THE UNIVERSITY of York

Next generation gamma-ray detectors for nuclear physics based on large scintillators coupled to silicon photomultipliers

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with thanks to Pankaj Joshi, Marcin Jazstrab and Cobus Schwartz

Energy resolution

Timing resolution

Scintillators for nuclear physics

Inside magnetic field

Particle ID

Cost

Particle Physics

Homeland security

Scintillators for nuclear physics

Well logging

Space science

PET/SPECT

Typical scintillation detector

PMT - fragile, needs HV but low noise, well-established technology

Sodium iodide - best resolution ~ 7%
Hygroscopic
Relatively low cost

New scintillators

First Generation scintillators

NaI(Tl): energy resolution of 7% at 662 keV, strong non linearity, bad time resolution

BaF_2: bad energy resolution, excellent time resolution

BGO: bad energy resolution, bad time resolution, excellent efficiency

CsI(Tl): good for the measurement of light charged particles

Second Generation scintillators

Lanthanum Halide: **$LaBr_3$:Ce, $LaCl_3$:Ce**

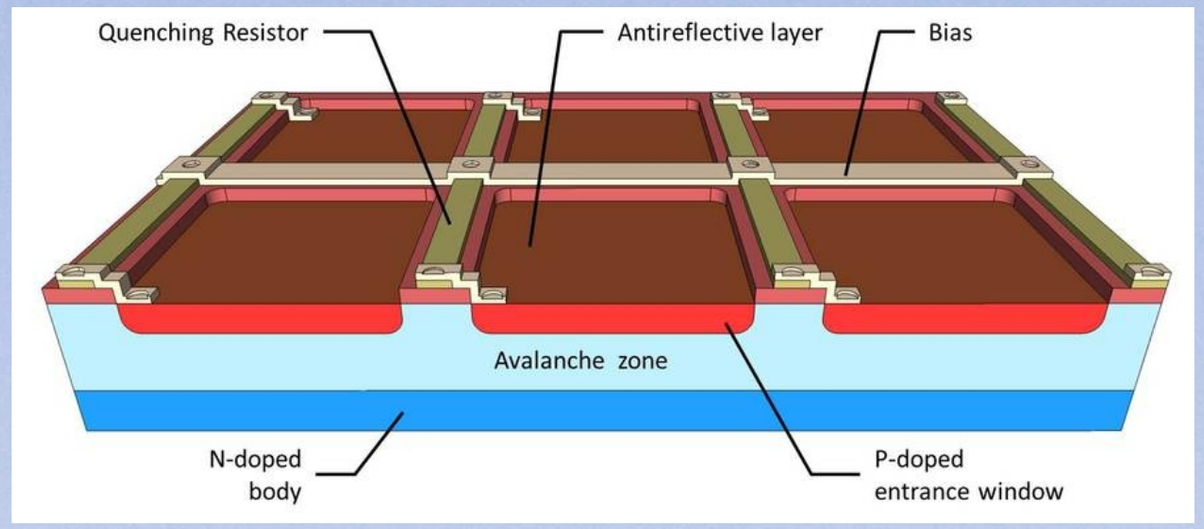
New Materials: **SrI_2:Eu, $CeBr_3$**

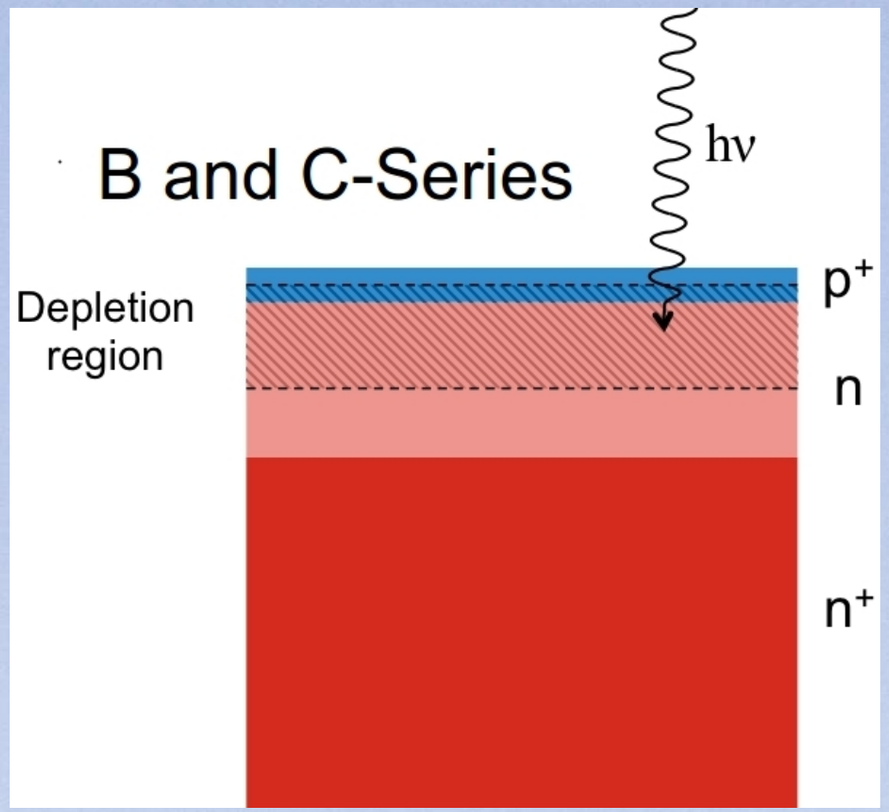
Elpasolide : **CLYC:Ce, CLLB:Ce, CLLC:Ce**

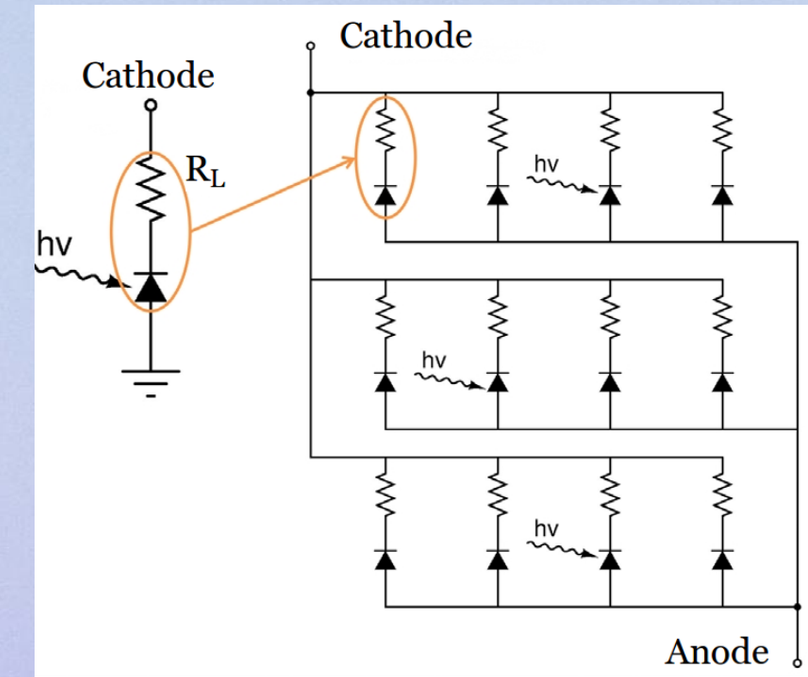
Ceramic: **GYGAG:Ce**

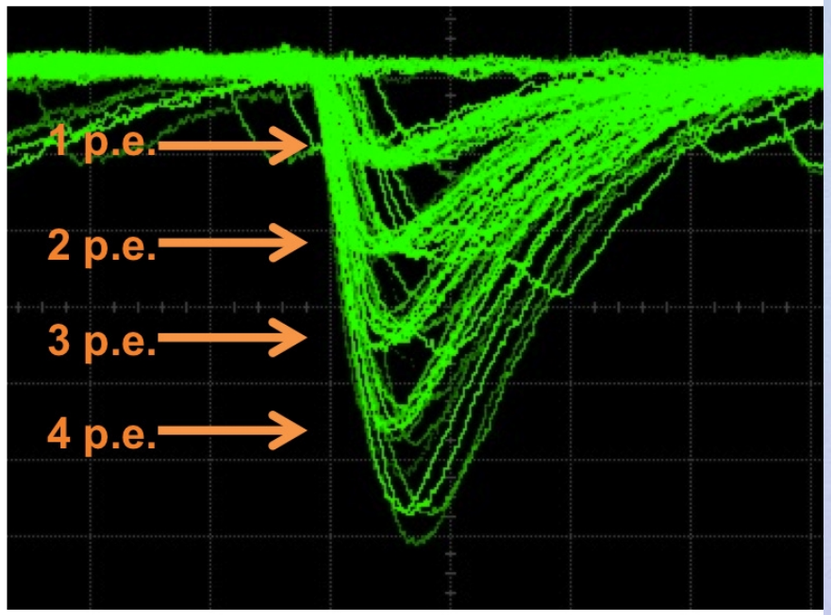
Material	Light Yield [ph/MeV]	Emission λ_{max} [nm]	En. Res. at 662 keV [%]	Density [g/cm^2]	Pricipal decay time [ns]
NaI:Tl	38000	415	6-7	3.7	230
CsI:Tl	52000	540	6-7	4.5	1000
$LaBr_3$:Ce	63000	360	3	5.1	17
SrI_2:Eu	80000	480	3-4	4.6	1500
$CeBr_3$	45000	370	<5%	5.2	17
GYGAG:Ce	40000	540	<5%	5.8	250
CLYC:Ce	20000	390	4	3.3	1 CVL 50, ~1000

Silicon photomultipliers


Quenching Resistor
Antireflective layer
Bias
Avalanche zone
N-doped
body
P-doped
entrance window

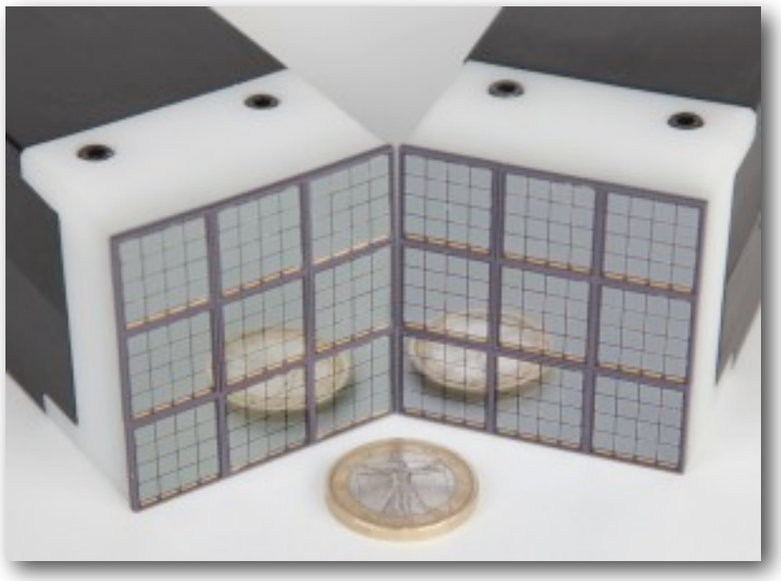

B and C-Series
hν
Depletion
region
p+
n
n+

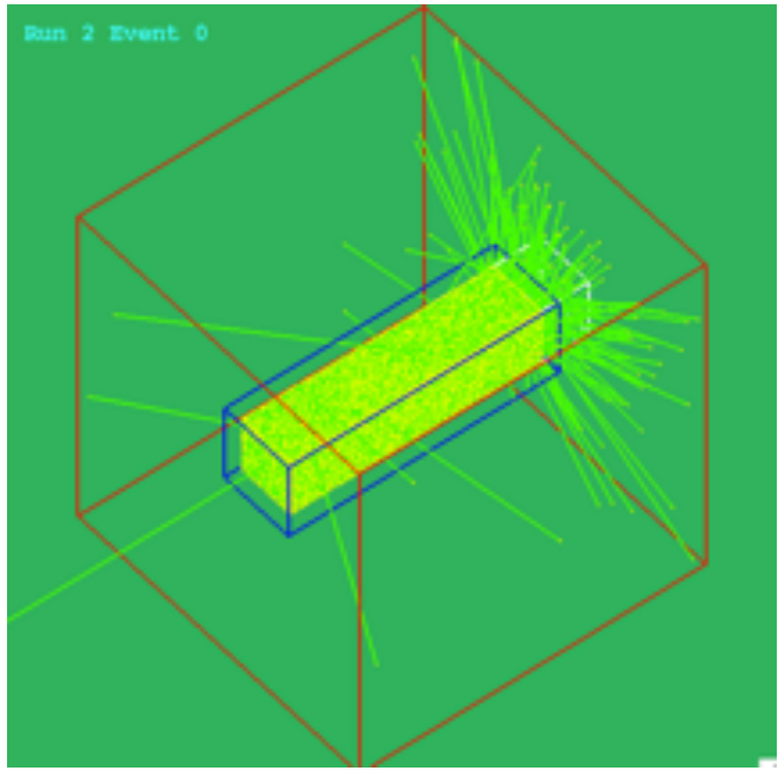

Cathode
Cathode
RL
hv
hv
hv
hv
Anode


1 p.e.
2 p.e.
3 p.e.
4 p.e.

Silicon Photomultipliers

- Developments of large arrays of SiPMs
- Technology directed towards simultaneous PET and MRI
- Bespoke electronics and readout developed
- Suffer from high dark current IMPROVING
- Major gain instability with temperature IMPROVING
- Excellent timing resolution (100s of ps)

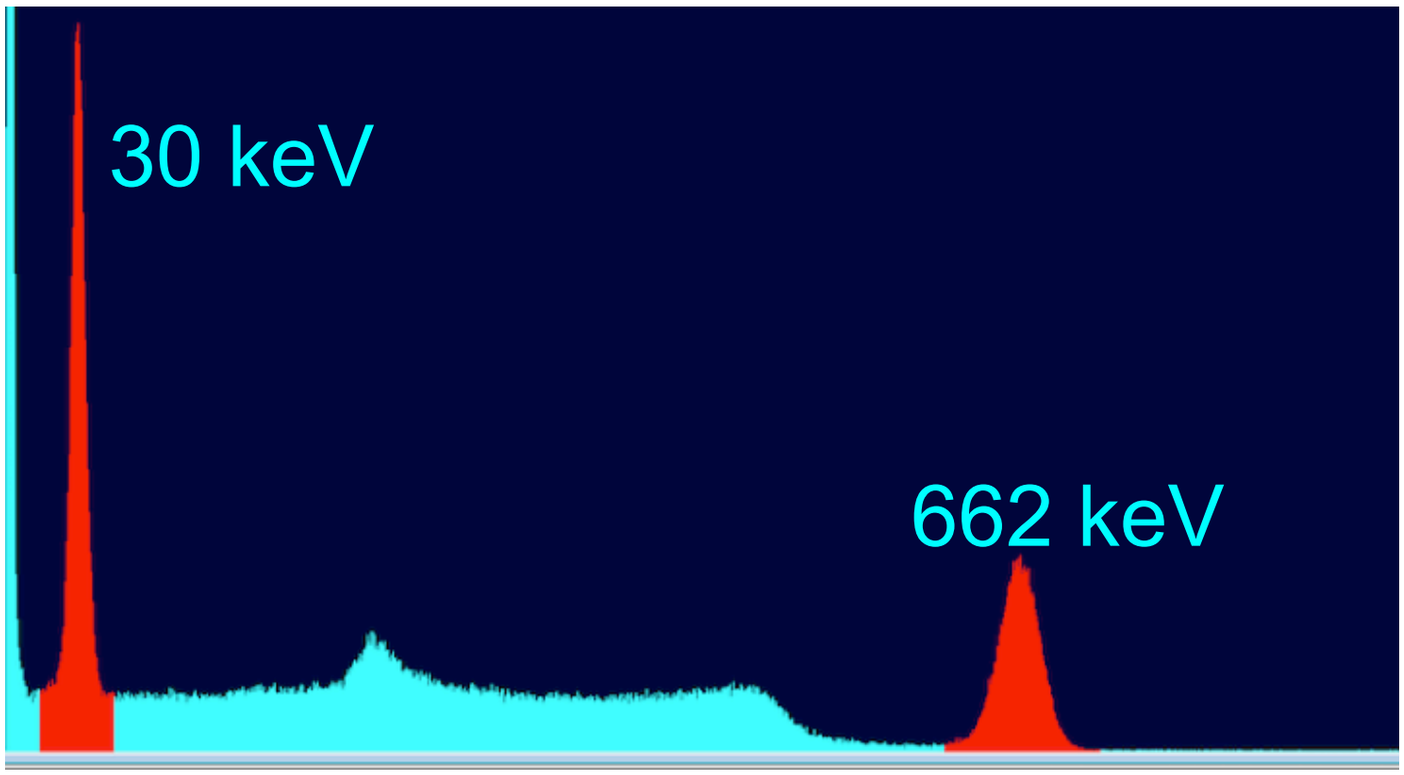




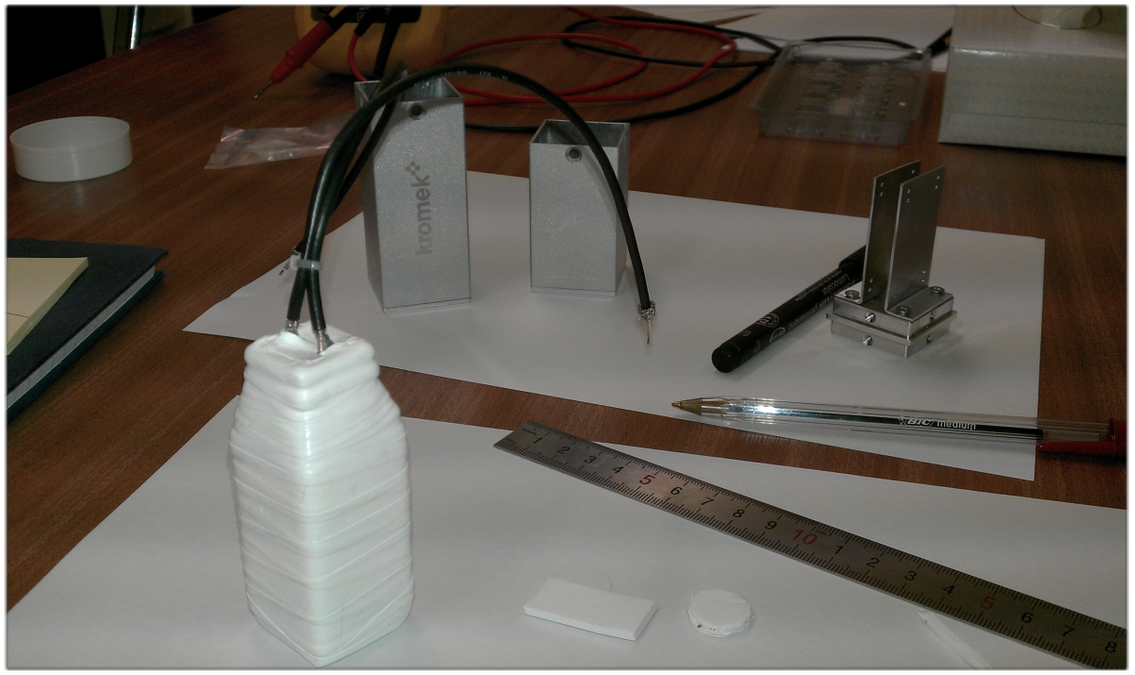
CsI(Tl) coupled to SiPM e.g. from Hamamatsu or SensL

Typical energy resolution ~ 6-7% at 662 keV

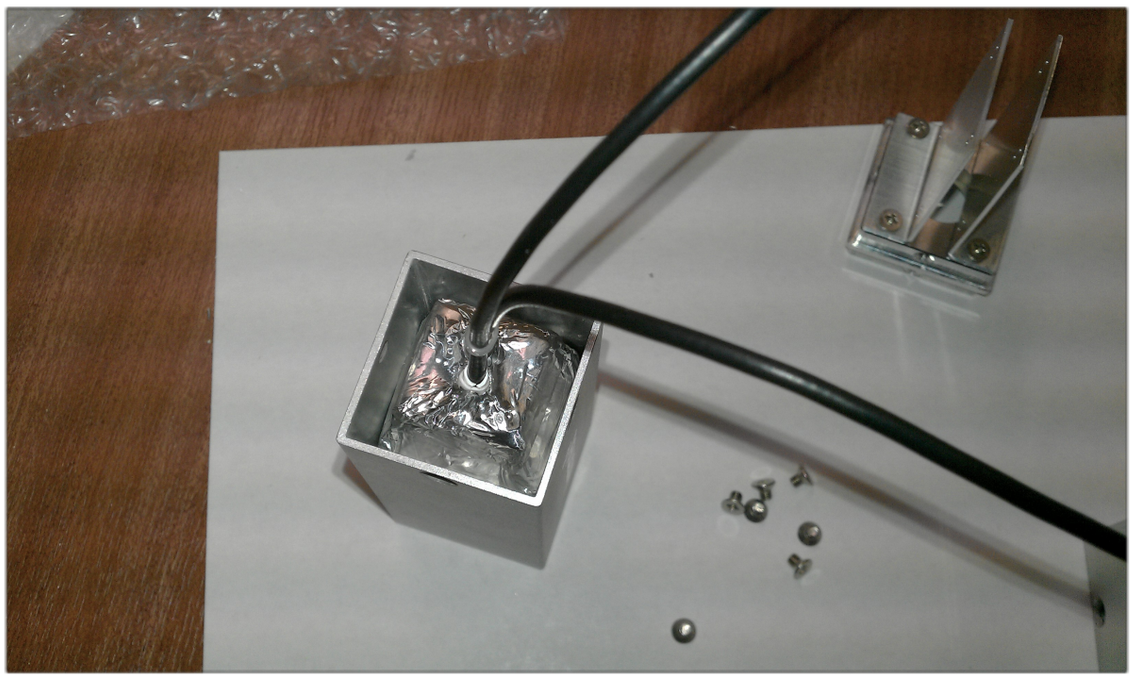
Crystal non-linearity an issue




kromek


kromek


kromek



Kromek PLC produced D3S product

12000 units ordered by US government

$6M order value

Significant employment generated

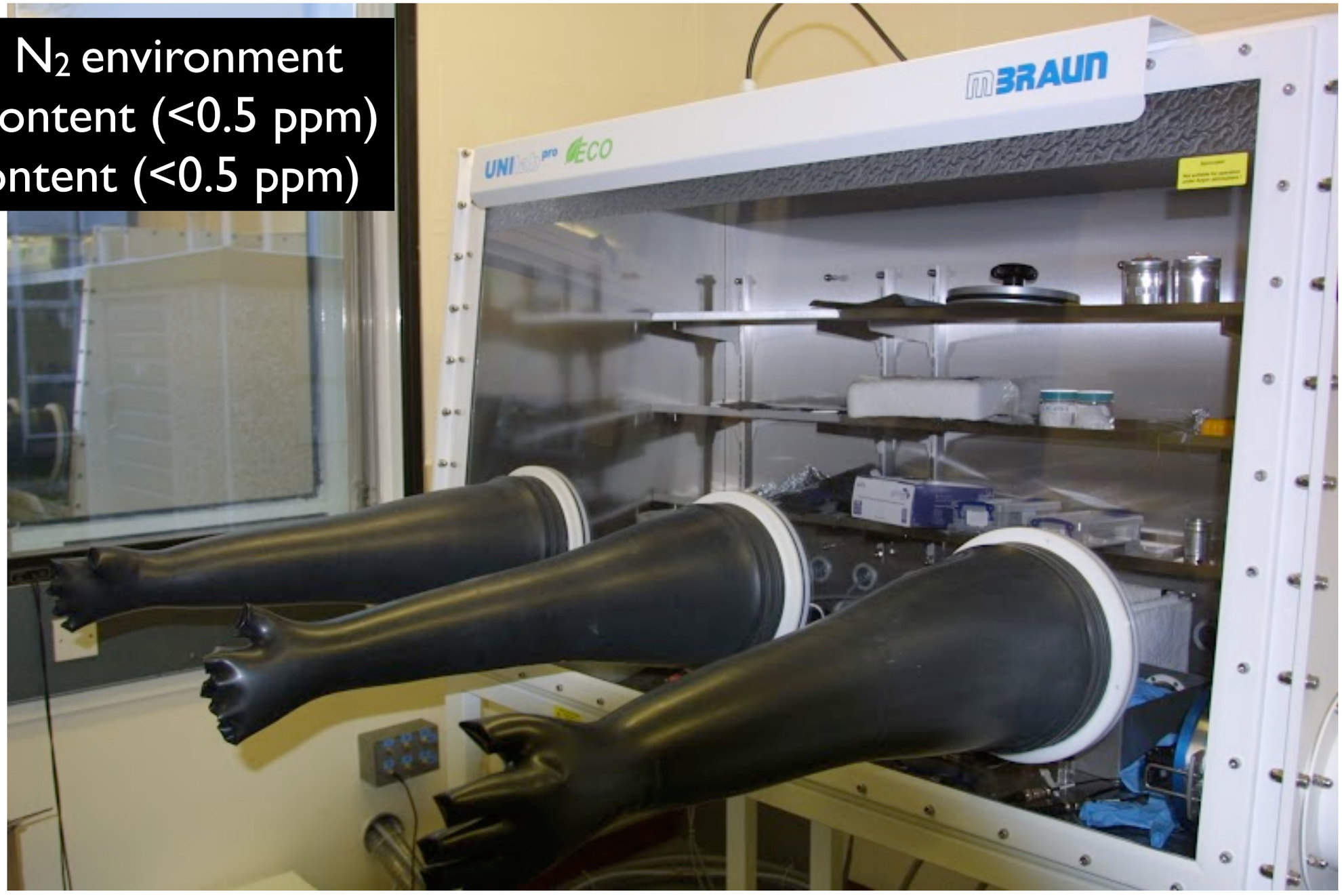
York and Kromek working to upgrade the system to be more sensitive

Kromek contributing £60k/year to nuclear applications group at York

£1.25M grant income in last three years in related areas

Handling hygroscopic materials

Regulated N_2 environment
Low H_2O content (<0.5 ppm)
Low O_2 content (<0.5 ppm)



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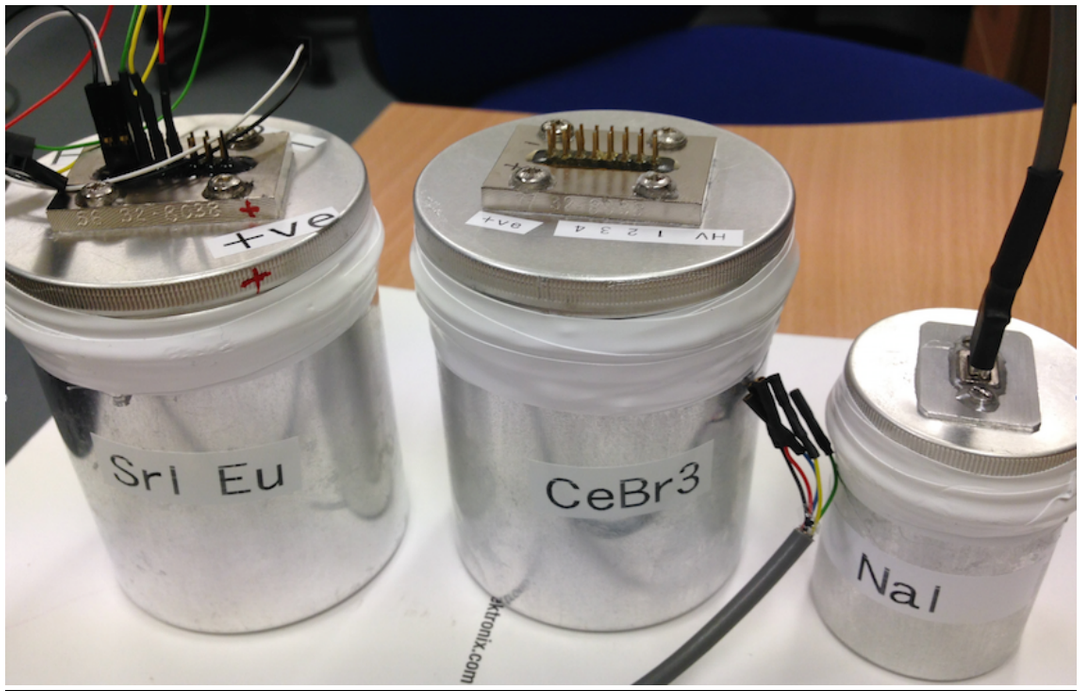
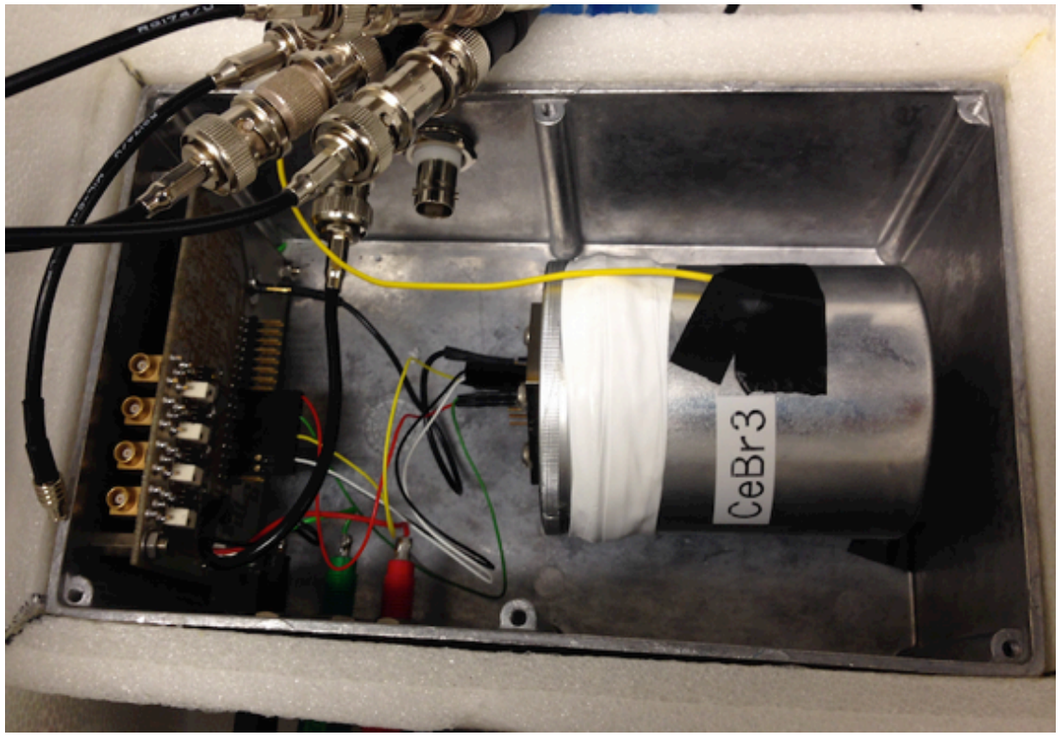
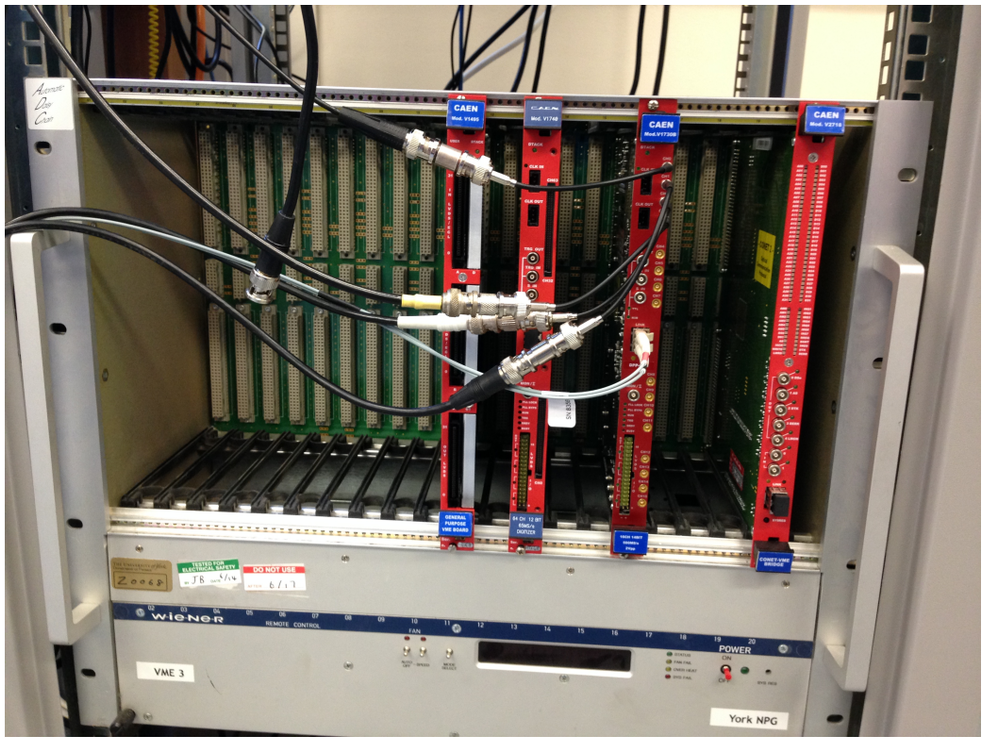
Evaluating next-generation scintillators and SiPMs with CAEN digital DAQ







SensL C-series