ATLAS LAr Calorimeter Degradation Studies for HL-LHC

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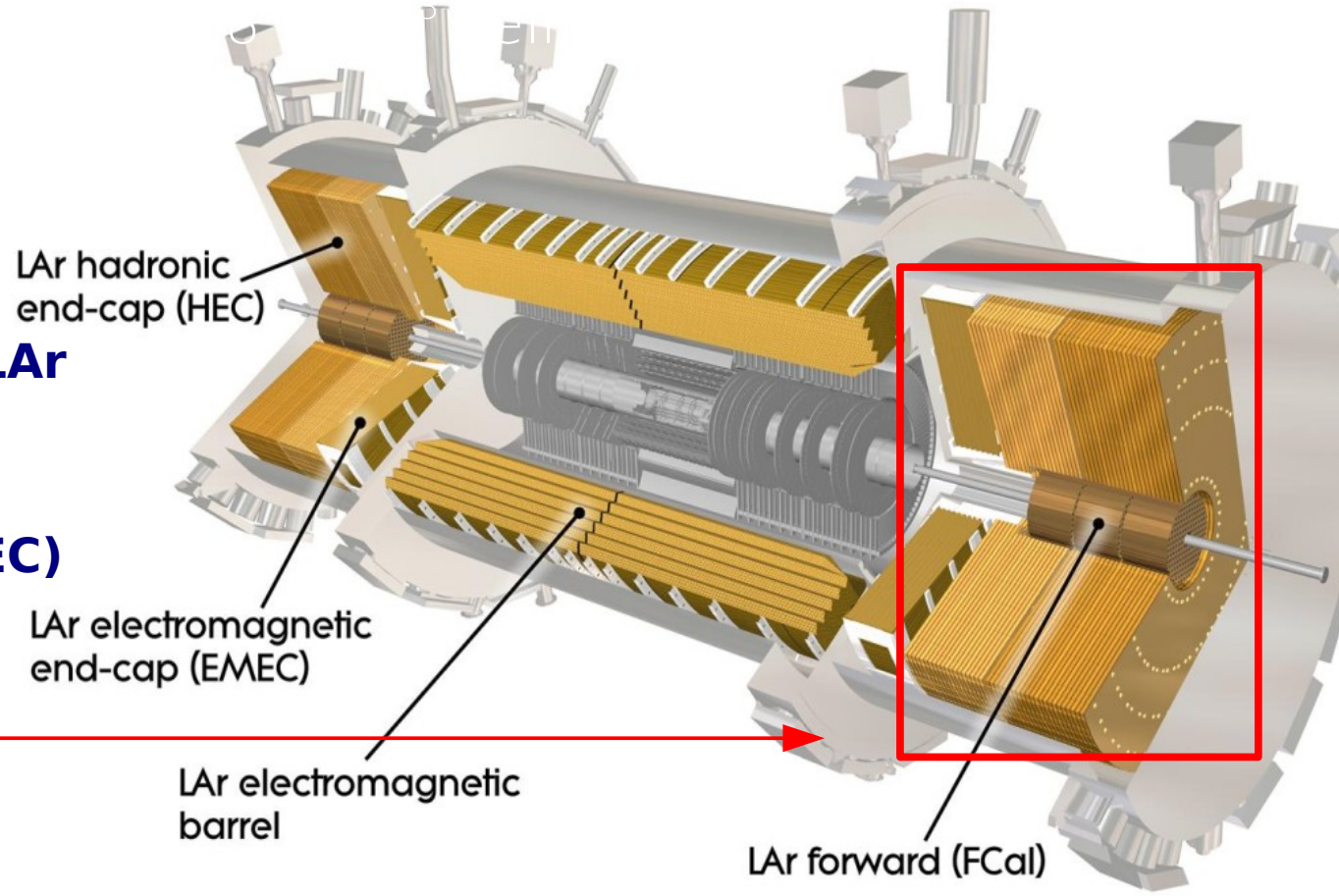
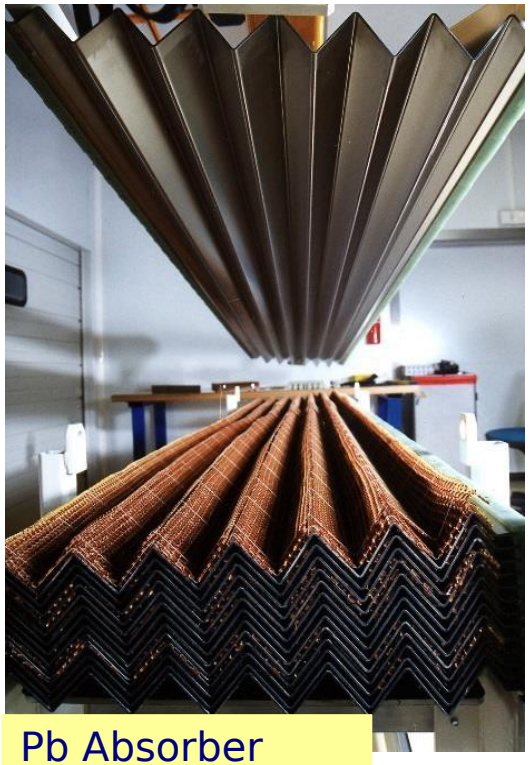
Liquid Argon Calorimeter

- **Active medium → Liquid Argon (LAr)**
- **The barrel cryostat**
  - **two electromagnetic (EMB) halves → lead-LAr**
- **The end-cap cryostat**
  - **Electromagnetic (EMEC)**
  - **Two hadronic wheels (HEC) → copper/LAr**
  - **three forward calorimeter wheels (FCal) → copper-tungsten/LAr**

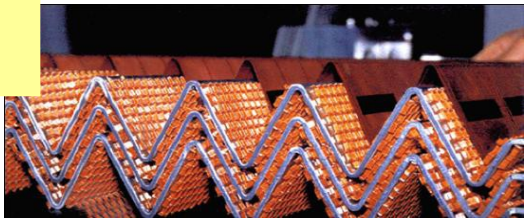


LAr technologies

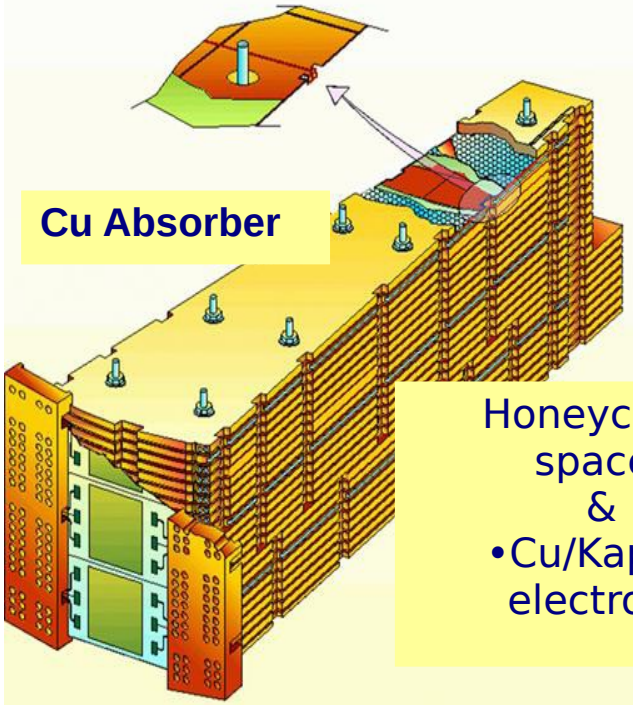
EM Cal Structure



Pb Absorber
•Honeycomb spacer
•Cu/Kapton electrode

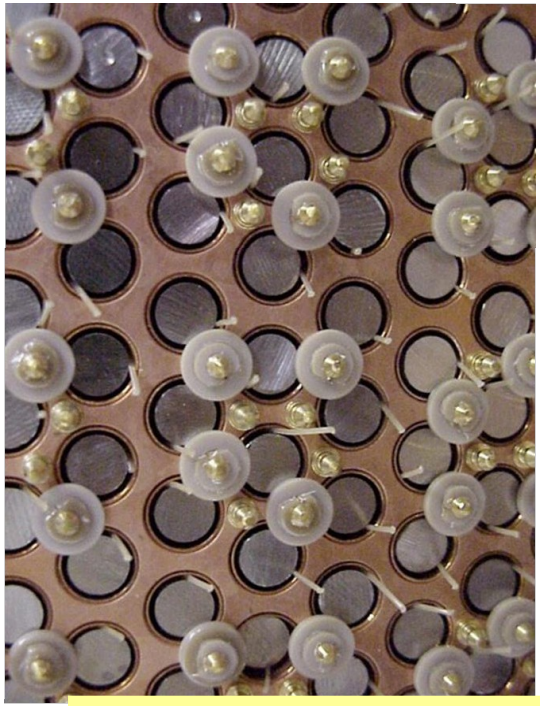


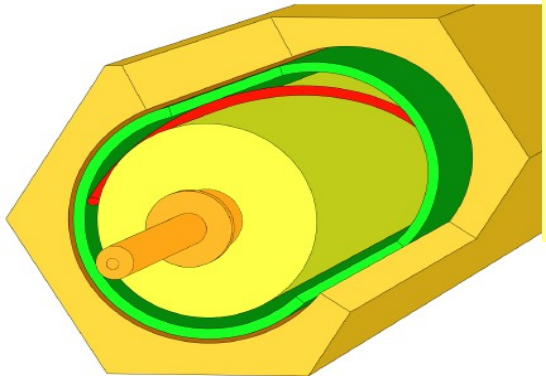
HEC Structure



Honeycomb spacer
&
•Cu/Kapton electrode

FCal Structure



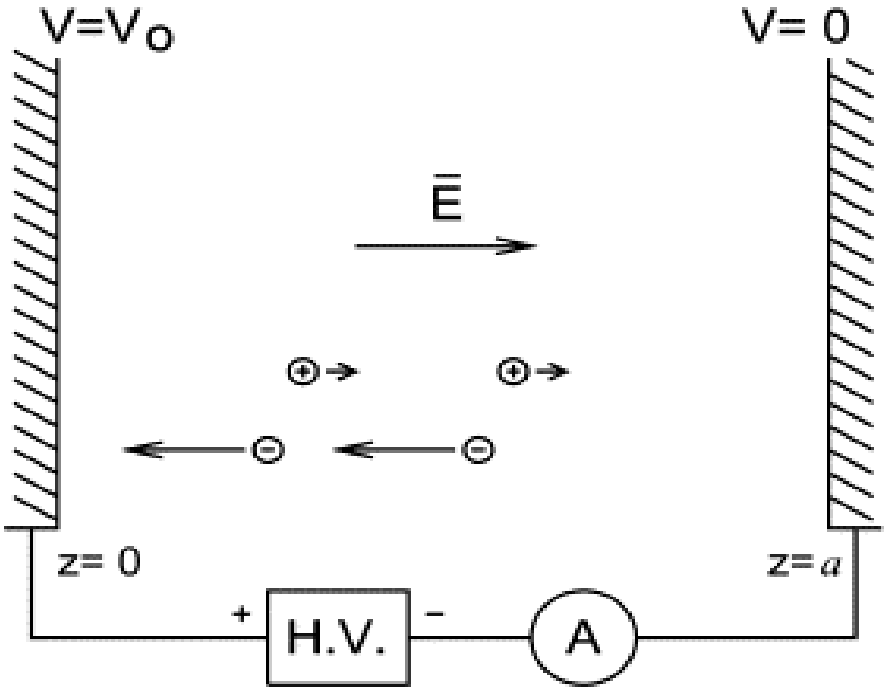


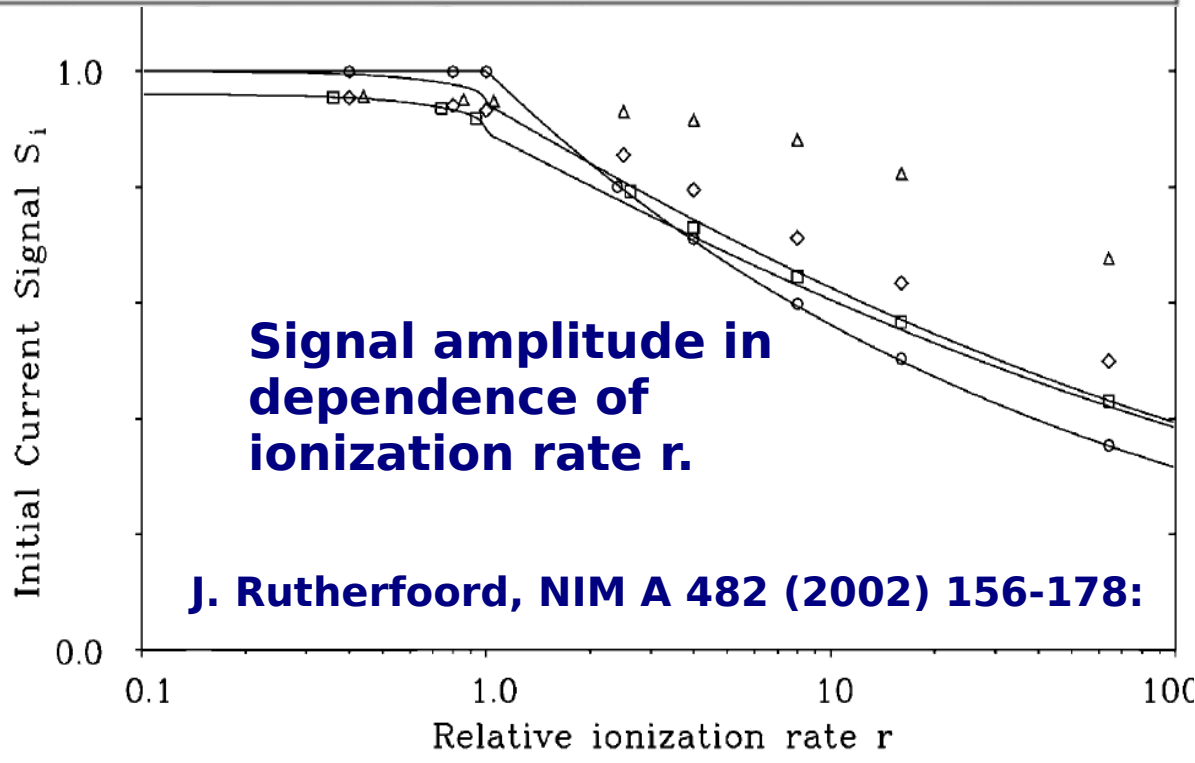
Electrode Rods &
Absorber Matrix
Cu (FCal1) 269 µm
W (FCal2/3)
376/508 µm

Problem of positive ion buildup:

Protons/spill	10^7	10^8	10^9	10^{10}	10^{11}	10^{12}
Protons/bunch	5	50	500	5000	$5 \cdot 10^4$	$5 \cdot 10^5$
LHC lumi equal [$cm^{-2}\,s^{-1}$]	10^{32}	10^{33}	10^{34}	10^{35}	10^{36}	10^{37}

HL-LHC





Signal amplitude in dependence of ionization rate r.

J. Rutherfoord, NIM A 482 (2002) 156-178:

D - ionization rate per volume

Dc - critical ionization rate → charge buildup in gap = to charge on electrodes

Relative rate **r = D/Dc**

Signal S:

1 for r≤1 and $(1/r)^{1/4}$ for r>1

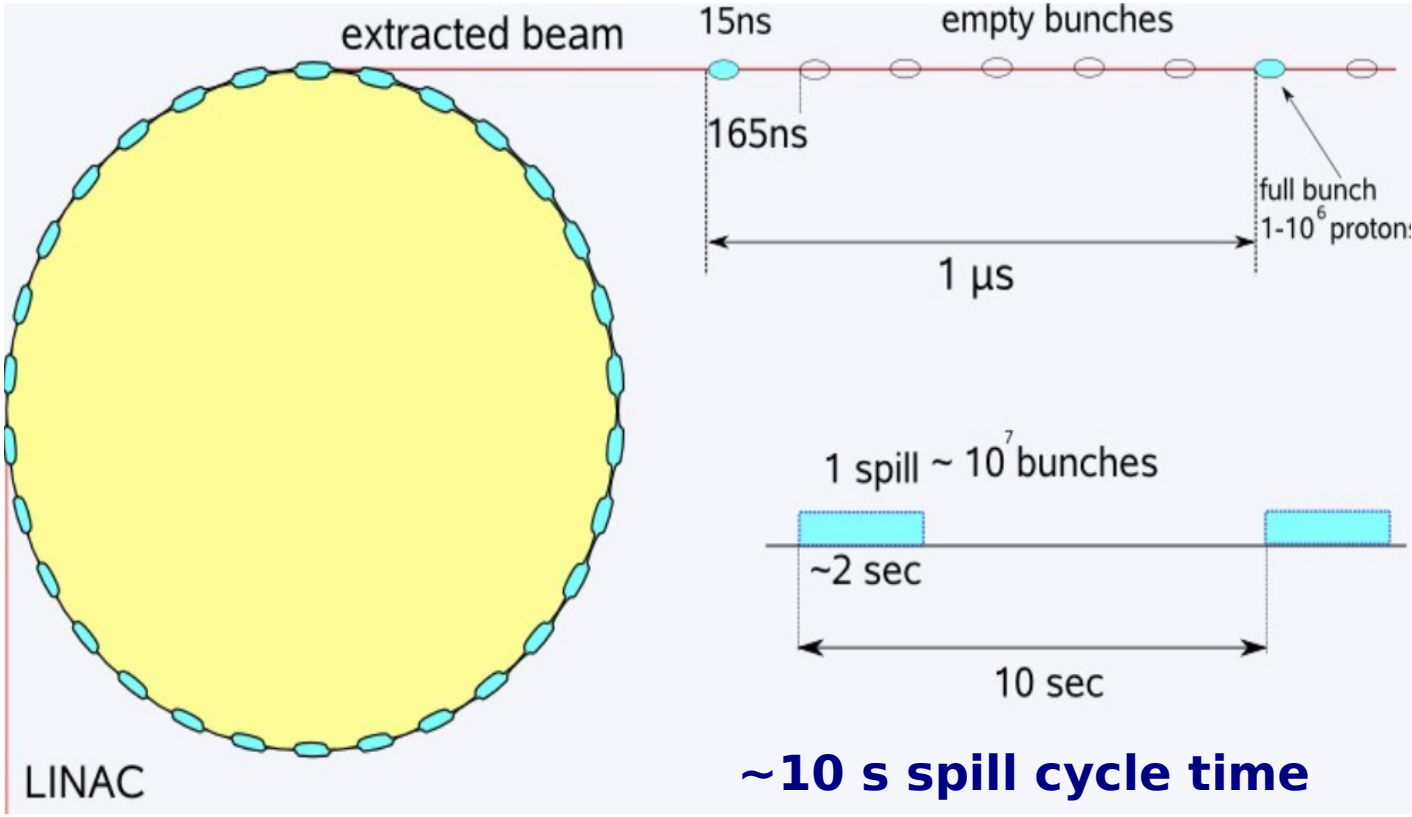
$$i/i_c = \begin{cases} I/I_c & \text{for } I<I_c \\ (I/I_c)^{3/4} & \text{for } I>I_c \end{cases}$$

HiLum R&D Project

IHEP/Protvino proton beam comes in bunches beam of 50 GeV

Bunch structure with every 6th bunch filled → ~1 μs bunch spacing

Extract one accelerator fill in ~1.2 s spill



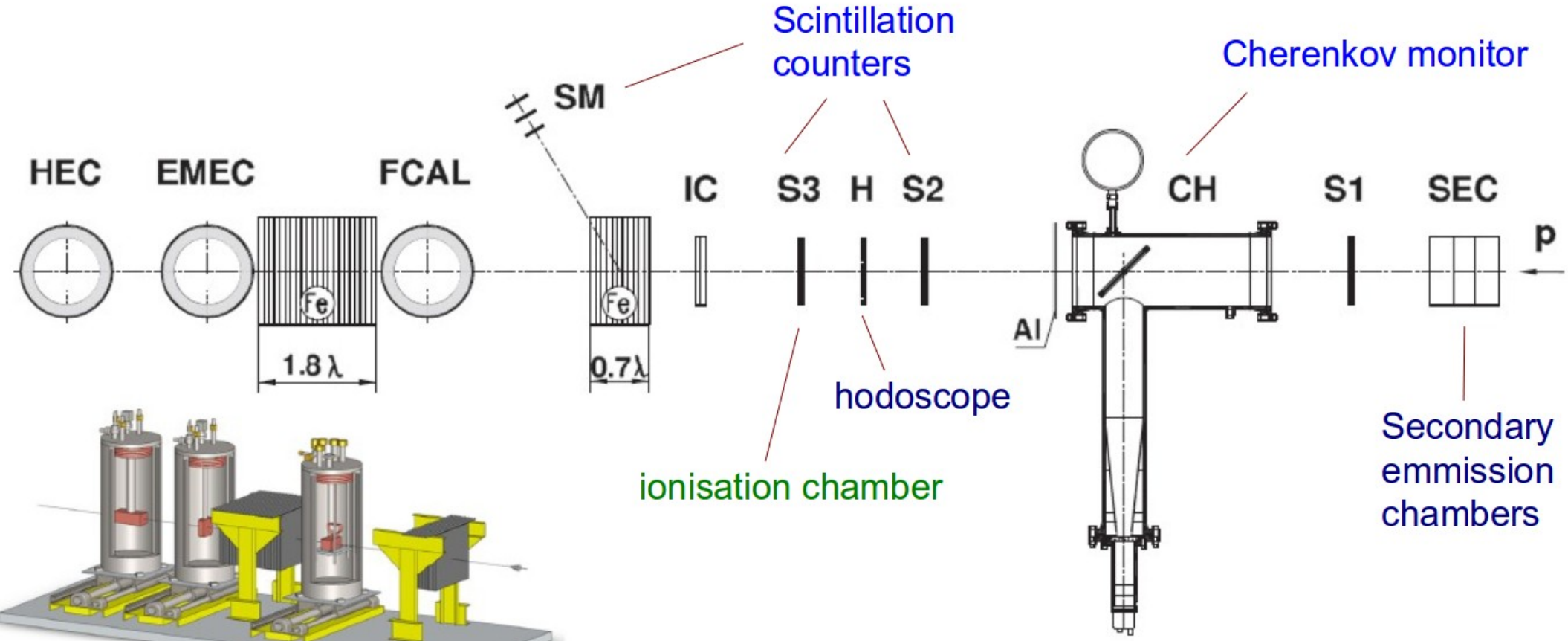
~10 s spill cycle time

Intensity range:

10^6 – ~3×10^{11} p/spill

Setup in experimental area

Hilum test beams in Protvino (2008, 2009, 2010, 2012, **2013**)



Test beam setup and absorber thickness was optimized in MC

Current talk is on the basis of 2013 Data

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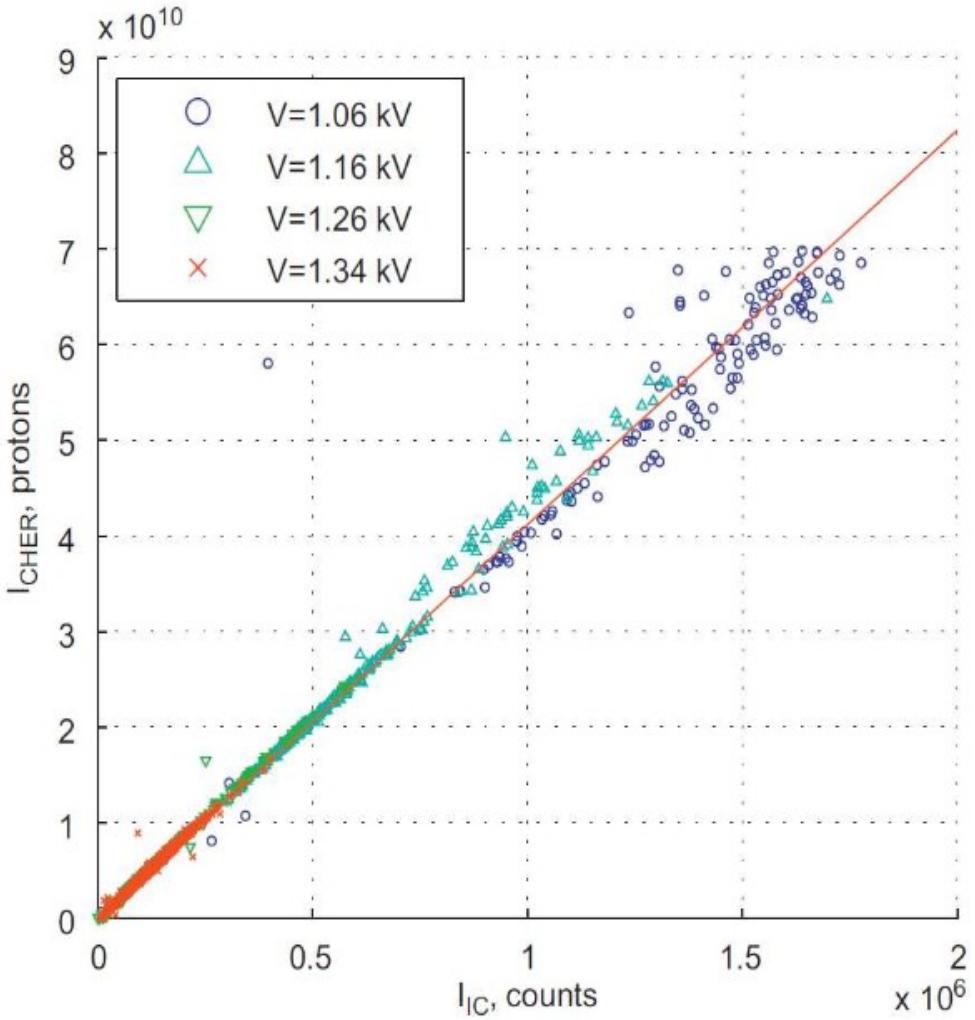
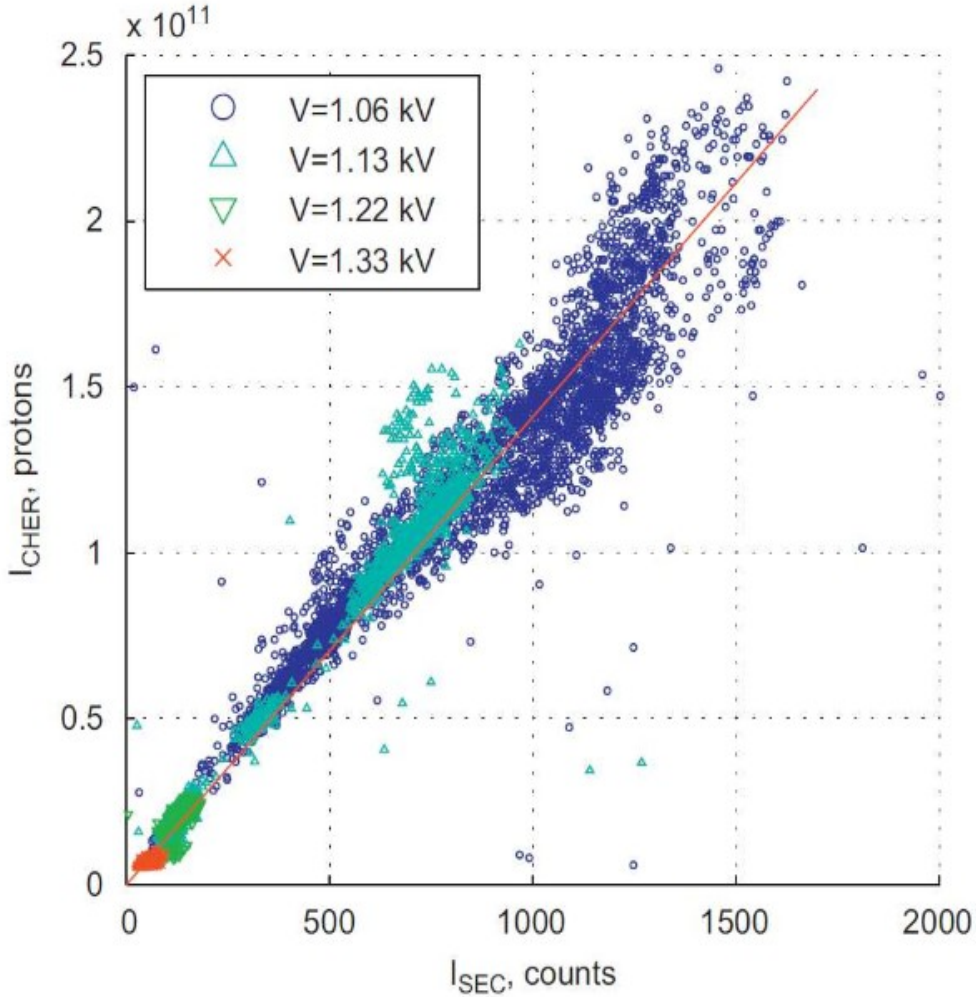
Intensity Measurements





Hilum: Liquid argon calorimeter performance at high rates
NIM A 669 (2012) 47–65.

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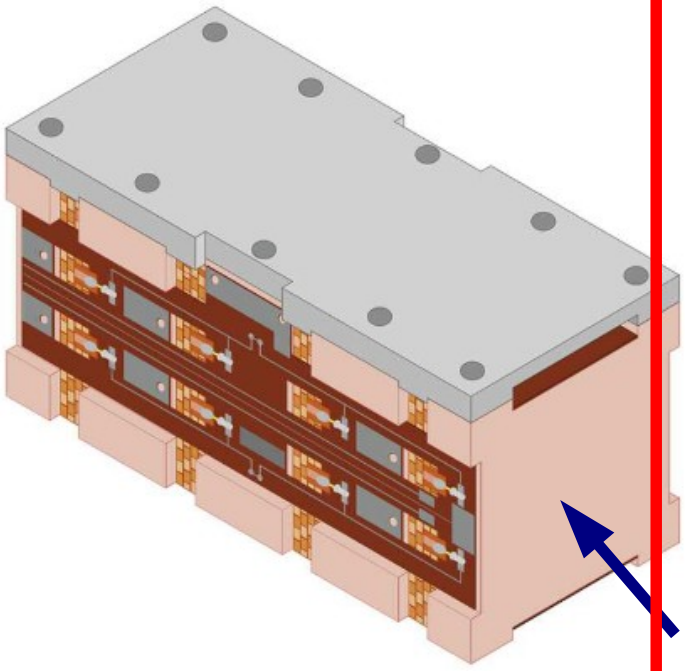
The calorimeter test modules

HEC

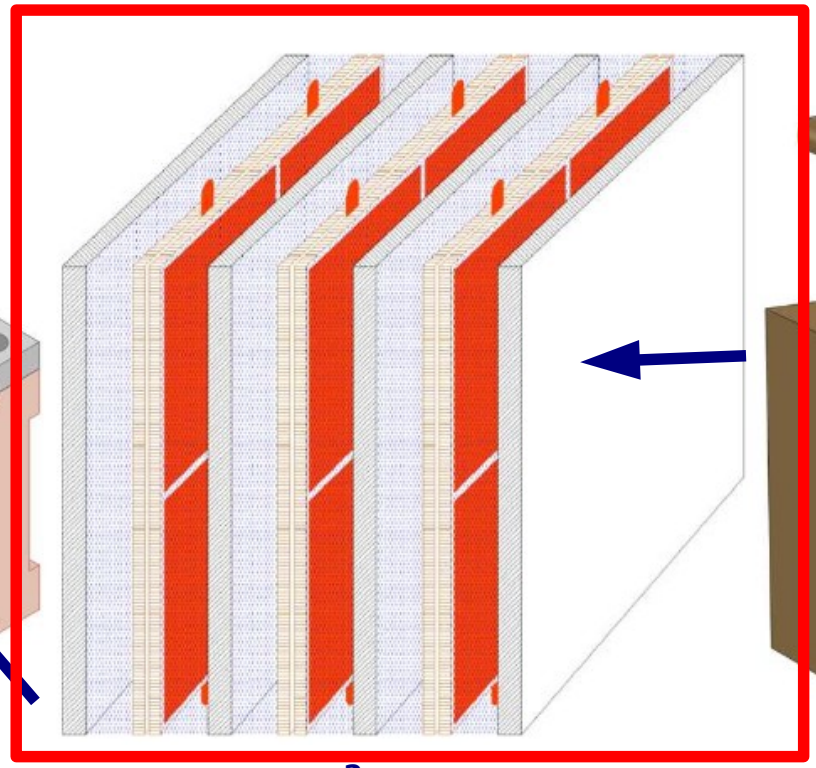


60×60 mm²

4 readout channels

4 HV channels

EMEC

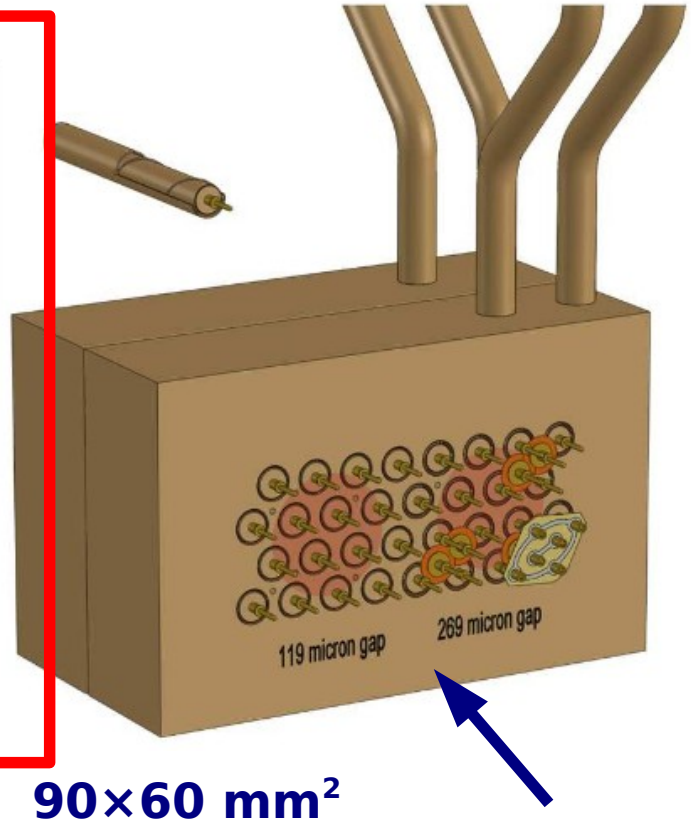


70×70 mm²

4 readout channels

3 HV channels

FCal1/sFCal



90×60 mm²

2x4 readout channels

2x4 HV channels

Each module is housed in a separate movable cryostat

HV Current Measurement

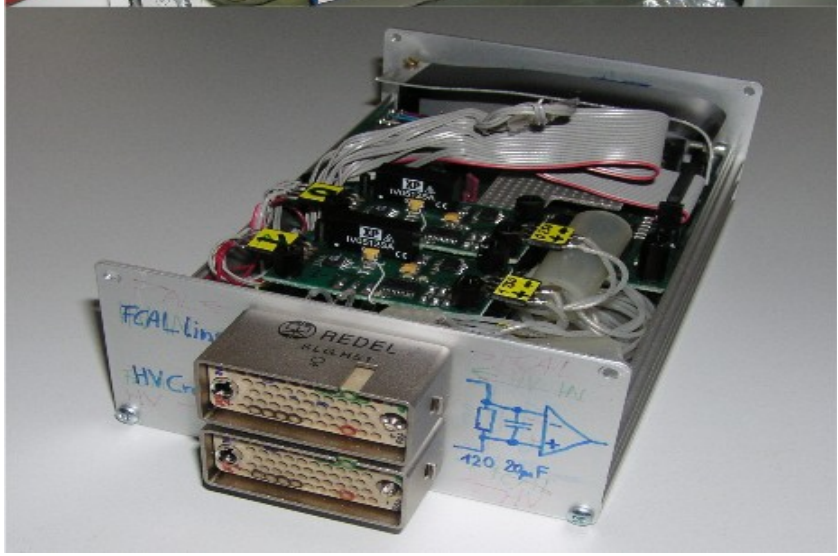
Device is installed between the HV power supply and the Filter Boxes of the Calorimeter modules

Measurement of the 3 EMEC HV channels in March 2013 run

Four 24-bit ADCs → Digital resolution of 1.2nA

Measurement rate: 10Hz / channel

Time-stamp of internal clock was synchronized with DAQ clock to ±1s



Stable and solid running

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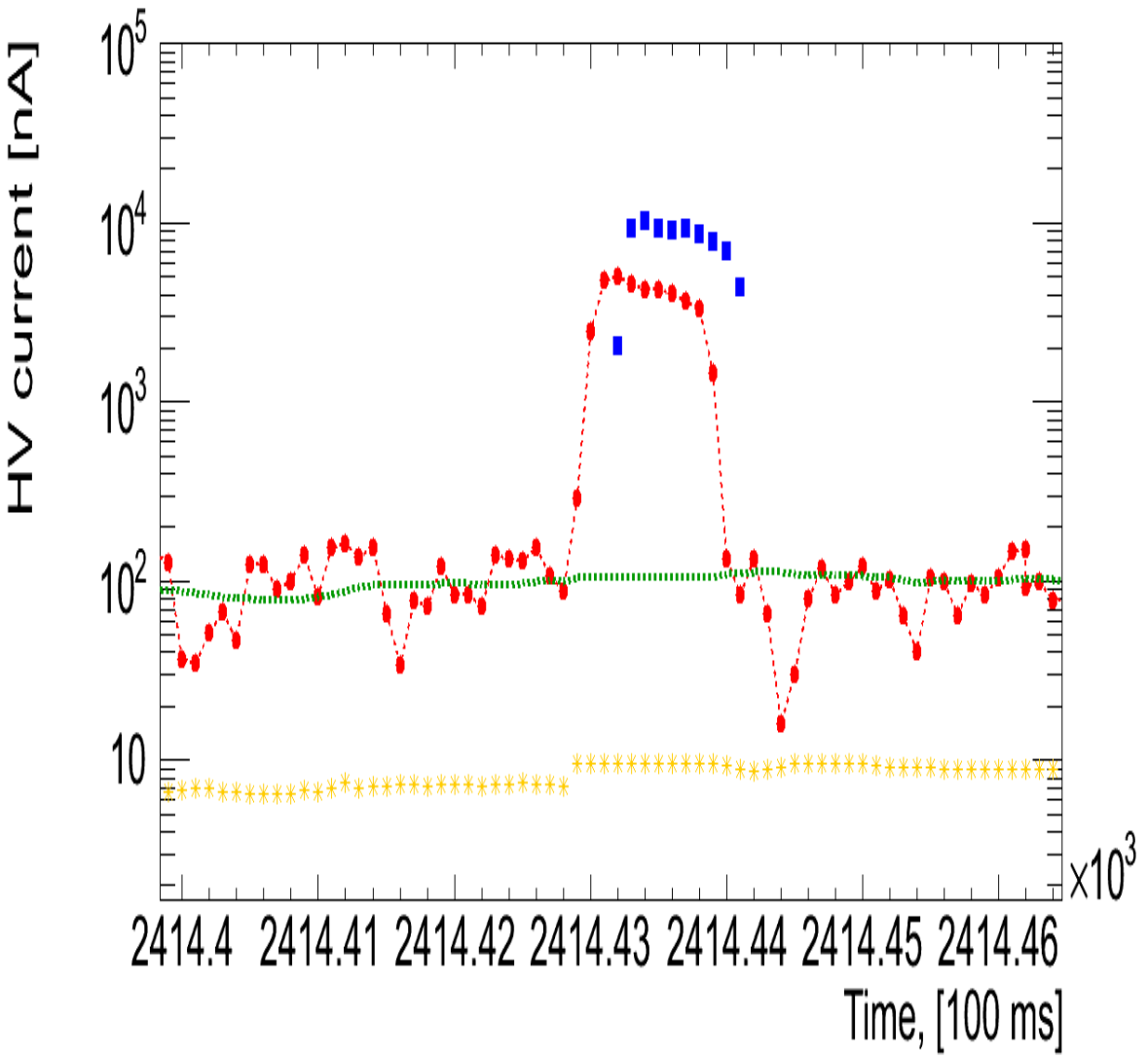
Data Analysis

HV Current signal:

- Sliding average
- Threshold of 5 sigma
- HV signal → HV Current – average
- Signal length > 0.4 s

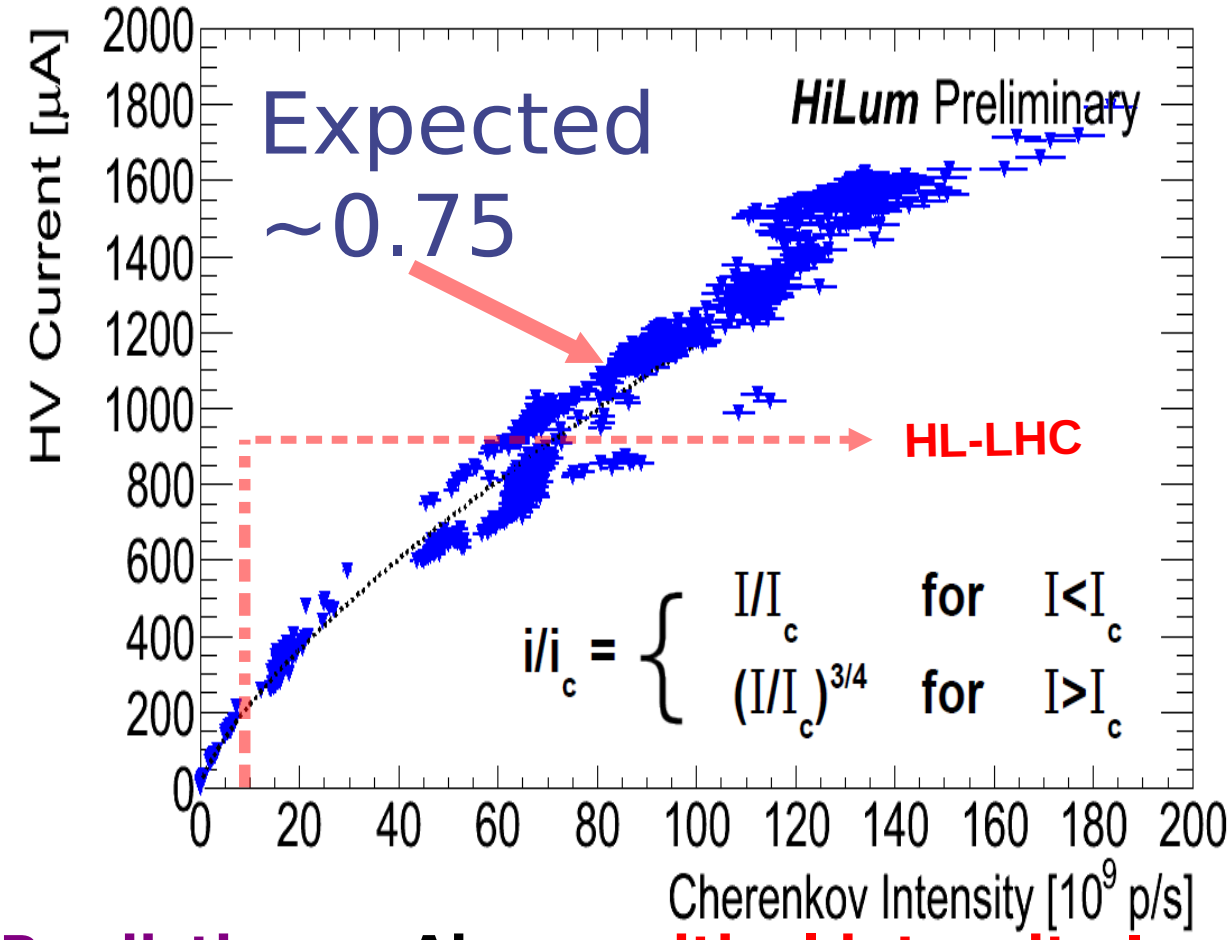
Cherenkov signal:

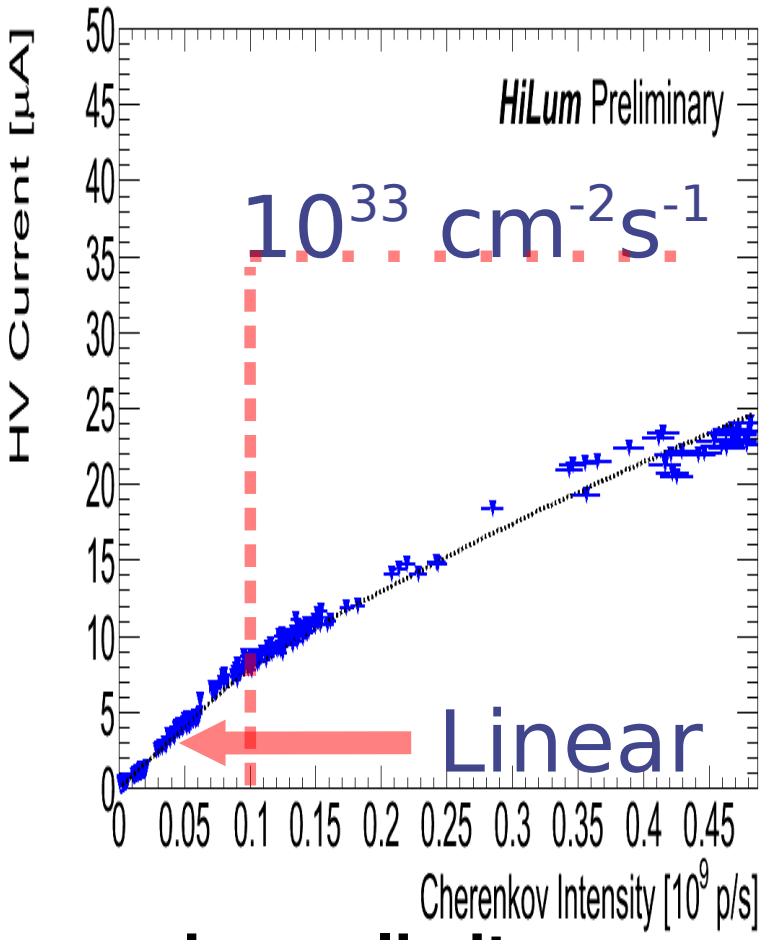
- Synchronization within 3 s with HV current
- Intensity → Ch Integral / spill length



HV Current from EMEC mock-up

over very wide range of beam intensity





Prediction → **Above critical intensity I_c → space charge limit.**
Current drawn at I_c is critical current i_c

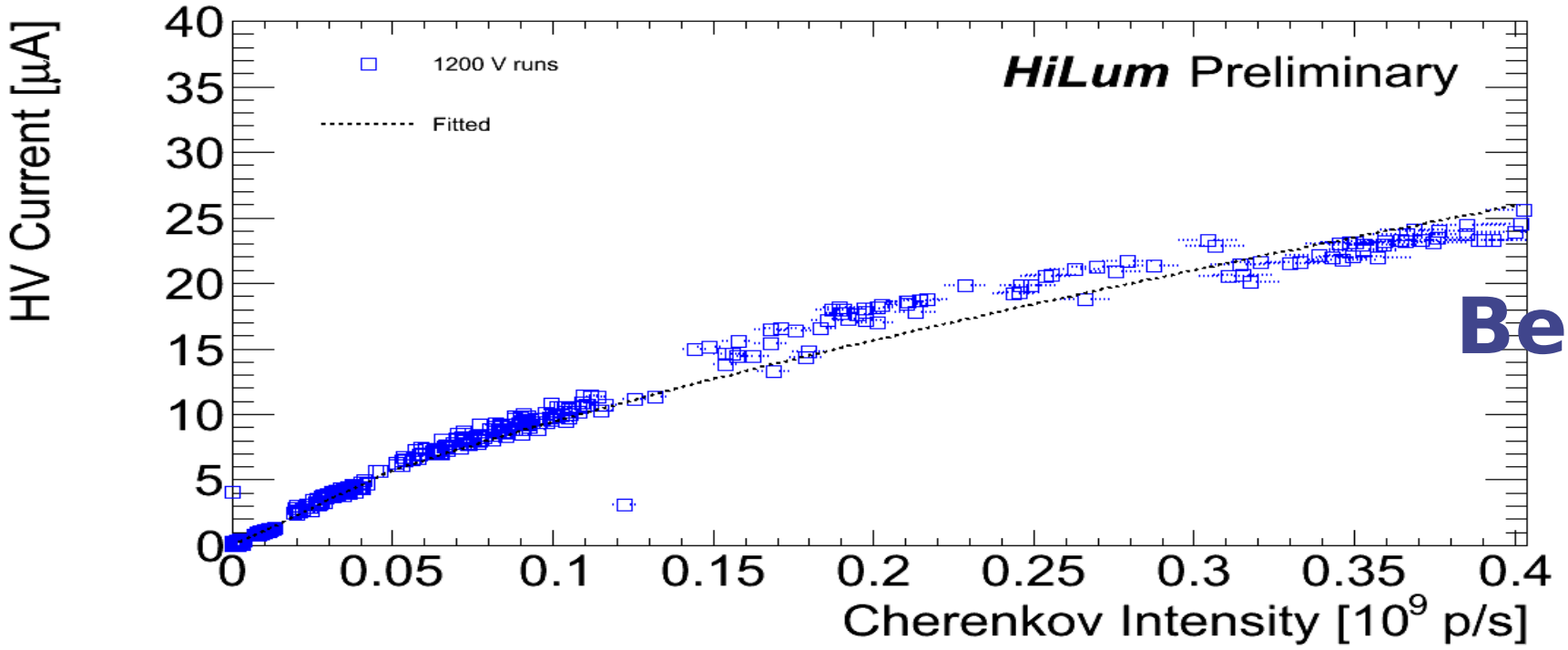
Protons/spill	10^7	10^8	10^9	10^{10}	10^{11}	10^{12}
Protons/bunch	5	50	500	5000	$5 \cdot 10^4$	$5 \cdot 10^5$
LHC lumi equal [$cm^{-2}\ s^{-1}$]	10^{32}	10^{33}	10^{34}	10^{35}	10^{36}	10^{37}

Linear

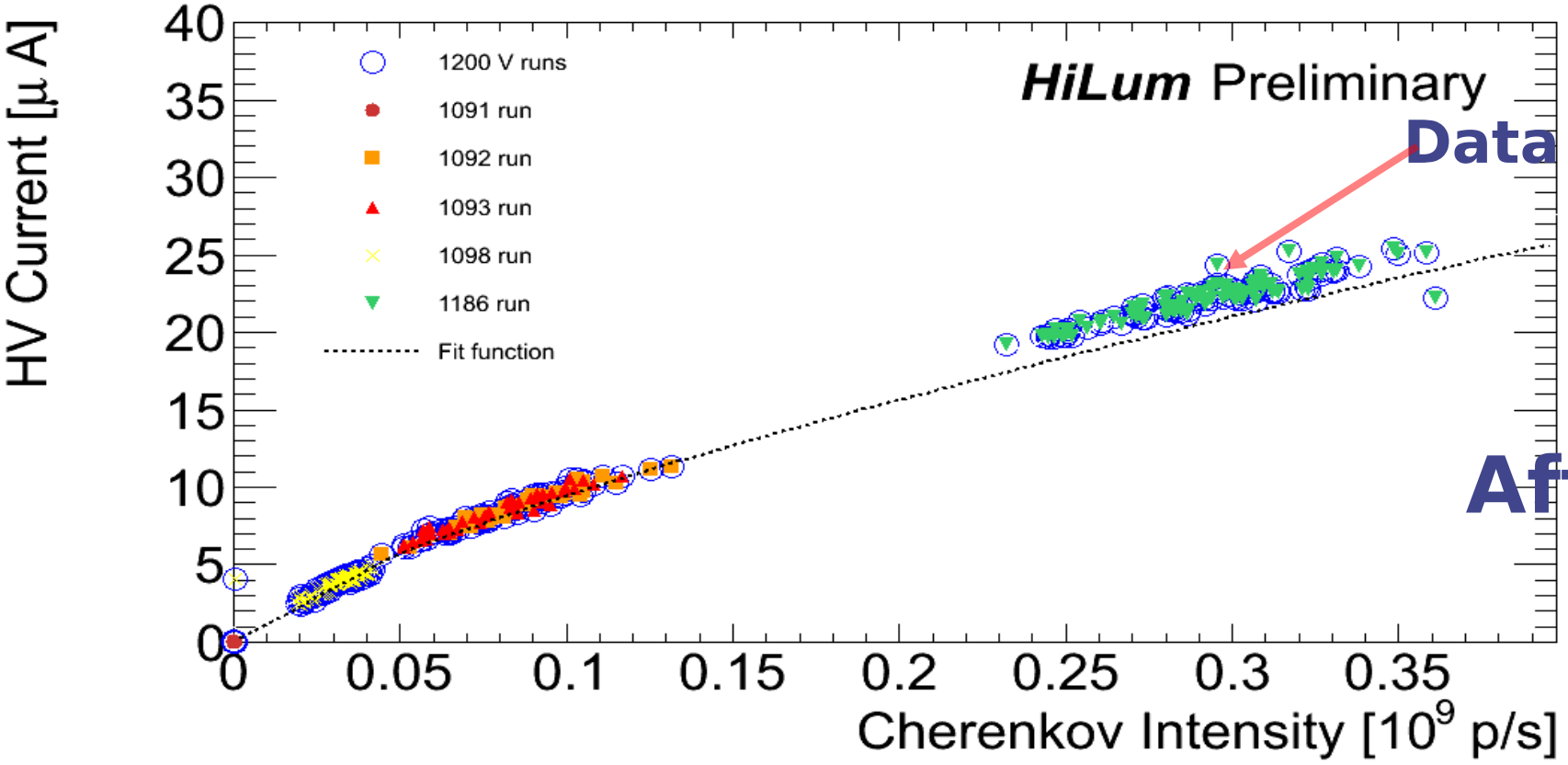
HL-LHC

Test to Destruction

- **Run IHEP proton beam with highest intensity for several days**
- **Compare HV currents before and after**
- **Roughly equivalent to worst place in EMEC after about 1000 fb^{-1}**



Before



Data after test

After

Conclusions

Liquid Argon Calorimetry

- Doesn’t degrade even at higher luminosities
- Up to exposures measured so far

- Critical intensity for ATLAS EMEC ~ 10^8 p/s