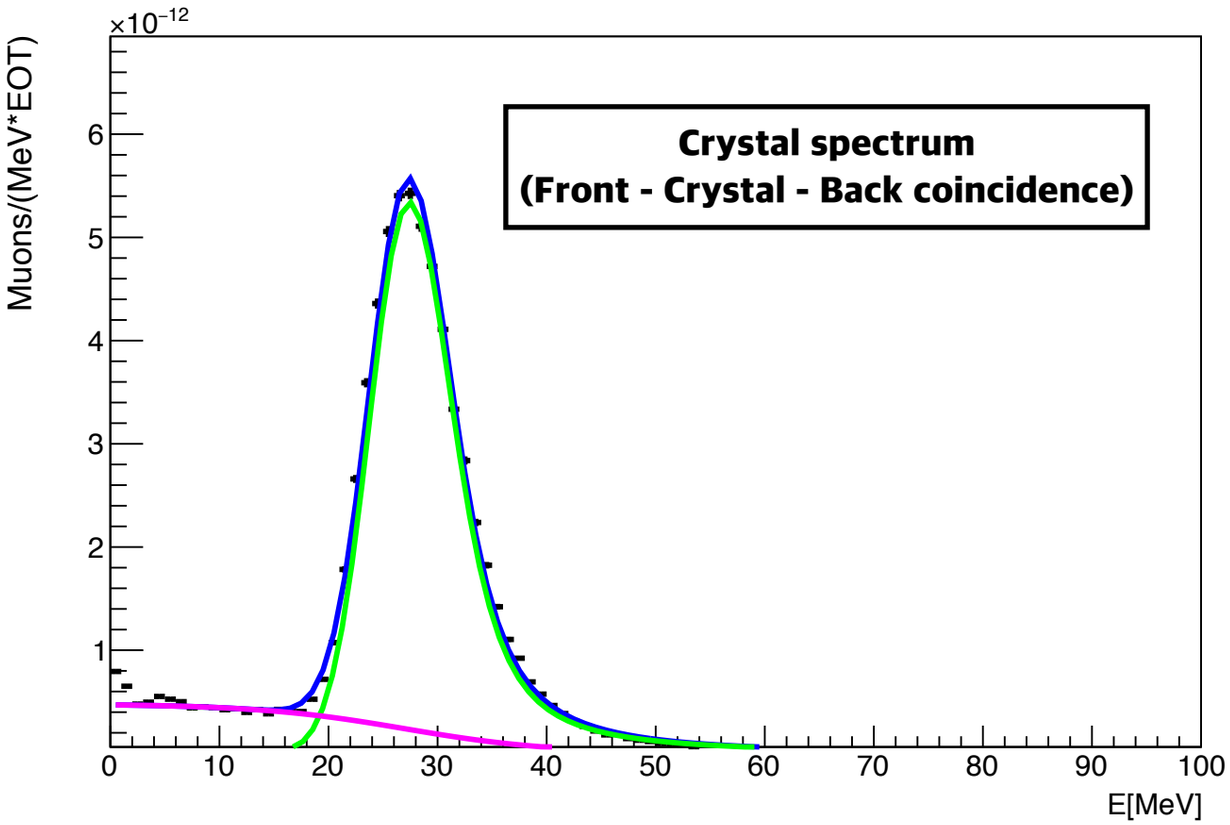


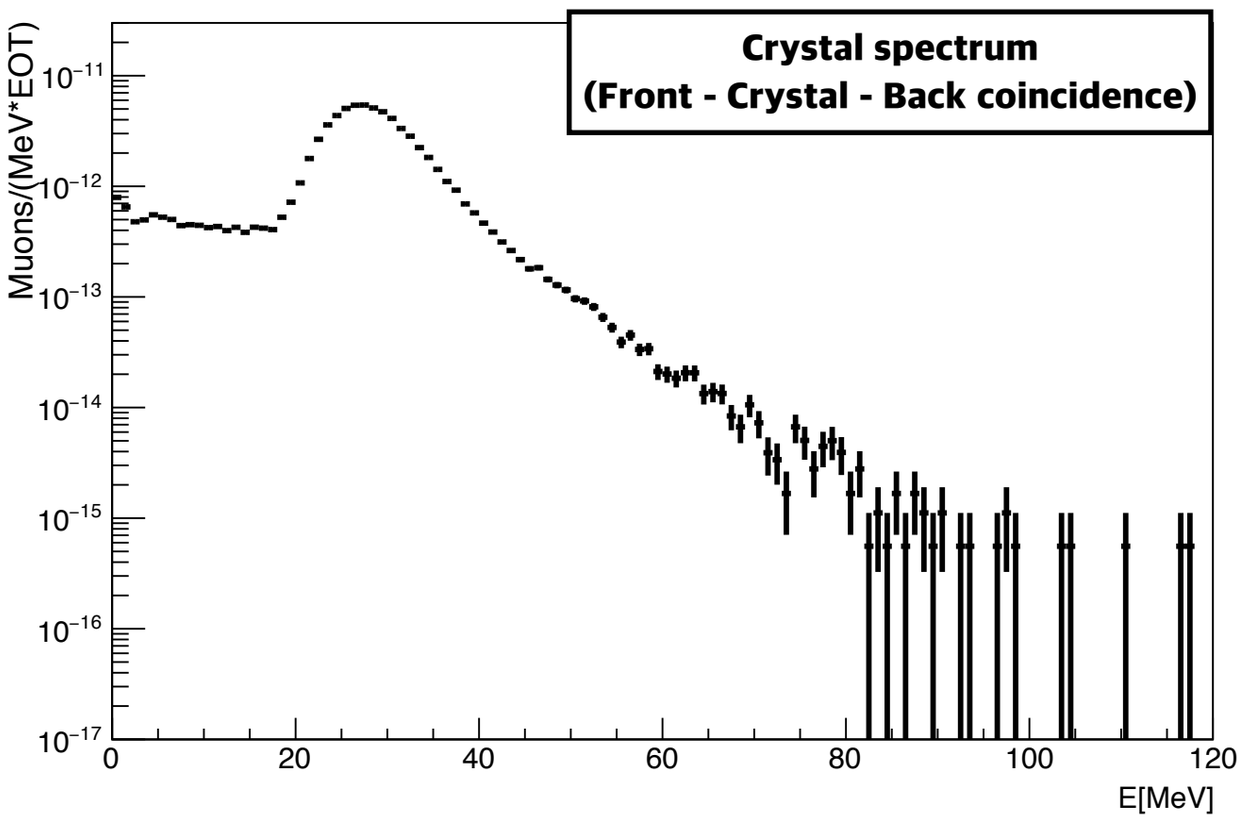


BDX MUON TEST
EXPERIMENTAL RESULTS



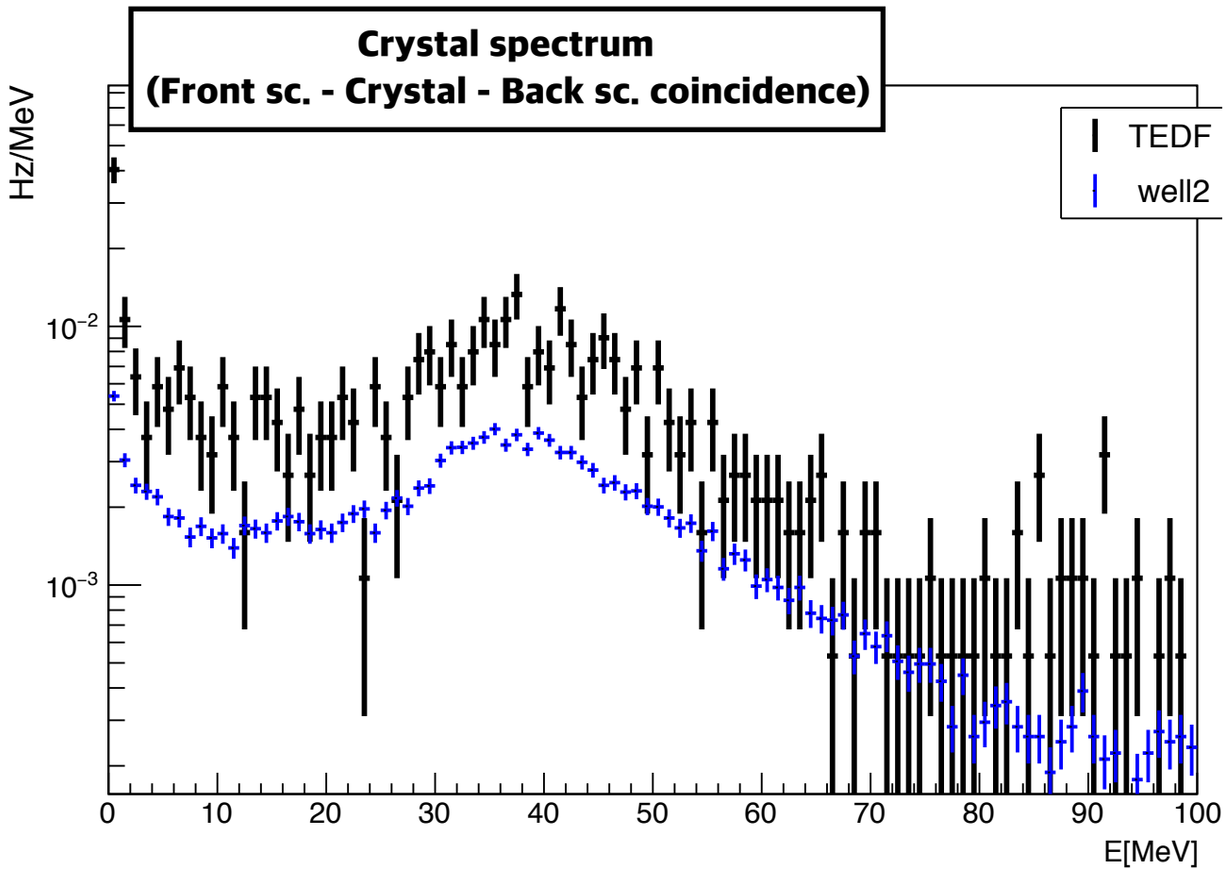
- In phase of analysis, the data have been cleaned excluding the beam-trip
- Red histo: events analyzed

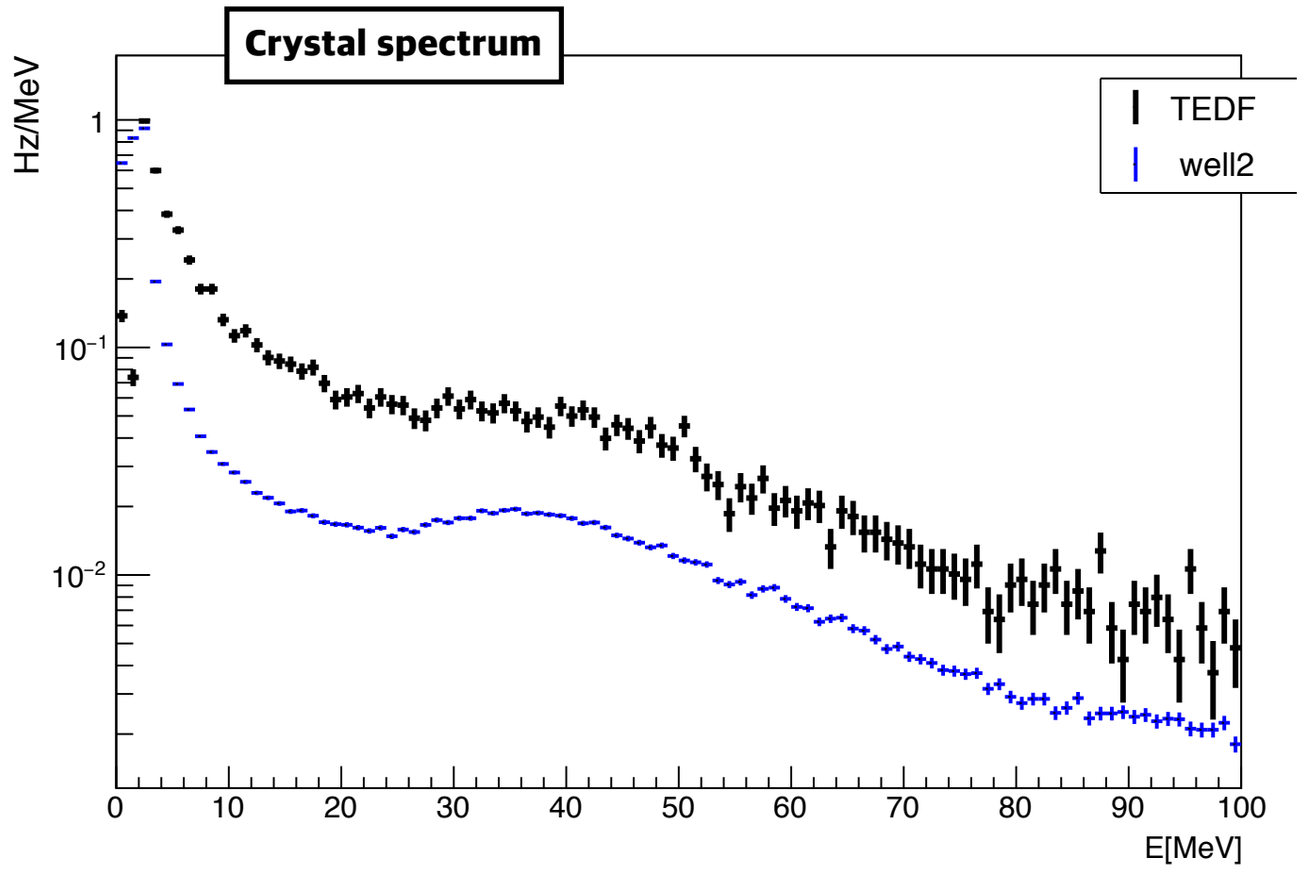




- The peak is fitted by Landau function convoluted with a gaussian function while the background with a Fermi function
- Rate extracted integrating the green fit

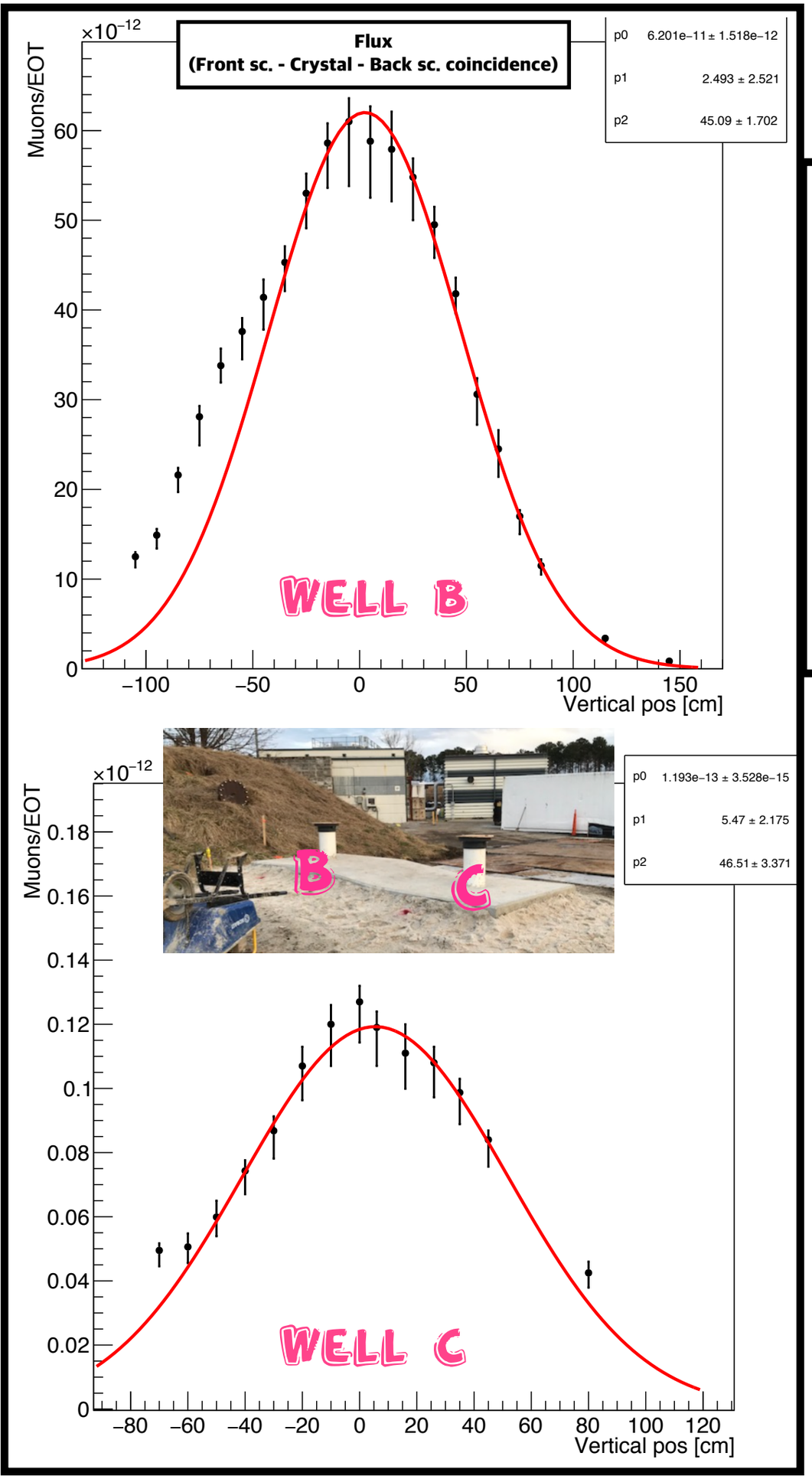
BDX MUON TEST
COSMIC BACKGROUND



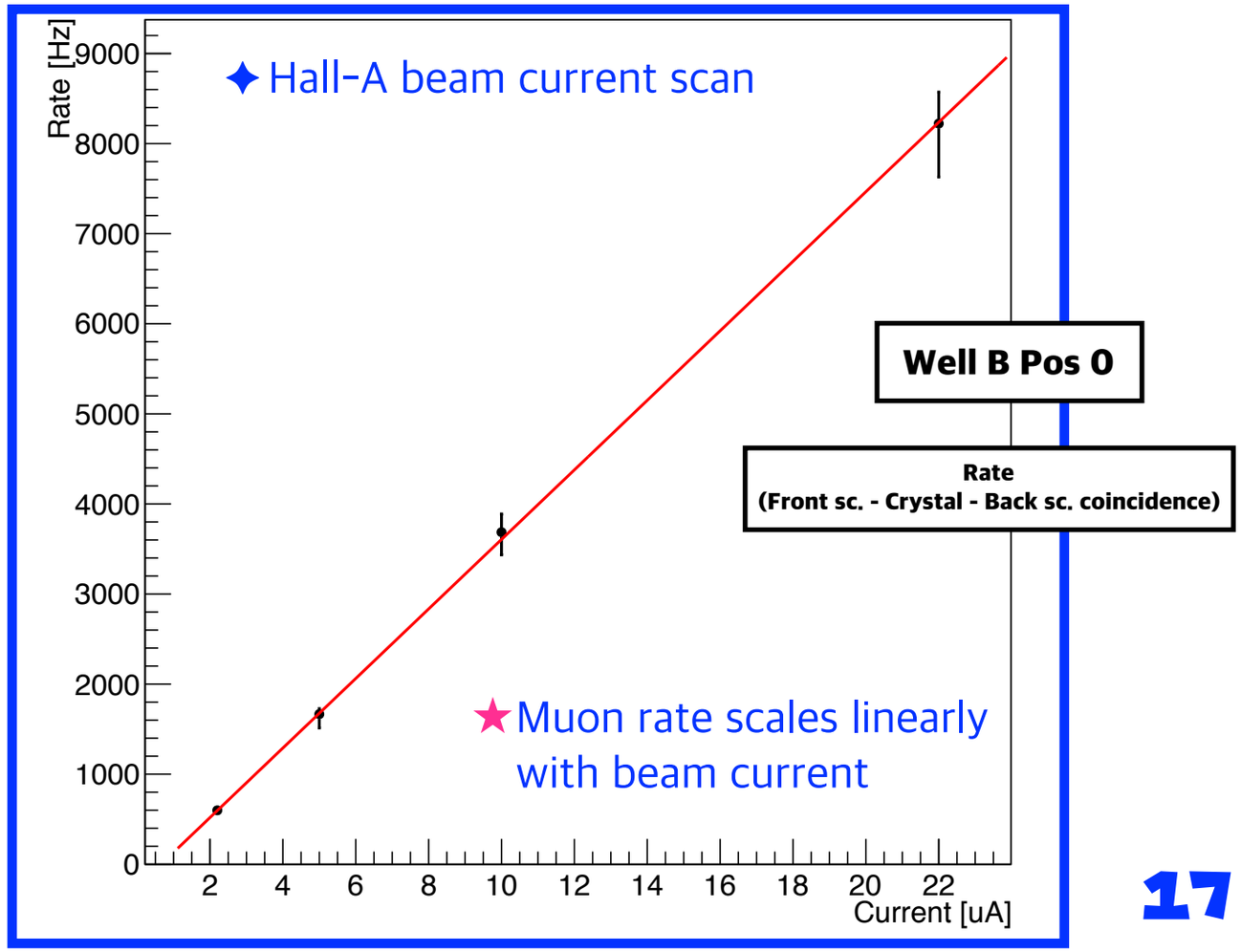


- ✦Black spectrum: measurement without shielding performed at TEDF building
- ✦Blue spectrum: measurement inside well C at 0 position
  - ★Reduction factor between TEDF and well is ~ 2.5
  - ★**No significant effect of cosmic muons on rates measured with beam-on**
    - ★**Front/Back/crystal coincidence rate is ~ 0.1 Hz -> Negligible**

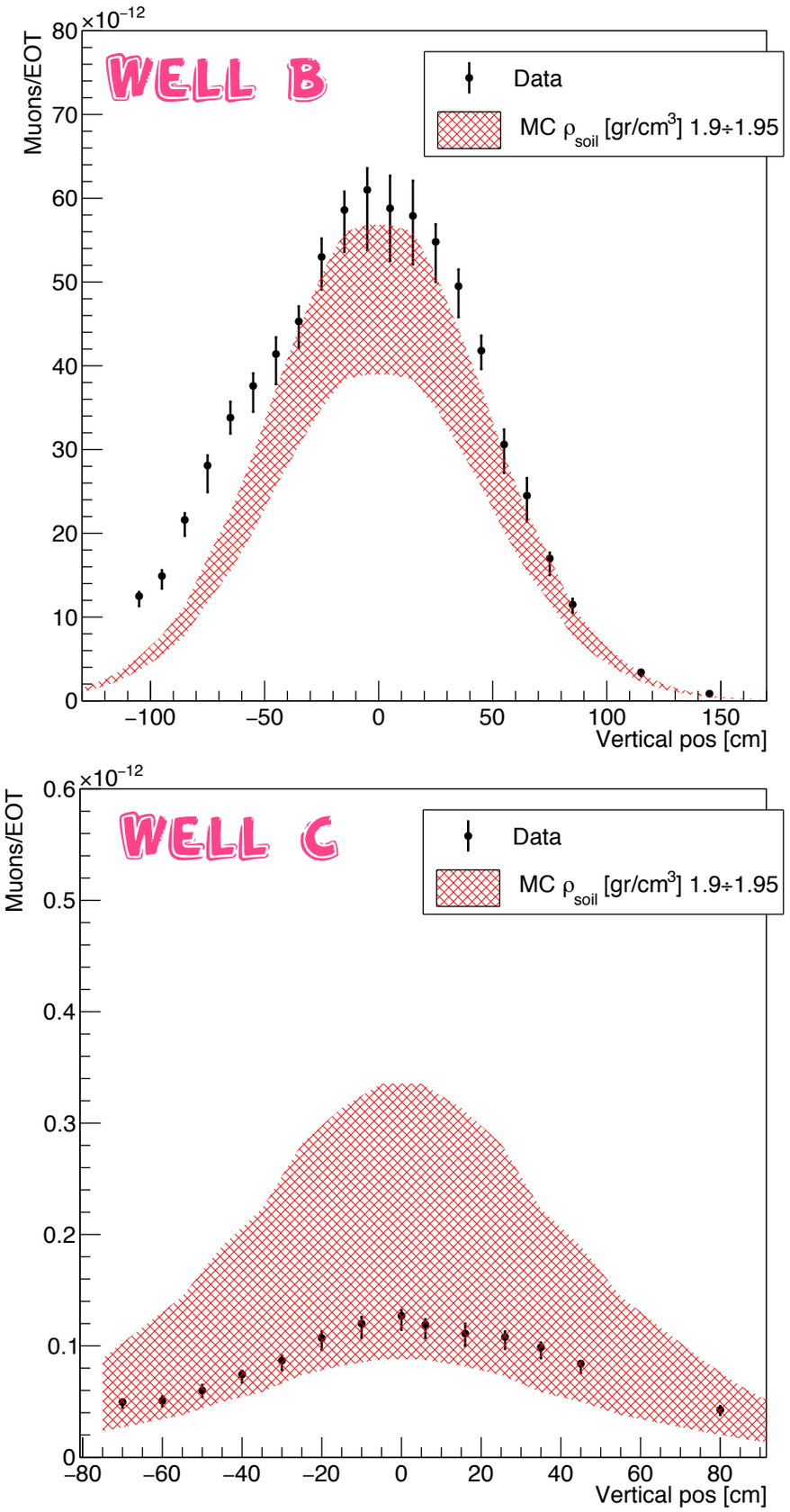
BDX MUON TEST EXPERIMENTAL RESULTS



- ✦ Muon rate measured in the two wells at different Z-distances from the beam-line height (Z=0)
  - ★ Rate well B (Z=0, I=22 uA) ~ 8 KHz
  - ★ Rate well C (Z=0, I=22 uA) ~ 15 Hz
- ★ Ratio of the two wells is ~ 500
- ★ **Similar bell shape** : both distributions are fitted to gaussian with the same width (**σ ~ 45 cm**)
- ★ The asymmetric shape in the left part of well B distribution could be due to a no constant soil density



BDX MUON TEST
DATA/SIM COMPARISON



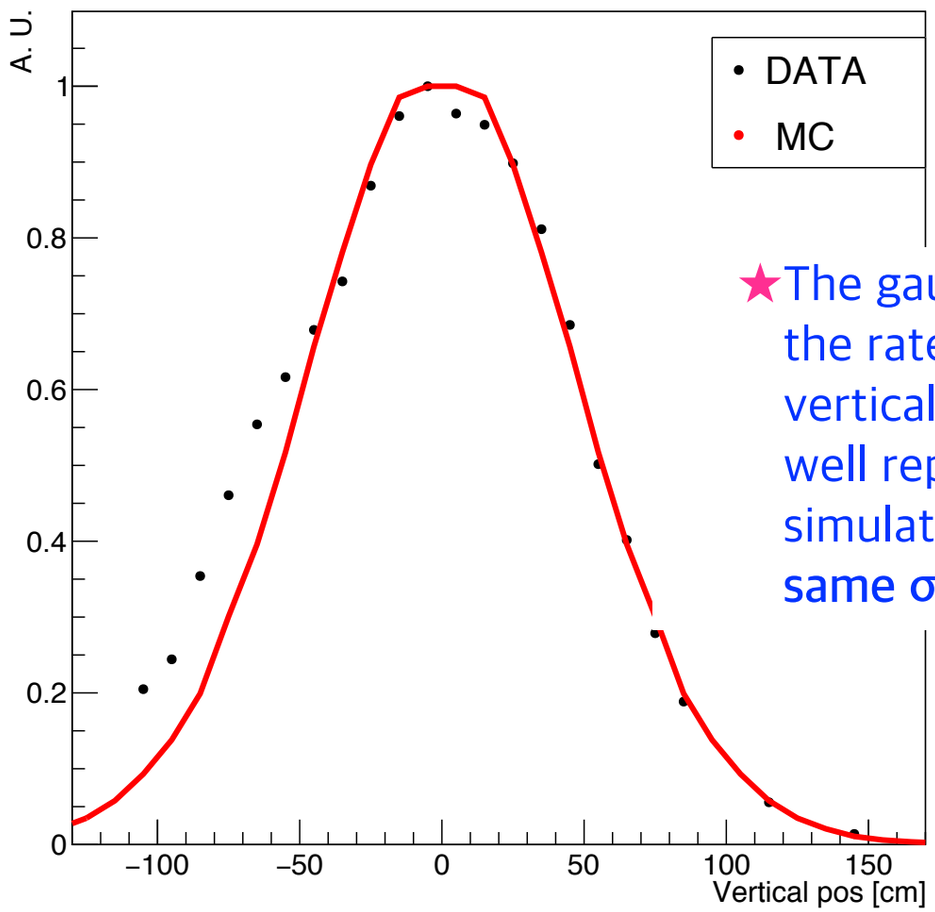
✦Absolute rates obtained

- generating muons by primary electron interaction on Hall-A beam dump (FLUKA)
- propagating muons to the pipe positions using GEANT4
- BDX-HODO response with GEANT4

✦**Significant dependence on soil density** :

We assumed a density range of values : 1.9 - 1.95 gr/cm^3

★ Data in agreement with the simulation for the assumed density range



★The gaussian shape of the rate vs det. vertical position is well reproduced by simulations (**with the same σ**)

CONCLUSION

✦ Measurements to assess the BDX beam-on bg proposed to PAC45, endorsed and supported by JLab

✦The BDX-Hodo detector (CsI(Tl) + scintillator paddles) lowered in two wells located ~25m and ~28m downstream of the Hall-A beam-dump

✦Expected significant variation between the two wells and along the Z-profile

✦Despite the uncertainty in soil density, simulations reproduce both absolute rates and shape

✦Ready to present results to PAC46 seeking for BDX proposal full approval

THANK YOU FOR YOUR ATTENTION !

BDX MUON TEST
OVER THRESHOLD BACKGROUND ASSESSMENT

- ✦ BDX good events are defined as an electromagnetic shower in the calorimeter with no activity in two veto system
- ✦ The shower is characterized by: energy seed Eseed (<500 MeV), number of crystal with E>Ethr , total energy Etot
- ✦ Beam-on background has been simulated finding only hits from neutrino

CAN WE USE BEAM-ON BDX-HODO DATA TO CONFIRM THE (ALMOST) 0-BG?

beam-on BDX experiment	beam-on BDX-Hodo test
80 crystals (x10)	1 crystal
ermethic (2x) veto	few paddles
iron shield (no muon)	dirt shield (muons)
285 run days ~10 counts neutrino bg	~O(few) NO neutrino bg

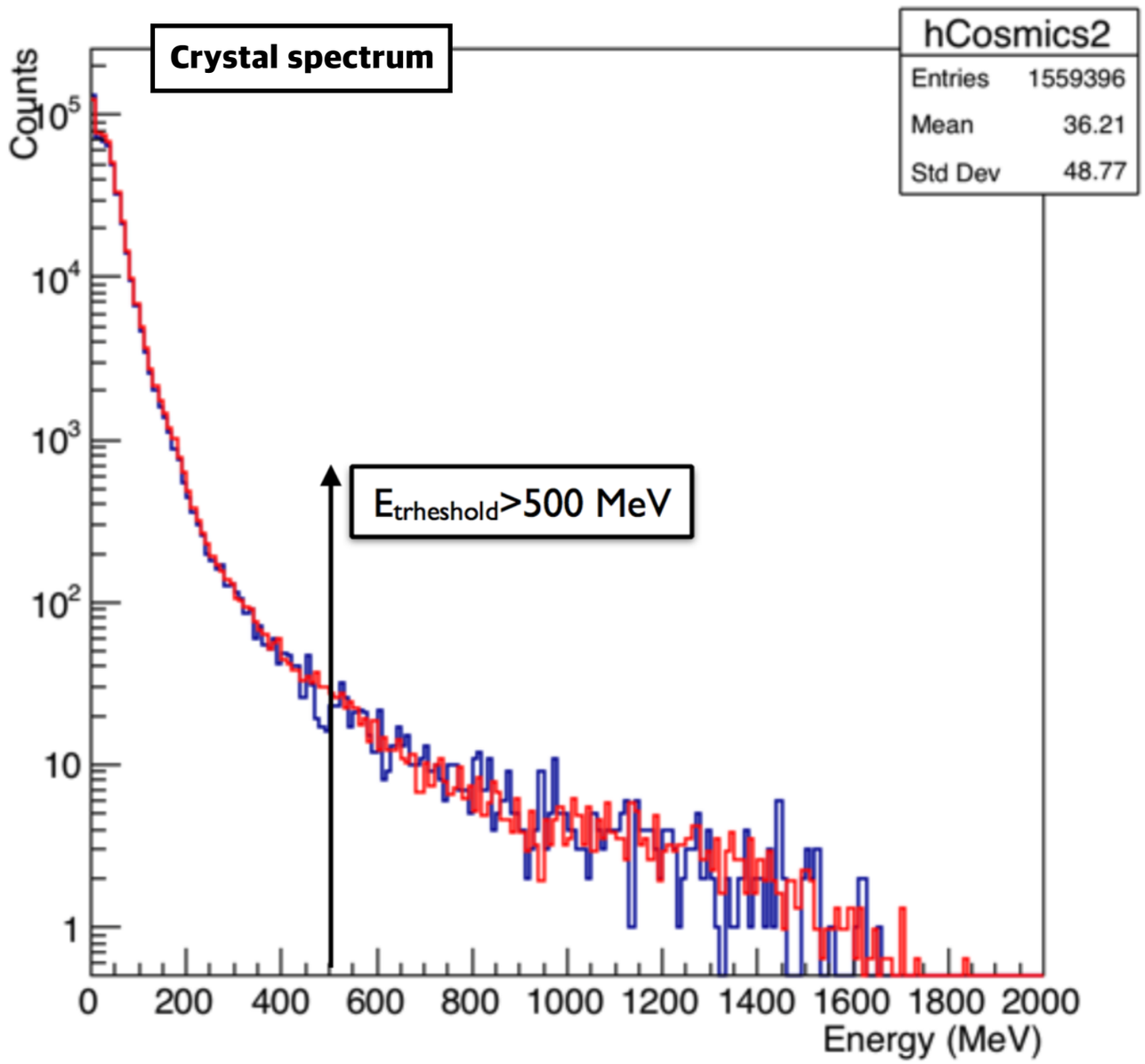
- ✦ Only Eseed information (conservative)
- ✦ BDX-Hodo in well 2
- ✦ reduce beam energy to range out muons

★Compare Beam on / Beam off energy spectra for E>Ethr

BDX MUON TEST
OVER THRESHOLD BACKGROUND ASSESSMENT

- A significant fraction of BDX-HODO data have taken at Ebeam =4.3 GeV (Ibeam ~ 22 uA)
- Good statistic with beam-off in the same experimental conditions
  - beam on : 6.5 days (EOT ~ $7.7*10^{19}$)
  - beam off: 20 days
- Analysis no involve plastic scintillator counters
- Comparison of energy distributions
  - Beam-off events scaled to beam time
- Normalizations E>500 MeV
  - ★ Beam-on : 705 events
  - ★ Beam-off: 692 events

★For E>Ethr=Eseed beam on spectrum is compatible with beam-off



BDX EXPECTED REACH

BEAM TIME REQUEST

- 10^{22} EOT (65 uA for 285 days)
- BDX can run parasitically to any Hall-A Ebeam>10 GeV experiments (e.g Moller)

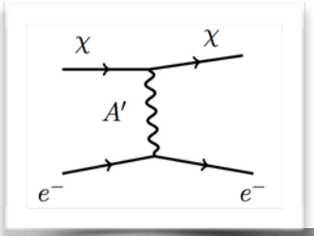
Beam-related background

Energy threshold	N_ν (285 days)
300 MeV	~10 counts

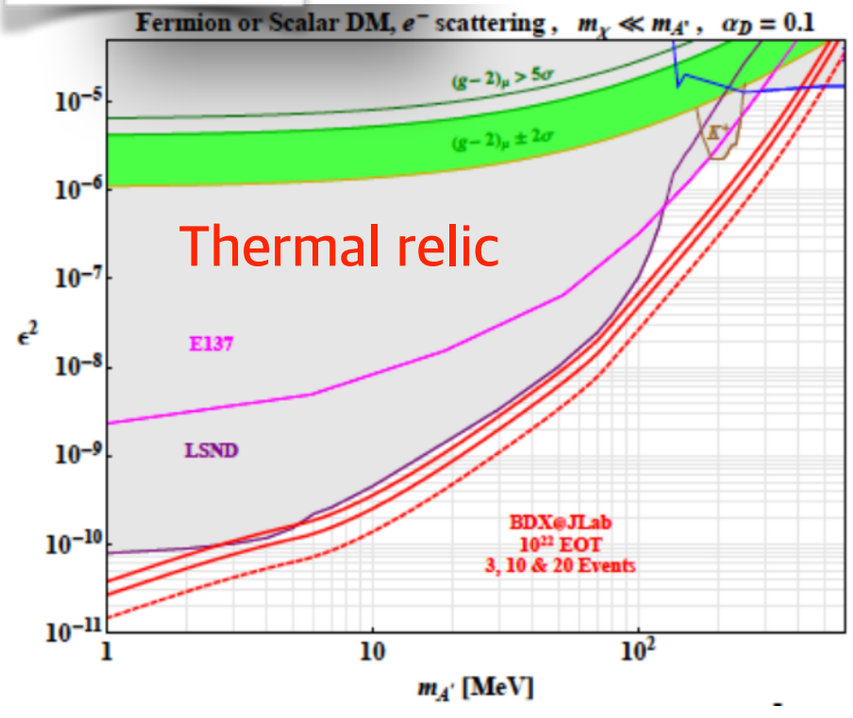
Cosmic background

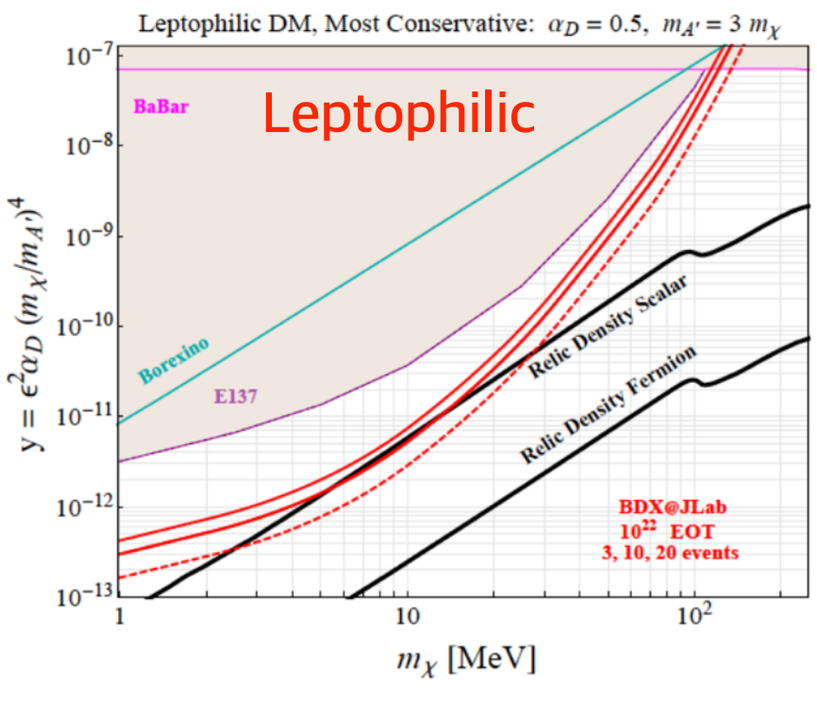
Energy threshold	$\sqrt{Bg}$ (285 days)
300 MeV	<2 counts

BDX SENSITIVITY IS 10-100 TIMES BETTER THAN EXISTING LIMITS ON LDM



Elastic X-e- scattering





Inelastic X-N scattering