European Physical Society
Conference on High Energy Physics

HEP2019
EUROPEAN PHYSICAL SOCIETY

Detector R&D
non-Accelerator Physics

10-17 July 2019 - Ghent, Belgium

Ezio Previtali
University and INFN of Milano Bicocca

...in the sky, on the earth and almost everywhere...
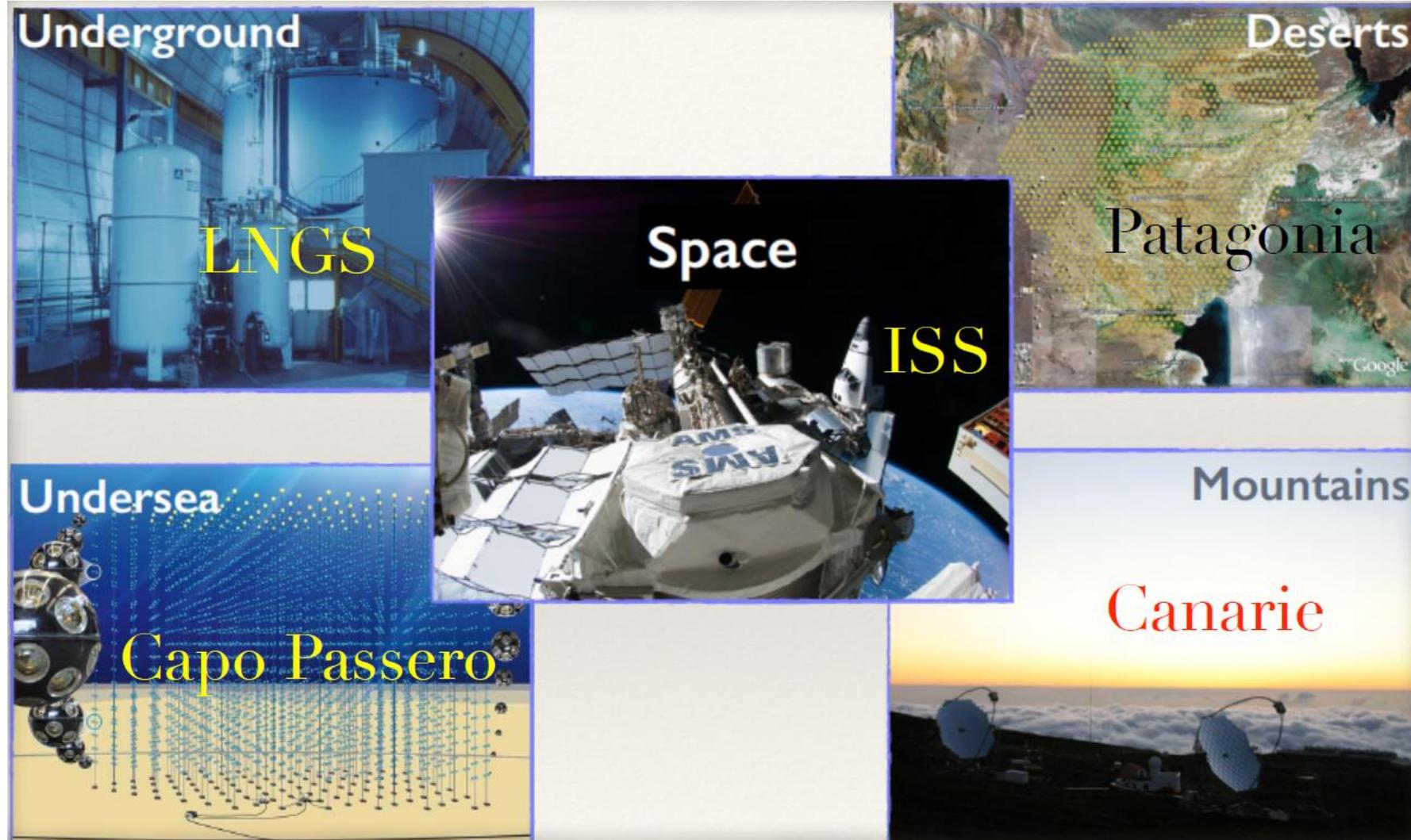
...I will do my best but...

Main experimental challenges

Physics challenges

Neutrino physics
> *Neutrinoless Double Beta Decay*
> *Neutrino Oscillation*
> *Direct Neutrino Mass Measurements*

Direct Dark Matter Search
> *Low and high mass WIMPs*
> *Axions*

High Energy Cosmic Rays

Gravitational Waves

………

Detector challenges

Increase signal
> *Large mass*
> *High intensity sources*

Detector performances
> *Energy resolution*
> *Time resolution*
> *Position/Angular resolution*
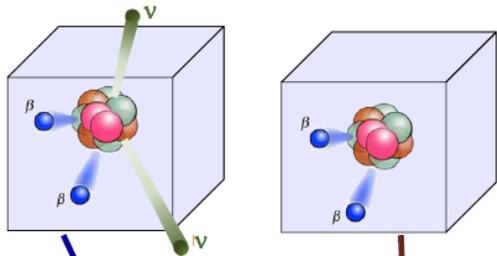
Low background
> *Underground labs*
> *Very high purity materials*
> *Large radioactive shields*
> *Signal/Background discrimination*

0νββ decay sensitivity

Approach:
SOURCE = DETECTOR

$$S\left(\tau_{1/2}^{0\nu}\right) \propto \epsilon \cdot \frac{a.i.}{A} \sqrt{\frac{M t_{meas}}{\Delta E \cdot BI}}$$

detector mass [kg]

detector efficiency

measuring time [y]

isotopic abundance
atomic number

energy resolution [keV]

background [c/keV/y/kg]
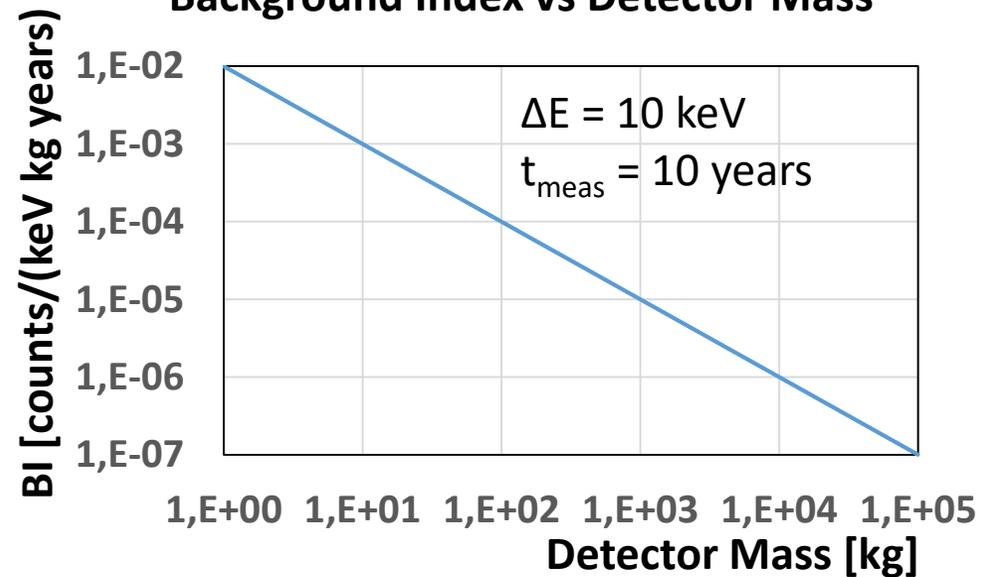
$\tau_{1/2}^{0\nu}$ **sensitivity**

BI = 0

$$S\left(\tau_{1/2}^{0\nu}\right) \propto \epsilon \cdot \frac{a.i.}{A} M t_{meas}$$
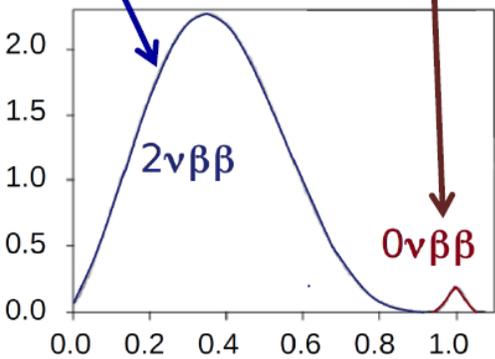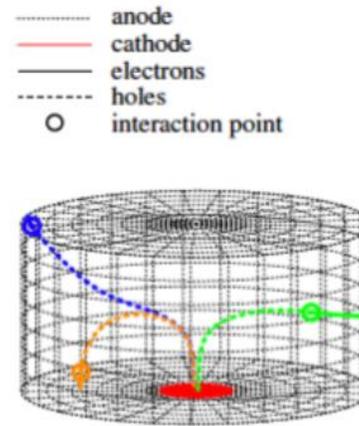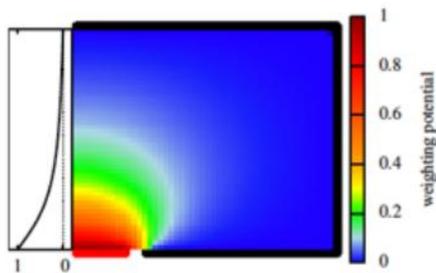
experimental sensitivity related

⬇ ΔE   BI

⬆ M   t_{meas}

Background Index vs Detector Mass

ΔE = 10 keV
t_{meas} = 10 years
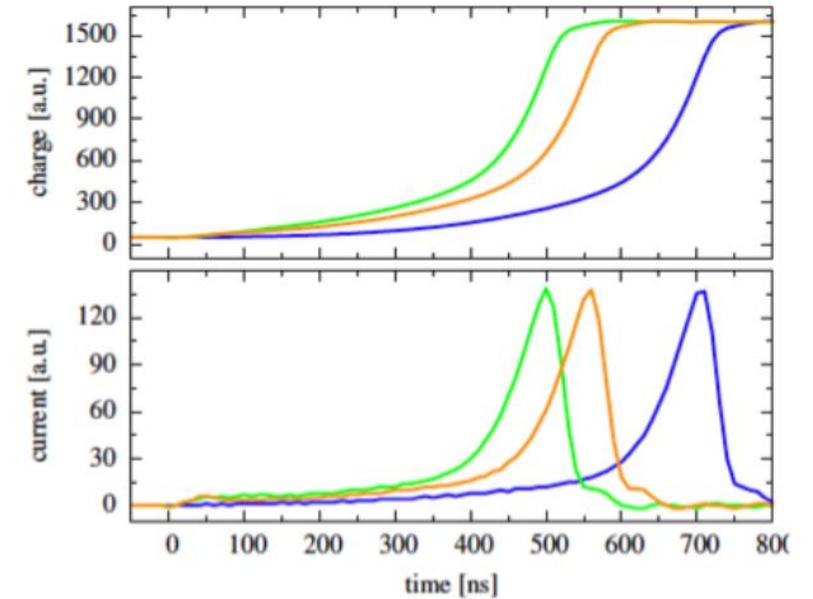
0νββ – GERDA, HPGe background rejection

Novel HPGe detectors allow for efficient PID
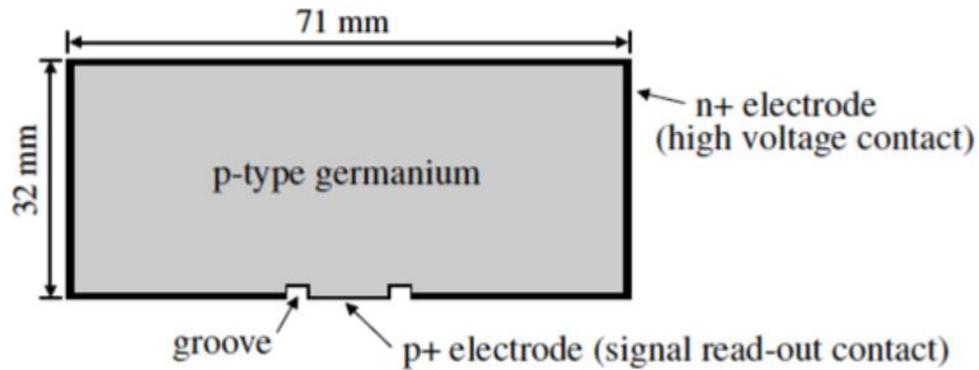
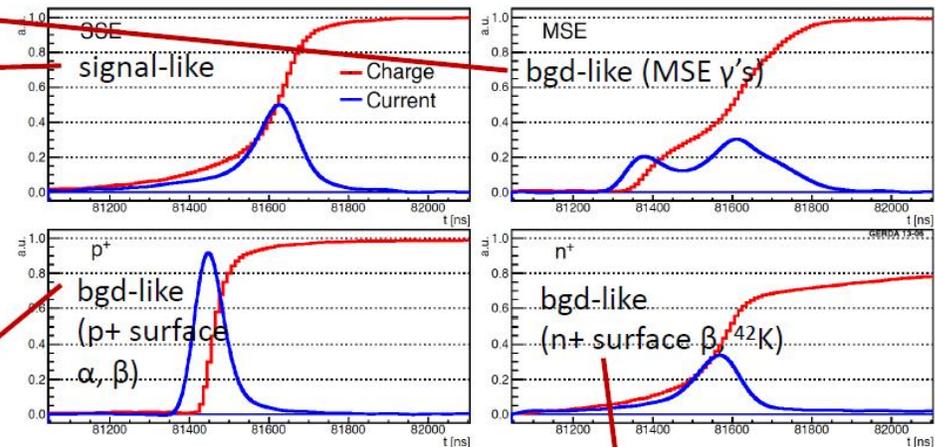(a) Trajectories

(b) Charge and current pulses

Thanks S. Shoenert

0νββ – GERDA, HPGe background rejection
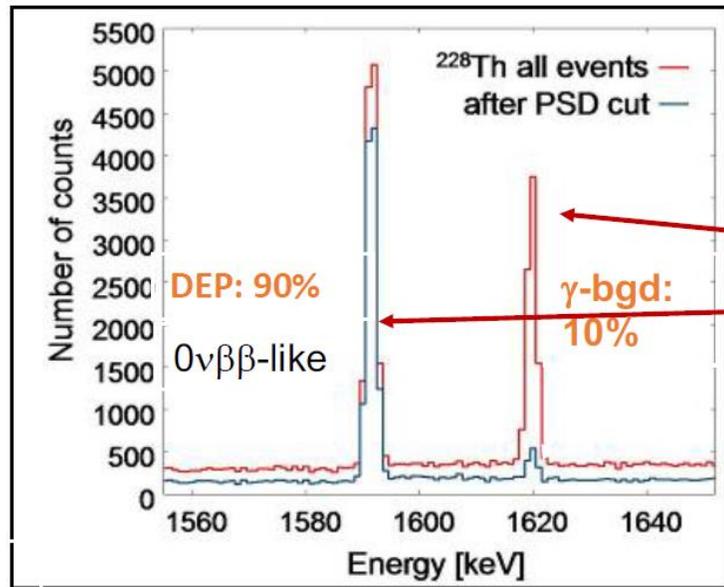
Novel HPGe allow for efficient PID

DEP: 90%   0νββ-like

γ-bgd: 10%

SSE signal-like — Charge / Current
MSE bgd-like (MSE γ's)
p⁺ bgd-like (p+ surface α, β)
n⁺ bgd-like (n+ surface β, ⁴²K)

<1E-4

<1E-2
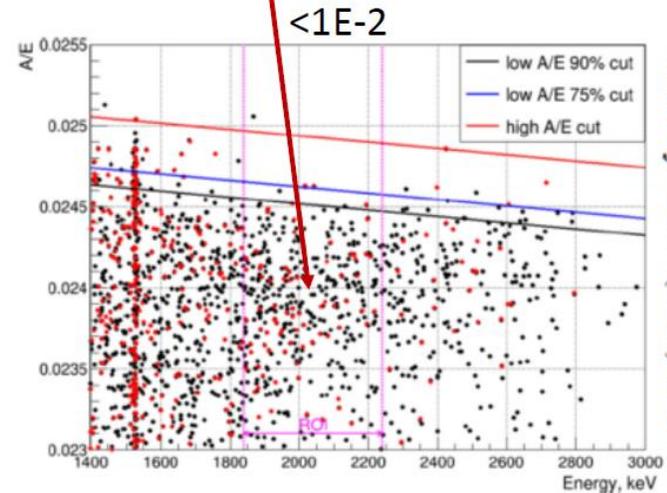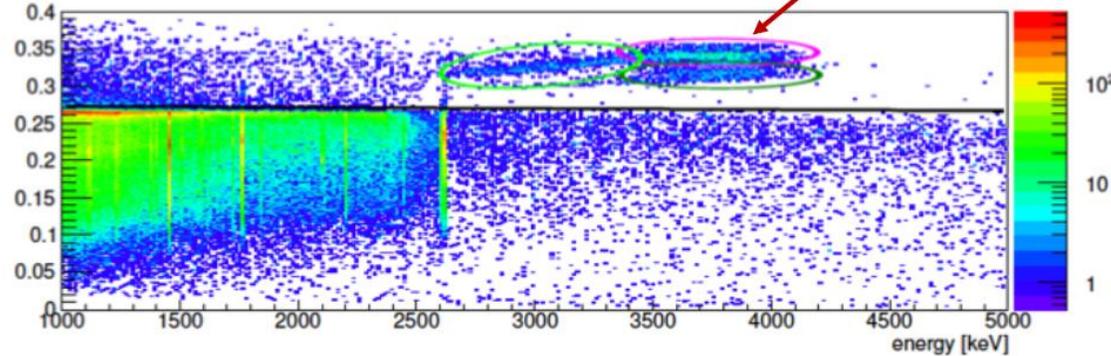
Thanks S. Shoenert

0νββ - GERDA background achivements
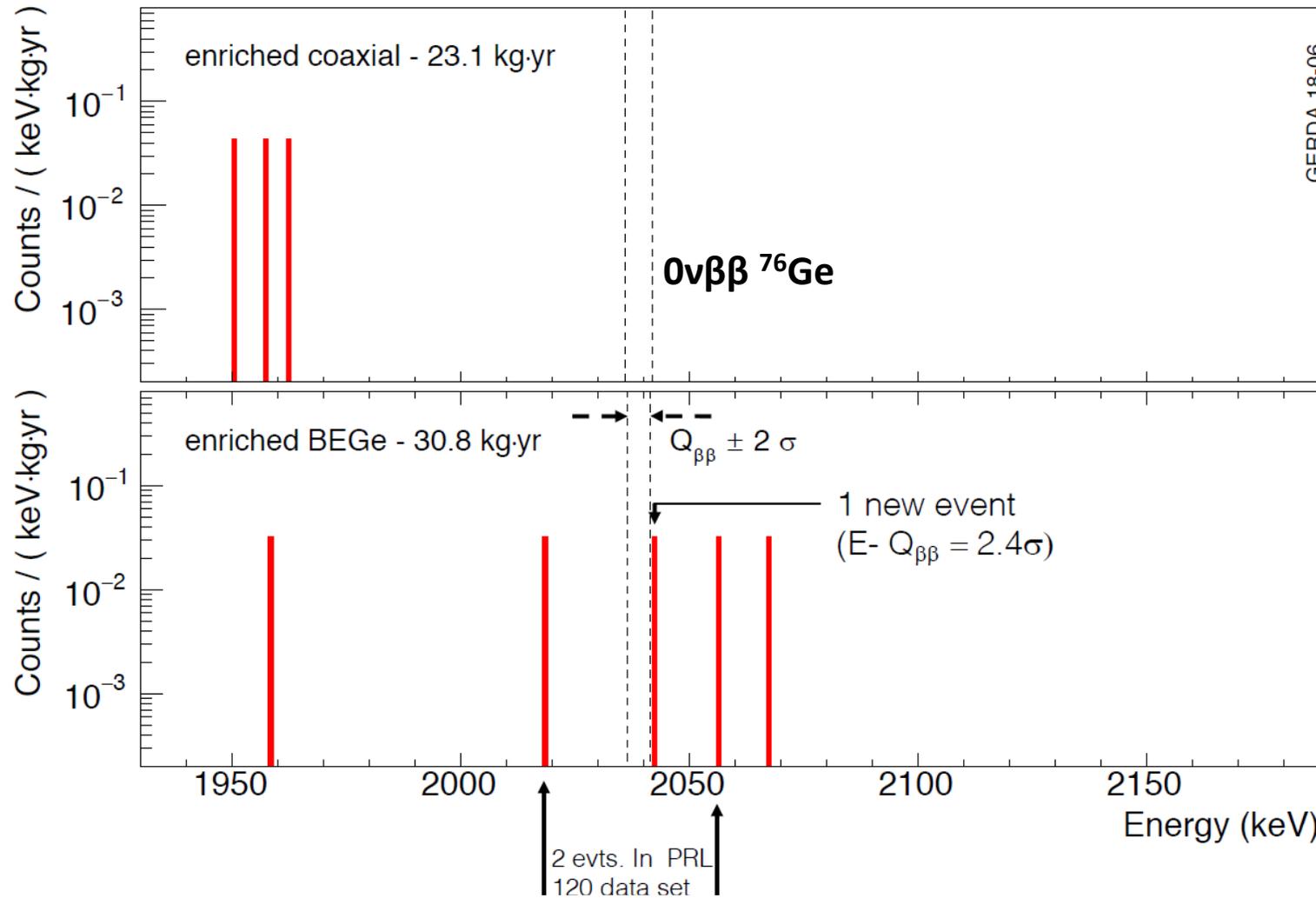
Background index[*]:

$$(5.7^{+4.1}_{-2.6} \cdot 10^{-4})\ \text{counts/(keV·kg·yr)}$$

$$(5.6^{+3.4}_{-2.4} \cdot 10^{-4})\ \text{counts/(keV·kg·yr)}$$

[*]: in 1930-2190 keV excluding ±5 keV at $Q_{\beta\beta}$ and lines at 2104 keV and 2119 keV.

Thanks S. Shoenert

GERDA experiment operates in a real **0 background conditions**

0νββ - From GERDA to LEGEND

LEGEND-200 (first phase):
- up to 200 kg of detectors
- BI <2E-4 cts/(keV kg yr) ←
- use existing GERDA infrastructure at LNGS
- design exposure: 1 t yr
- Sensitivity 10^{27} yr
- Isotope procurement ongoing
- Start in 2021

LEGEND-1000 (second phase):
- 1000 kg of detectors (deployed in stages)
- → BI <1E-5 cts/(keV kg yr)
- Location tbd
- Design exposure ~10 t yr
- 1.2×10^{28} yr

LEGEND.
To increase the experimental mass a **new HPGe detector configuration** will be adopted

Inverted Coaxial Detector guaranties the same rejection capability as BEGe detector with **a detector mass of 2 kg**

Inverted coaxial detectors:
R. Cooper, D. Radford, P. Hausladen, K. Lagergren Nucl. Instrum. Methods Phys. Res. Sect. A 665 (2011)
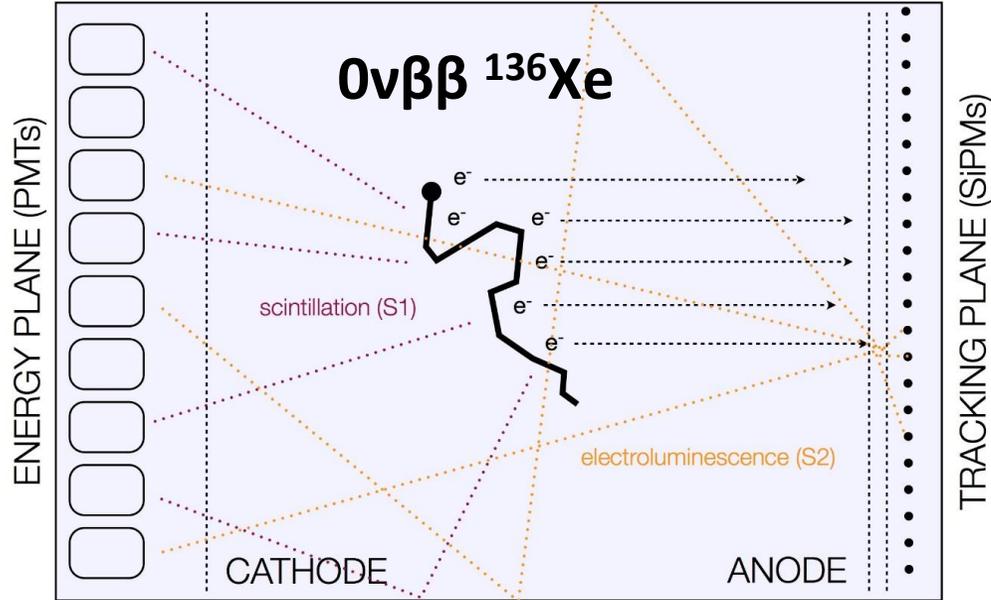
Pulse shape discrimination performance of Inverted Coaxial Ge detectors A. Domula, M. Hult, Y. Kermaïdicb, G. Marissens, B. Schwingenheuer, T. Wester, K. Zuber; NIMA 891 (2018) 106-110
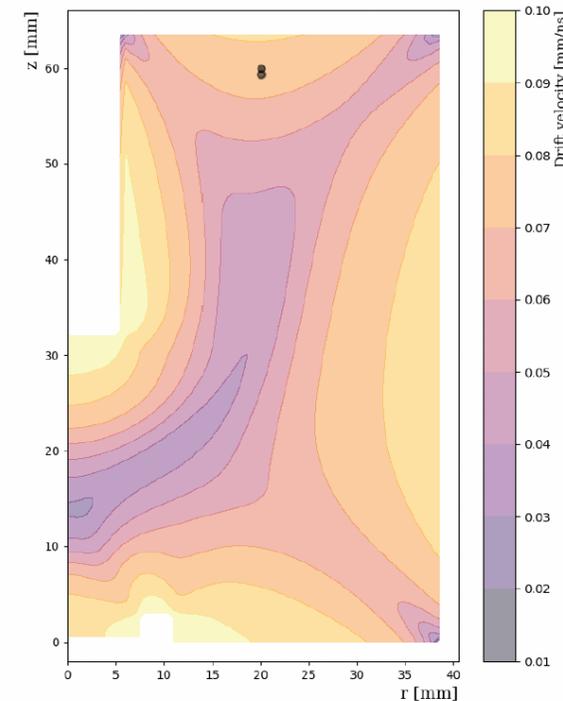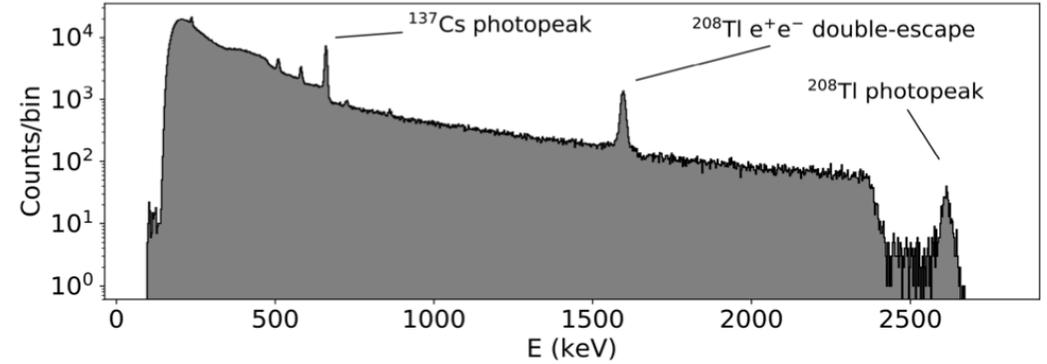

Thanks S. Shoenert

0νββ – NEXT, High Pressure Gas-Xe TPC

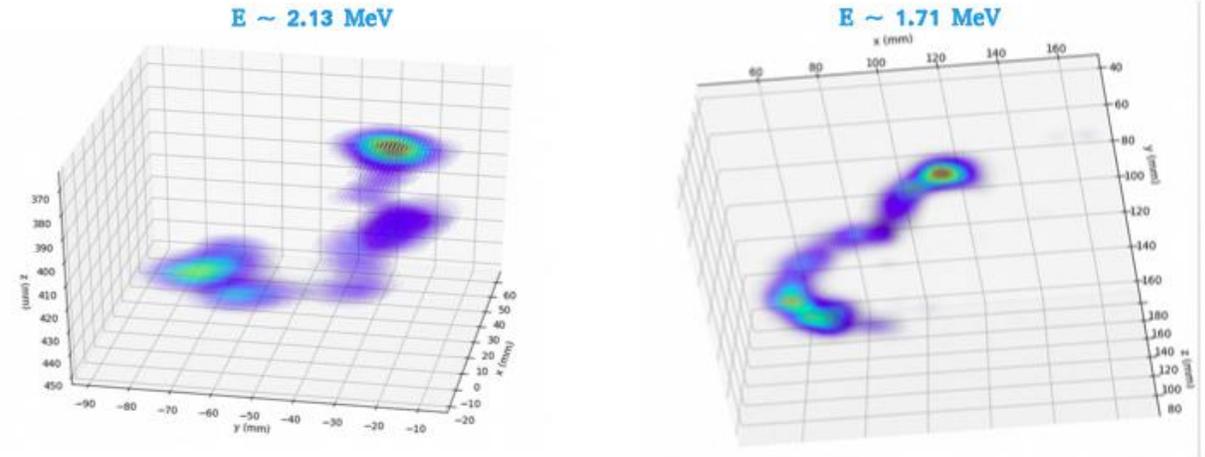**Gas-Xe TPC with two readout planes**

Energy resolution at $Q_{\beta\beta}$ < 1 % FWHM

High Energy Resolution
Topological evet reconstruction

Topological signature: 2nu candidates

Topological signature:
92 % signal efficiency 92 % background rejection

Talk P. Novella

Thanks J.J. Gomes Cadenas
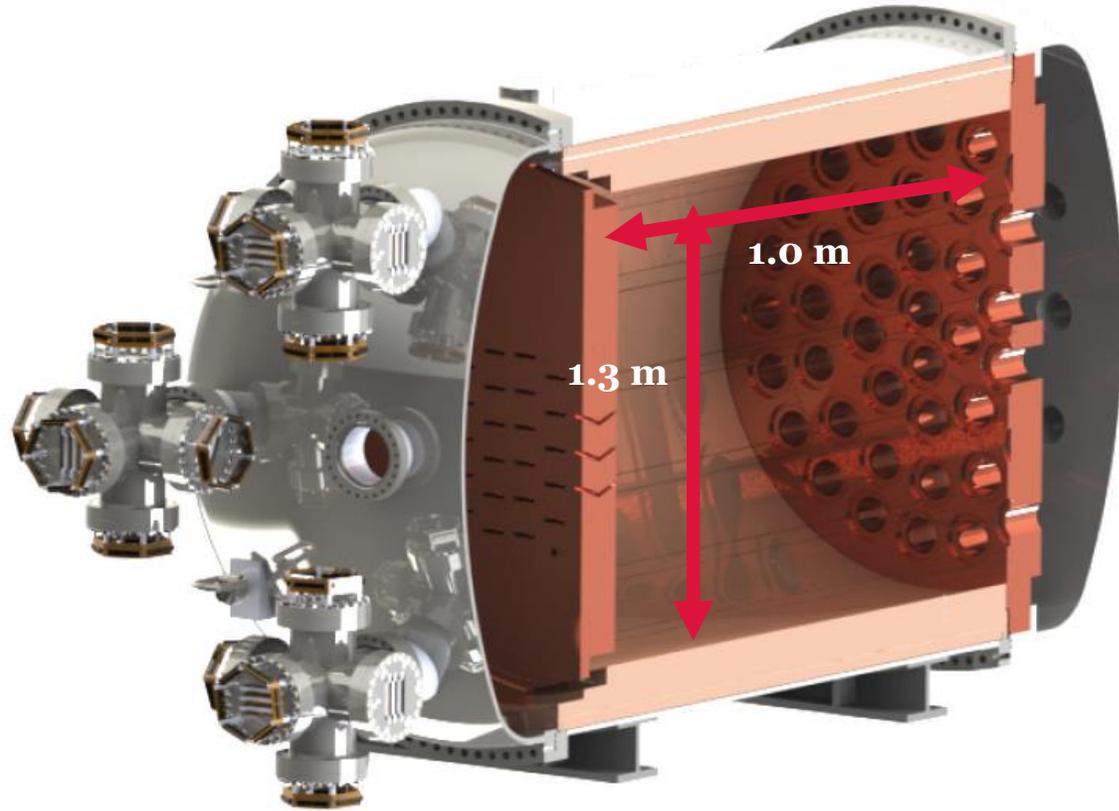
0νββ – NEXT, High Pressure Gas-Xe TPC

NEXT – 100 detector under preparation

1.0 m

1.3 m

Expected BI: < 4.09 x 10^{-4} cts / (keV kg year)

Energy resolution at Qββ < 1 % FWHM

E ~ 2.13 MeV

E ~ 1.71 MeV

Topological signature: 2nu candidates

Talk P. Novella

Thanks J.J. Gomes Cadenas
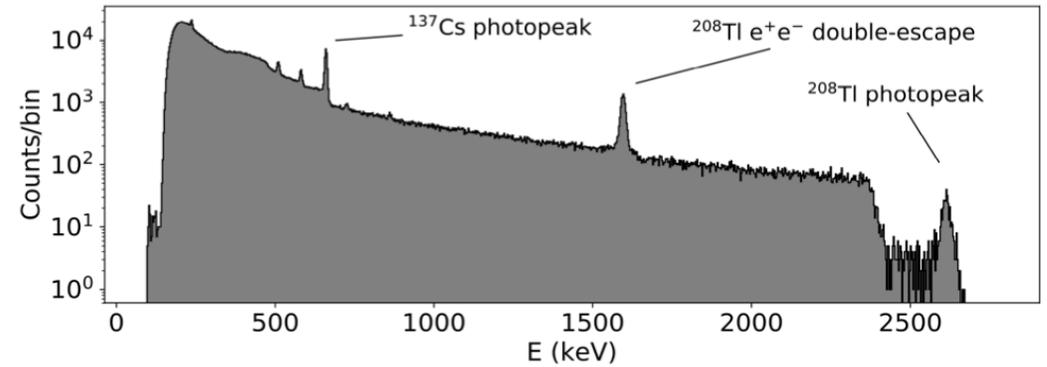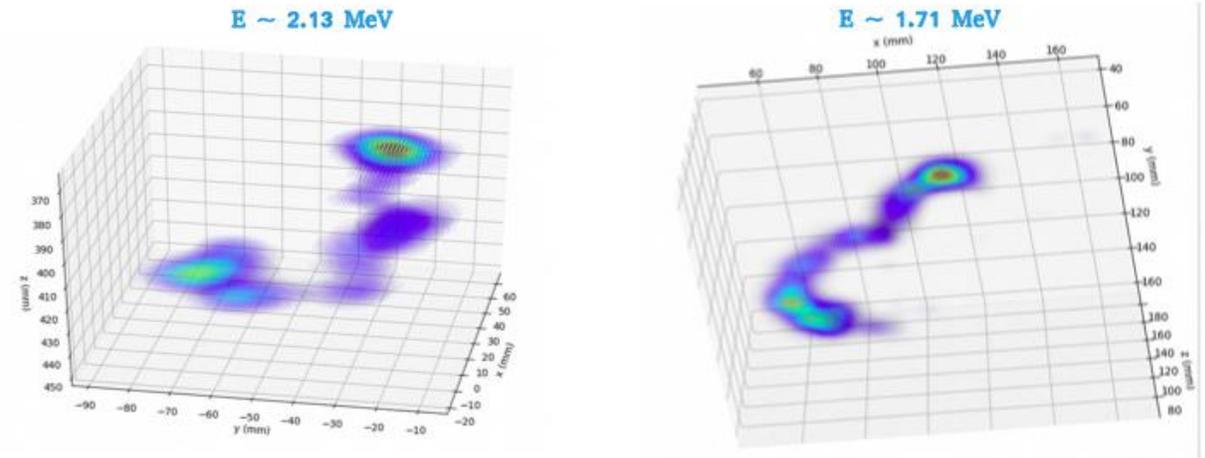
0νββ – NEXT, Ba⁺⁺ tagging

0νββ of ^{136}Xe

In the final state there are:
- 2 electrons
- 1 **Ba⁺ ion**

^{136}Xe → ^{136}Ba + 2 e⁻
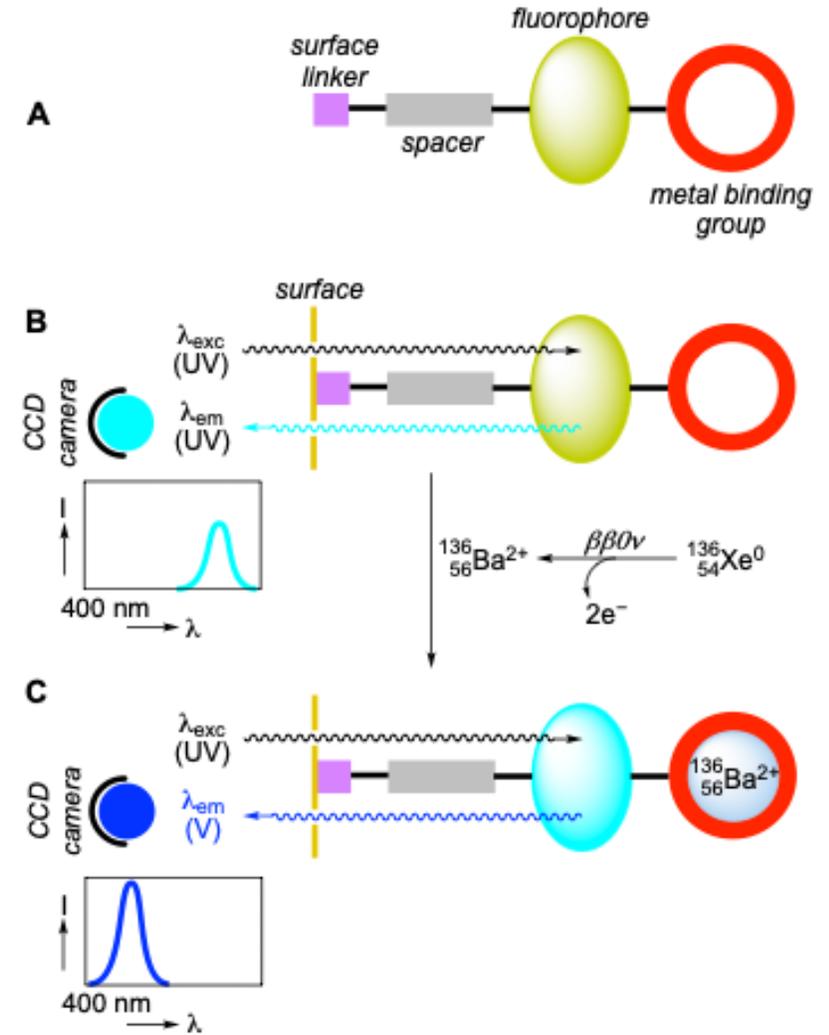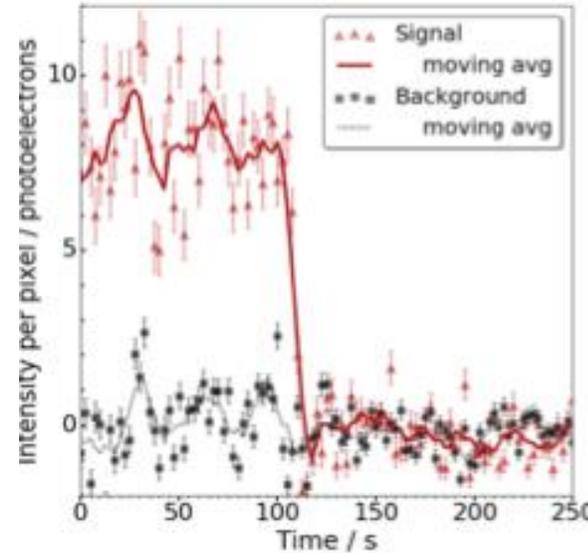
Electrons are detected by the TPC

Identification of Ba⁺⁺ ions will strongly suppress the background

A more clear determination of the **Ba detection efficiency** is needed

A

surface linker   spacer   fluorophore   metal binding group

B   surface

CCD camera λ_{exc} (UV) λ_{em} (UV)   400 nm λ I

$^{136}_{56}Ba^{2+}$ ← $\beta\beta 0\nu$ ← $^{136}_{54}Xe^0$ $2e^-$

C

CCD camera λ_{exc} (UV) λ_{em} (V) $^{136}_{56}Ba^{2+}$ 400 nm λ I

Bi-color molecules developed
R&D is ongoing

0νββ – EXO, LXe TPC

~100kg Liq-^{136}Xe

175nm scintillation light detecting APDs

$\vec{E}$

Charge collection grids

Cathode -HV

~40cm

EXO-200

0νββ ^{136}Xe

singlesite

multisite

Low background data

2νββ

^{228}Th calibration source

γ

^{228}Th source SS
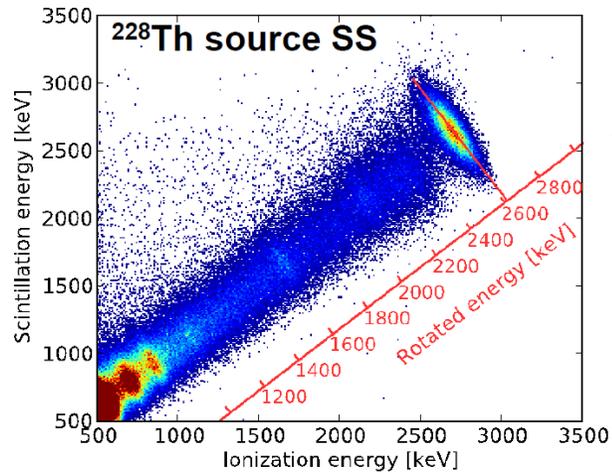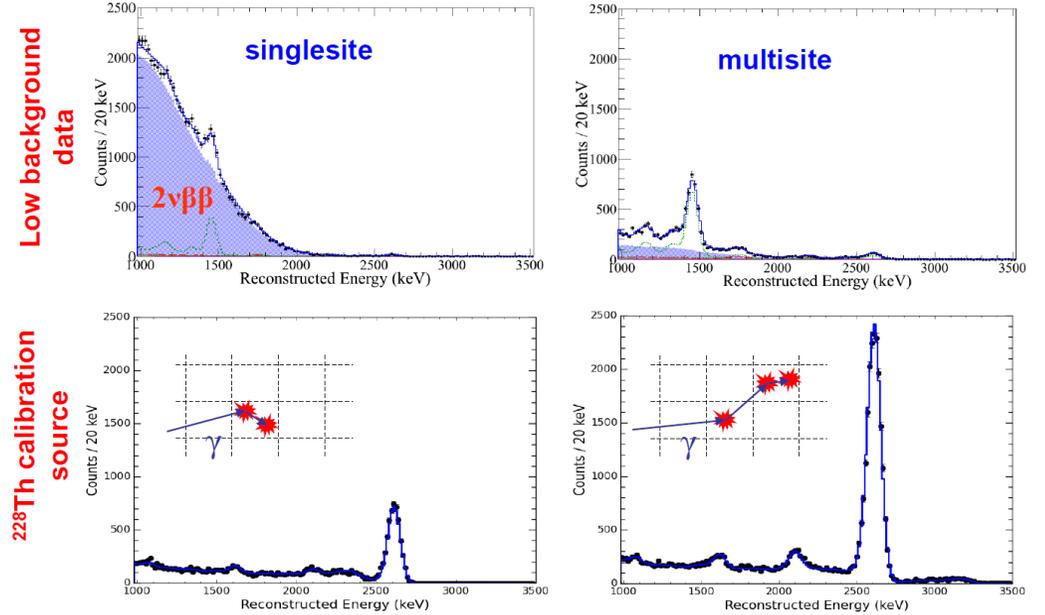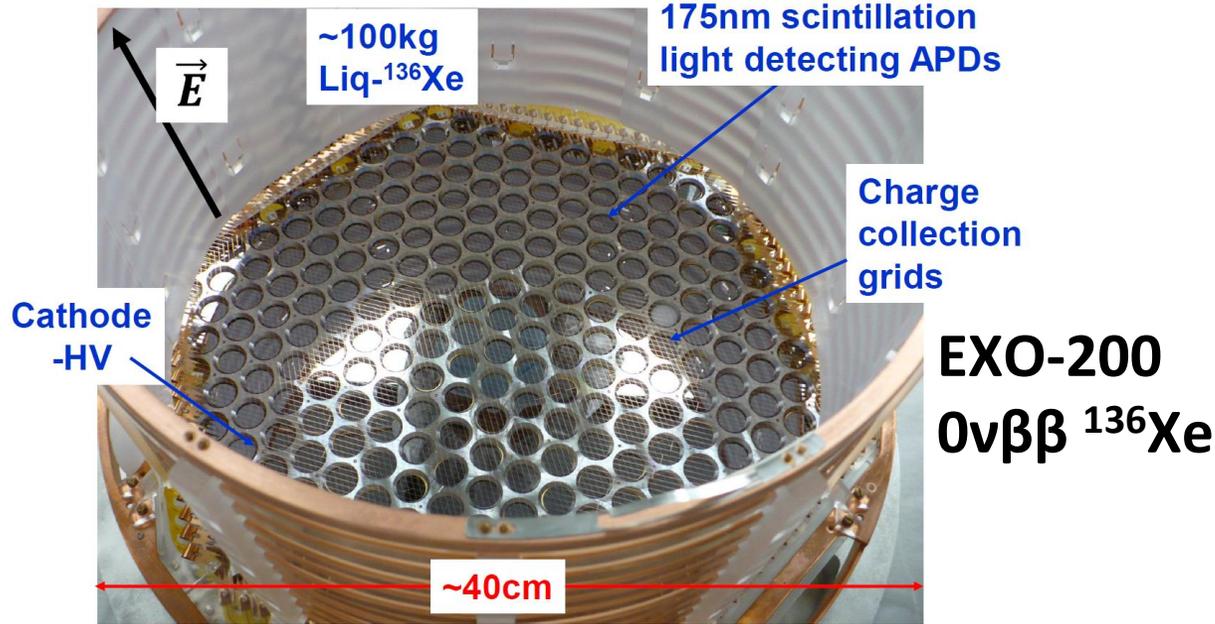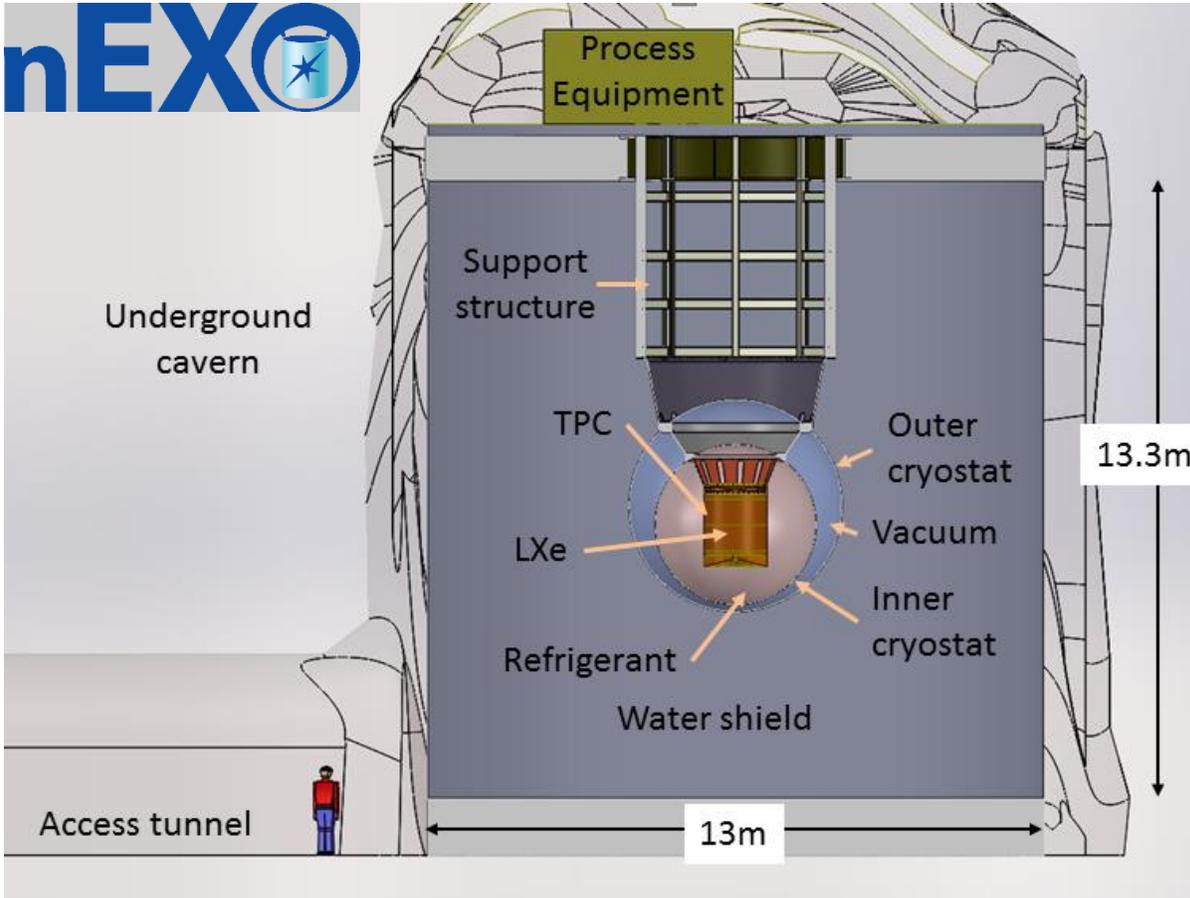
Anticorrelation between scintillation and ionization in LXe known since early EXO R&D

E.Conti et al. Phys Rev B 68 (2003) 054201

Scintillation: 4.80%
Ionization: 2.84%
Rotated: 1.15%

(σ/E resolution)

@2615 keV γ line
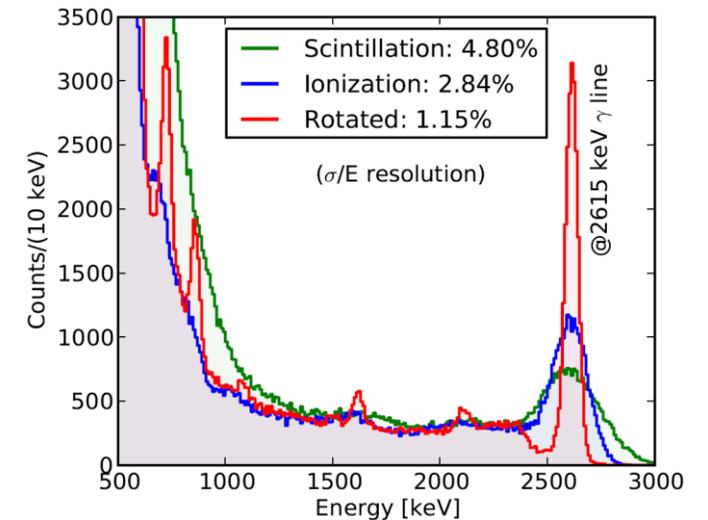
0νββ – From EXO200 to nEXO

Thanks G. Gratta

5 ton LXe enriched in ^{136}Xe

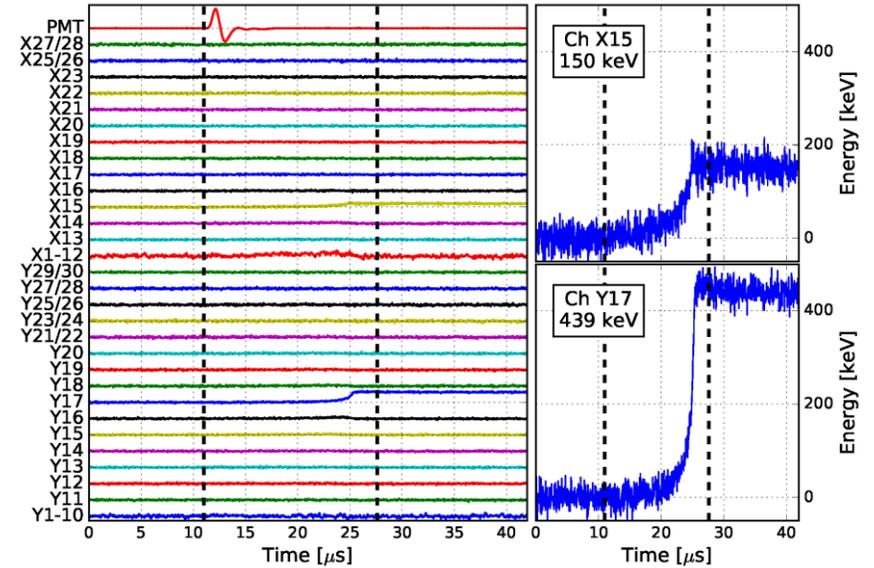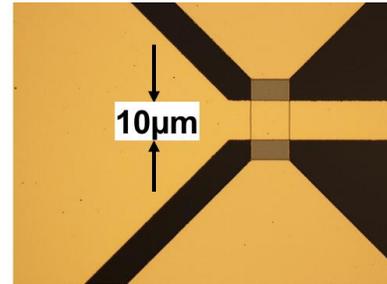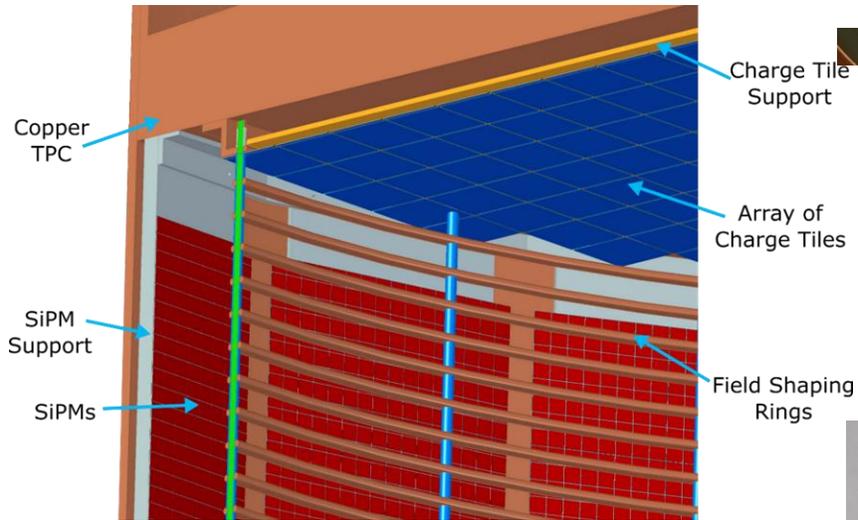| Parameter	nEXO	EXO-200
Fiducial Mass (kg)	4780	98.5
Enrichment (%)	90	80
Data taking time (yr)	5	5
Energy resolution @$Q_{\beta\beta}$ (keV)	58	88 (58)
Background in ROI (ev/yr/mol$_{136}$)	$6.1 \cdot 10^{-4}$	0.022 (0.0073)
Background in ROI inner 3000kg (ev/yr/mol$_{136}$)	$1.6 \cdot 10^{-4}$	-

0νββ – nEXO R&D to finalize detector design

New charge collection tiles

M.Jewell et al., "Characterization of anIonization Readout Tile for nEXO'', J.Inst. 13 P01006 (2018)
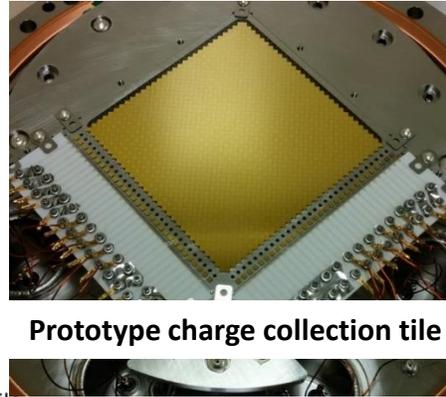
Prototype charge collection tile

Copper TPC

Charge Tile Support

Array of Charge Tiles
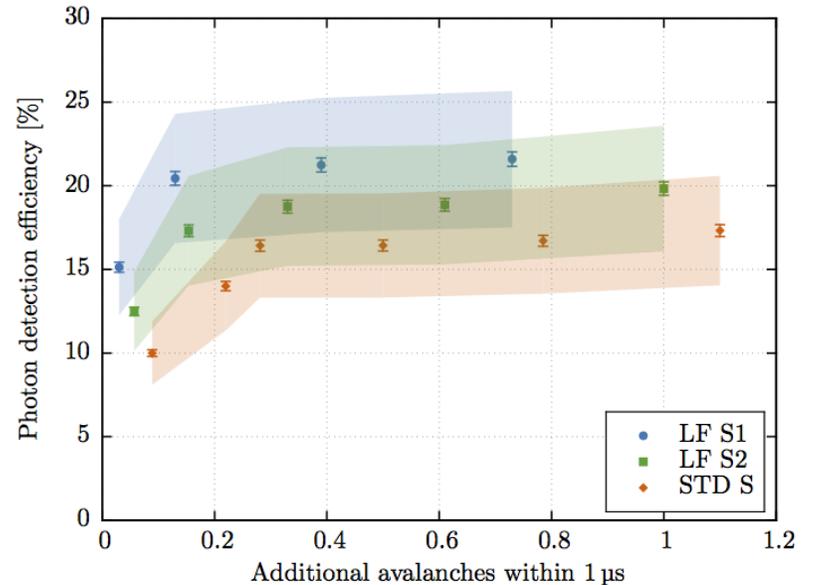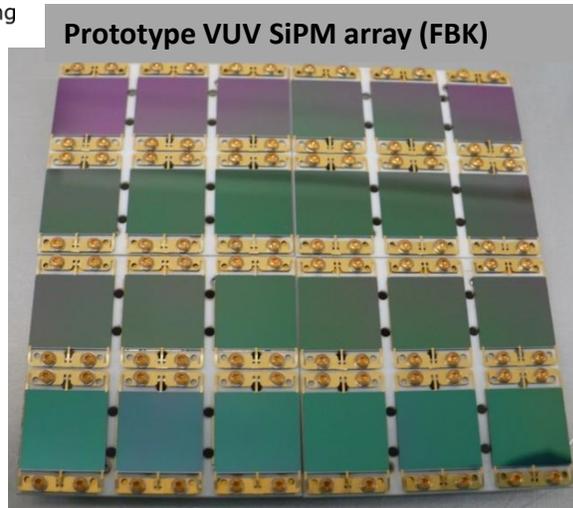
SiPM Support

SiPMs

Field Shaping Rings

10μm

Prototype VUV SiPM array (FBK)

New SiPM

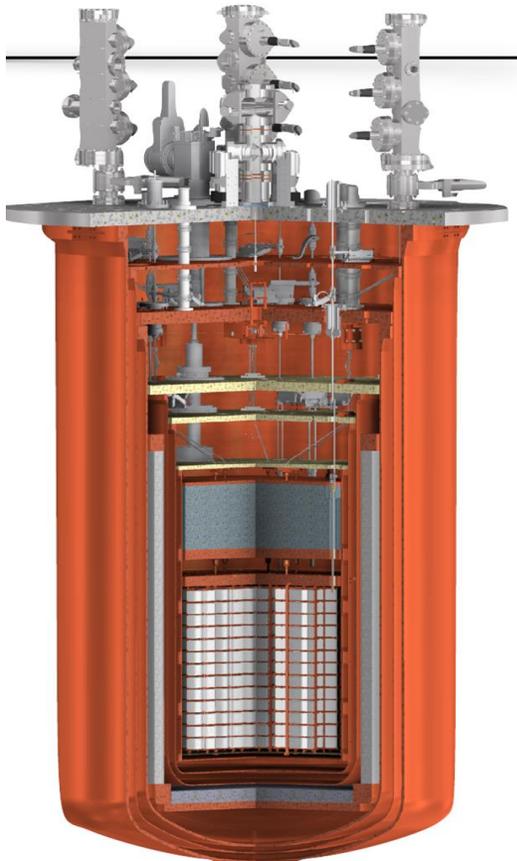"VUV-sensitive Silicon Photomultipliers for Xenon Scintillation Light Detection in nEXO" IEEE Trans NS 65 (2018) 2823

Thanks G. Gratta

0νββ – CUPID: CUORE Upgrade with Particle IDentification

- CUORE cryostat: **most powerful cryostat** ever realized

- **Tens of ton of materials** cooled at 10 mK

- Cryogenic detectors are **reliable**

CUORE alpha background
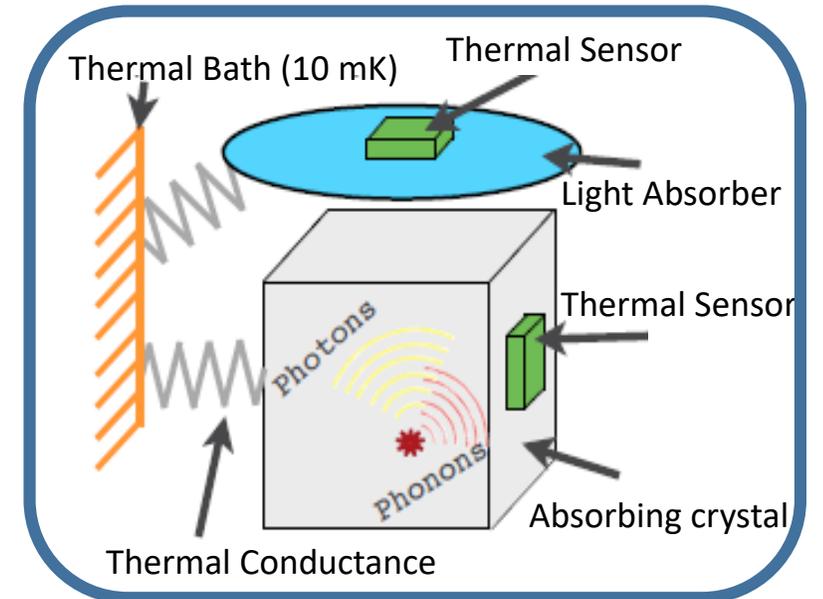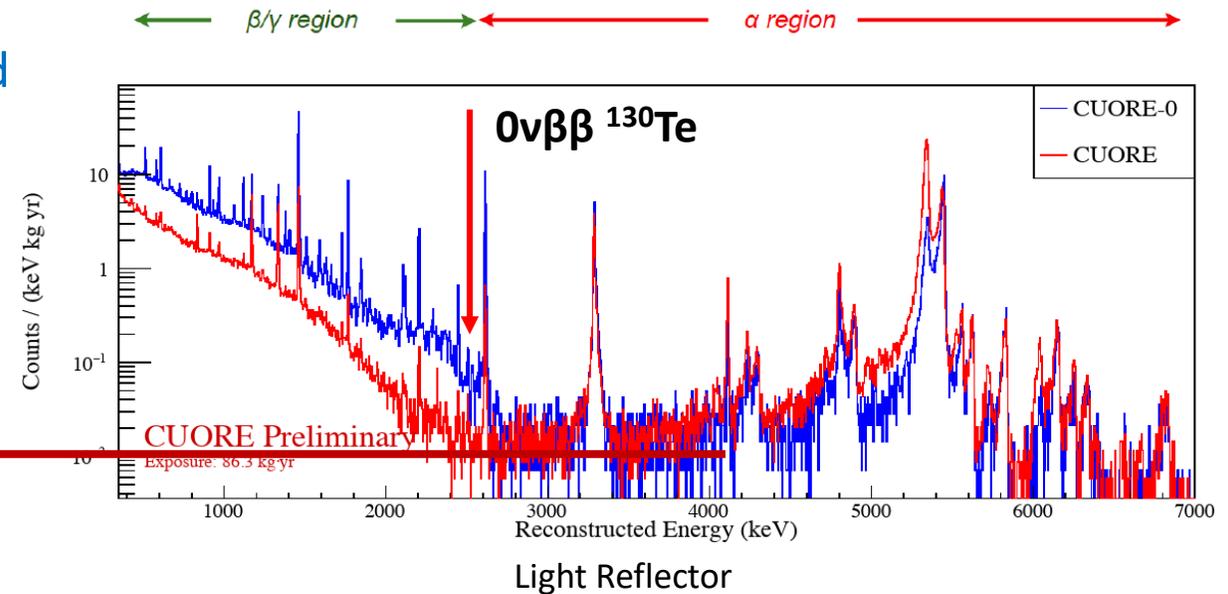**BI ~ 10⁻² counts/(keV kg years)**

CUPID - scintillating bolometers detector

Simultaneous read-out of **Photons and Phonons**

High energy resolution: **as bolometer**
High discrimination capability: **as scintillator**

Talks A. Branca, L. Pattavina

Ezio Previtali

0νββ – CUPID scintillating bolometer background rejection

- Scintillating crystals and light detectors operated @ 10 mK
- Grown from **various ββ emitters** (**multi-isotope approach**)
- **Excellent energy resolution** @$Q_{\beta\beta}$ (<1%)
- Possibility to high $Q_{\beta\beta}$ (3 MeV) for ^{82}Se and ^{100}Mo
- **$LY_\alpha \neq LY_{\beta/\gamma}$ → Particle ID**
- **$LShape_\alpha \neq LShape_{\beta/\gamma}$ → Particle ID**
- **$HShape_\alpha \neq HShape_{\beta/\gamma}$ → Particle ID**
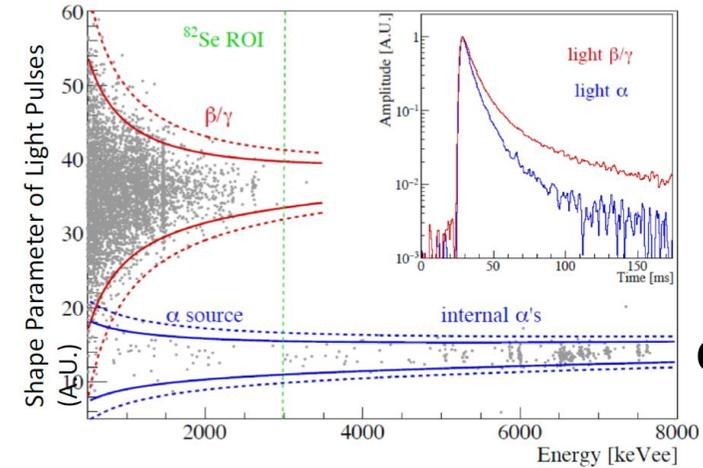
CUPID-0 Data
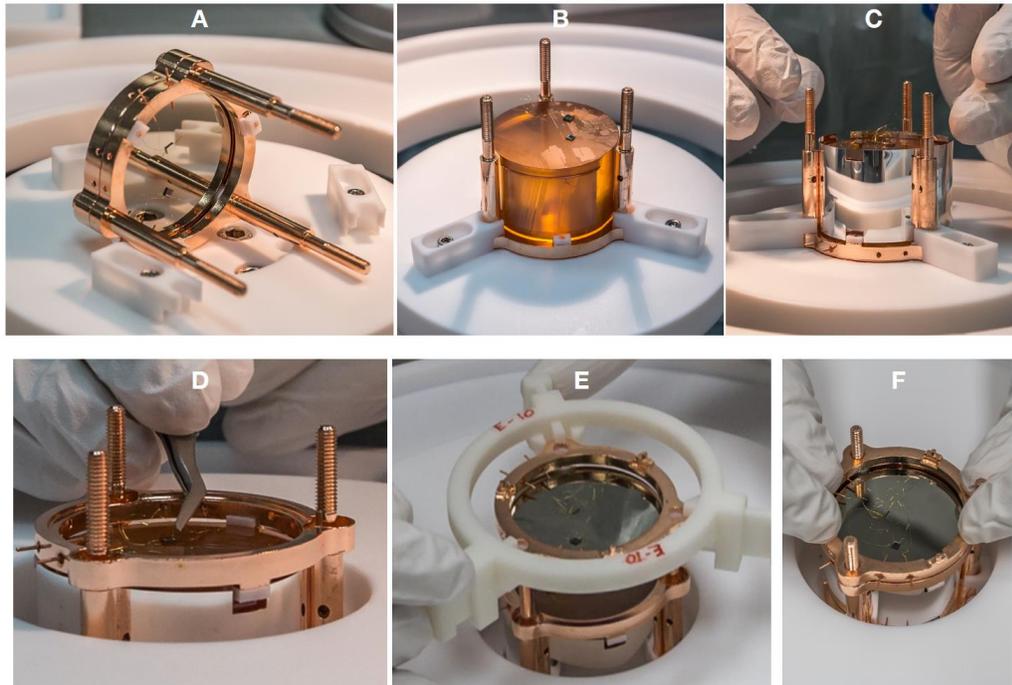
Particle identification using Pulse Shape Parameters (decay time)

Calibration Light VS Heat scatter plot of a ZnSe crystal
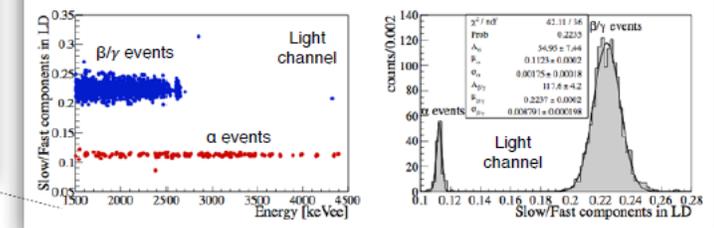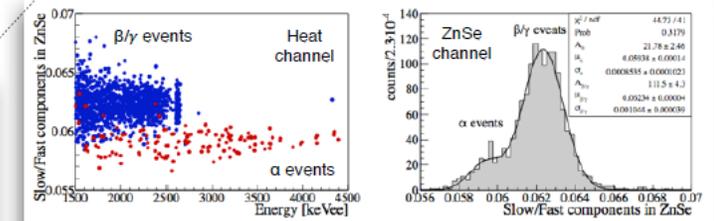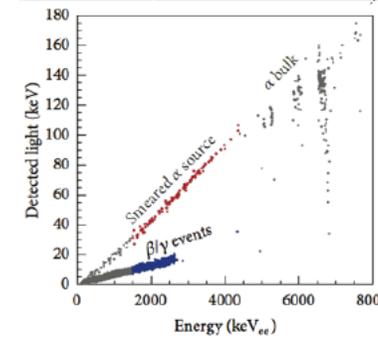
Discrimination potential @ ROI:

$$DP(E) = \frac{|\mu_\alpha(E) - \mu_{\beta\gamma}(E)|}{\sqrt{\sigma_\alpha^2(E) + \sigma_{\beta\gamma}^2(E)}}$$

Heat channel
DP@ROI = 2

Light channel
DP@ROI = 11

**Full rejection of α events
shapeHEAT+shapeLIGHT+light**

Talk L. Pattavina

EPS-HEP2019 - 10-17 July 2019, Ghent, Belgium

Ezio Previtali

0νββ – CUPID Conceptual Design

- Re-use *CUORE cryogenic infrastructure* at LNGS

- $Li_2{}^{100}MoO_4$ scintillating crystals

- ~1500 crystals for *250 kg of ^{100}Mo*

- Active background rejection using light and heat signals

- Options for *multiple isotopes*.

- TDR and *construction readiness in 2021*

Expected BI ~ 1 x 10^{-4} cts / (keV kg year)

CUPID CDR available soon
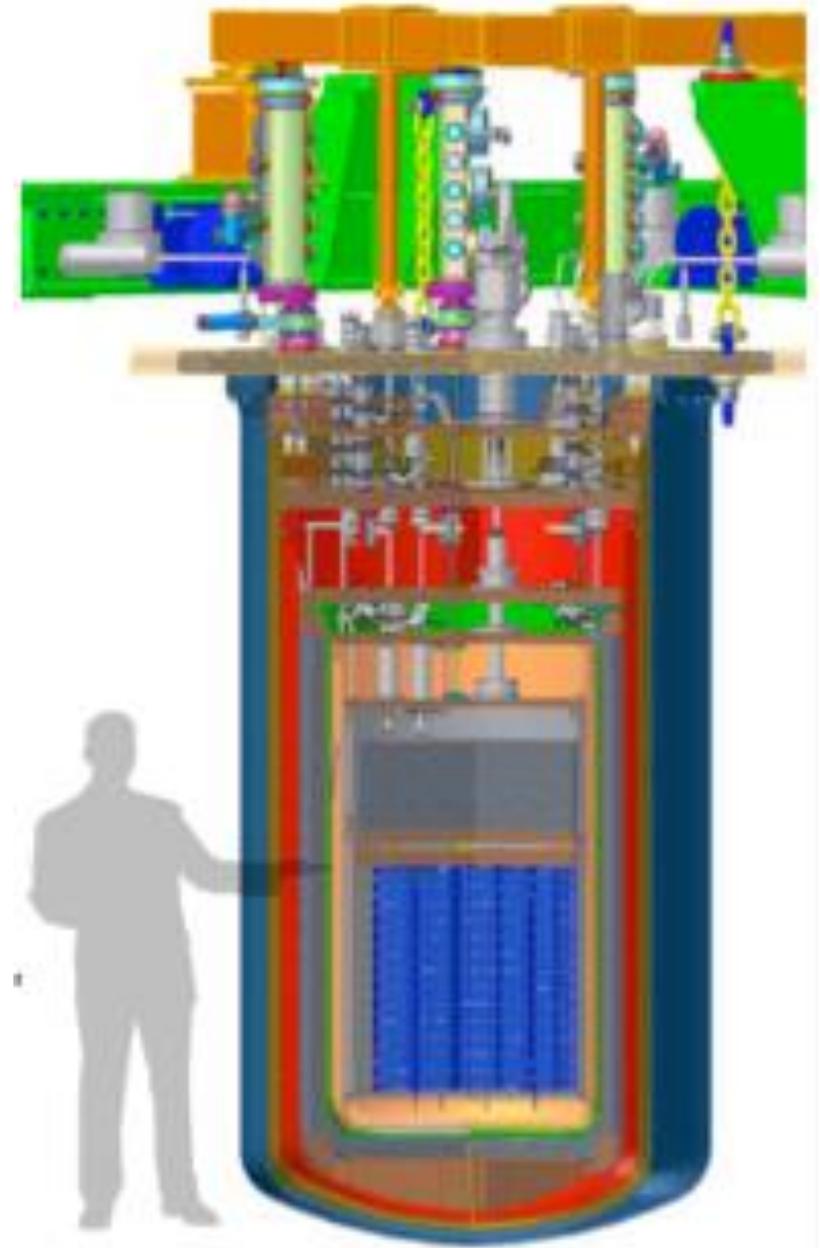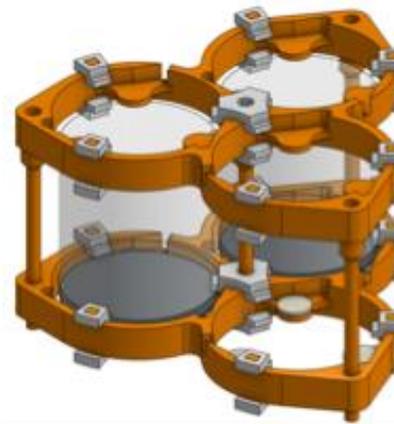
Talk L. Pattavina

0νββ – CUPID-CROSS surface background rejection

Numerous above-ground tests (CSNSM, Orsay) with **20x20x10 mm Li$_2$MoO$_4$** and **TeO$_2$ crystals** and recently with a **large (75 g) Li$_2$MoO$_4$ crystal**
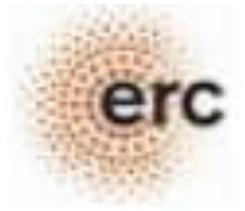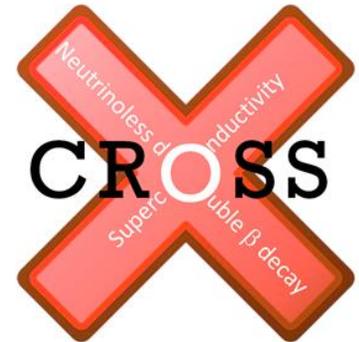
10-μm-thick Al film

75 g Li$_2$MoO$_4$ crystal

DP= 8.7

Bulk

Surface

U alpha source irradiating the film
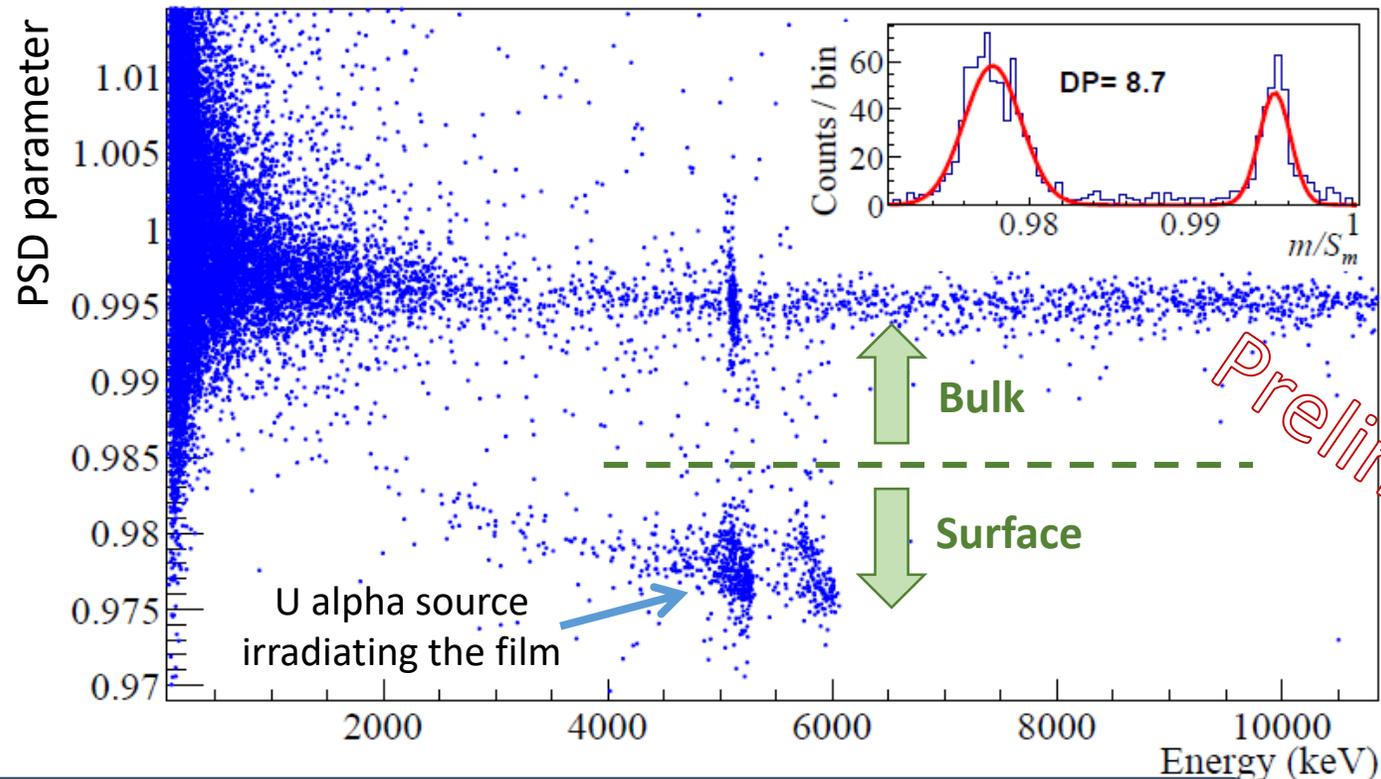
Preliminary

Alphas impacting on the film side are clearly discriminated
Next test: **fully coated crystal**

Thanks A. Giuliani

Direct neutrino mass measurement with ^{3}H

$$\beta: dN/dE = K\ F(E,Z)\ \underbrace{p}_{p_e}\ \underbrace{E_{tot}}_{E_e}\ \underbrace{(E_0-E_e)}_{E_\nu}\ \underbrace{\sum |U_{ei}|^2 \sqrt{(E_0-E_e)^2 - m(\nu_i)^2}}_{p_\nu}$$

essentially phase space:

very tiny signature !

$m_\nu = 0$ eV

$m_\nu = 1$ eV

$E_\nu\ p_\nu \rightarrow$

2×10^{-13}
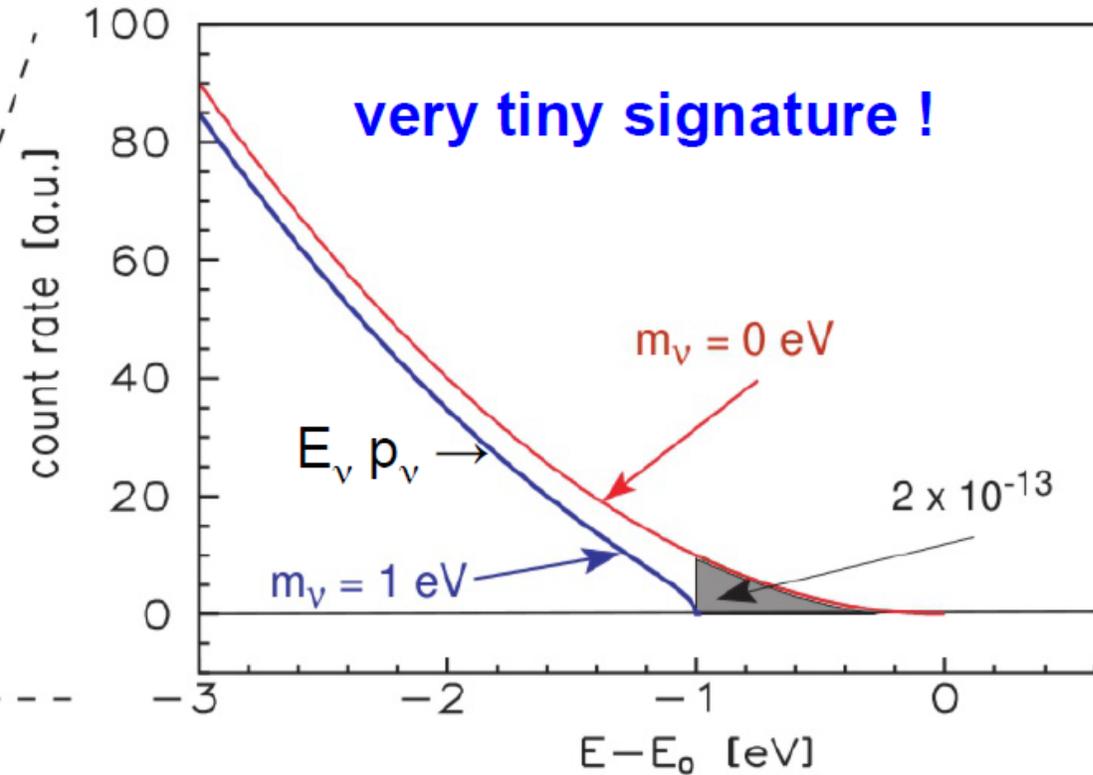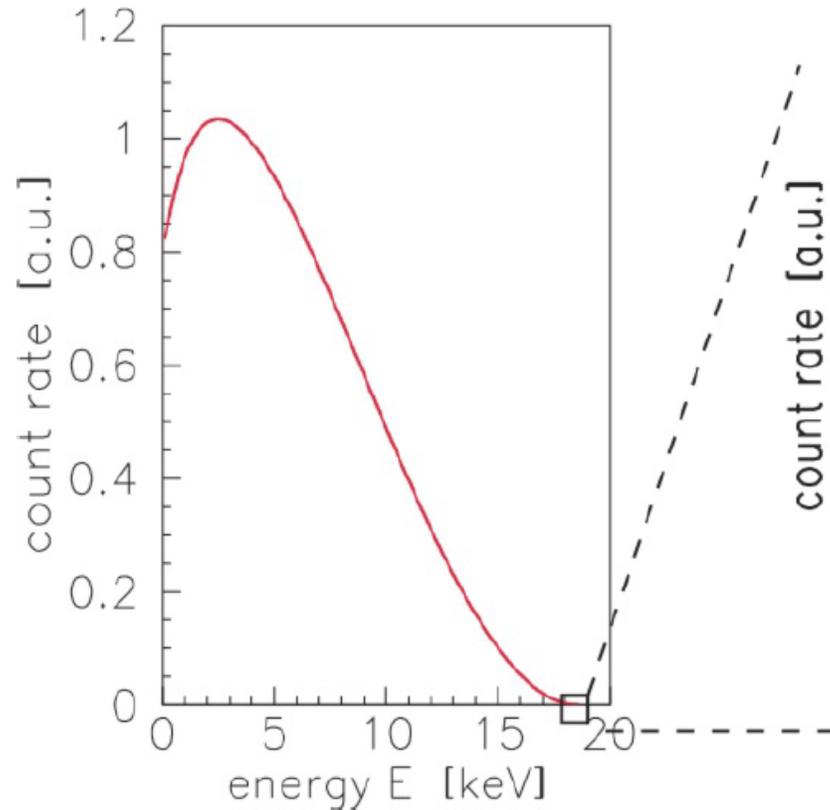
Talk S. Pascoli

KATRIN - Direct neutrino mass measurement
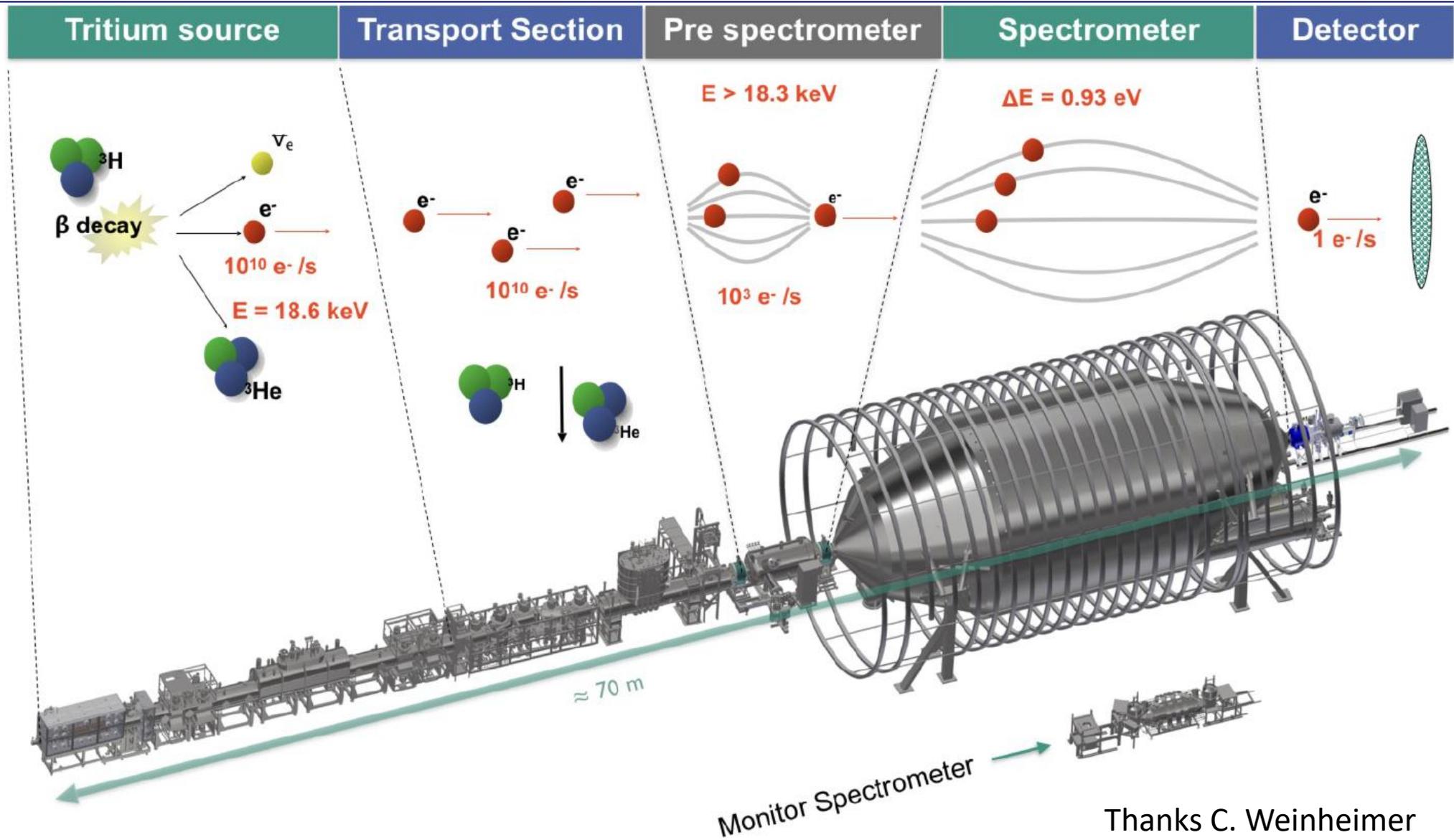
Thanks C. Weinheimer

KATRIN – Many technological challenges

10 kg/a tritium throughput	→ huge circulation and purification system, special TMPs
10^{-3} stability of tritium source column density	→ temp. regulation by dual phase Ne
10^{-3} isotope content in source	→ laser Raman spectroscopy
10^{-5} non-adiabaticity in electron transport	→ novel computational code KASSEIPEIA, pulsed angular-defined electron gun
10^{-6} monitoring of HV-fluctuations	→ ultra-precision HV divider, novel e^- source
10^{-8} remaining ions after source	→ dipole drift electrodes, FT-ICR
10^{-14} remaining flux of molecular tritium	→ 3K cryopumping section with Ar snow
10^7 dynamic rate range	→ electronics and DAQ
10^{-2} background rate envisaged	→ huge cold-baffles to catch radon
10^{-11} mbar ultrahigh vacuum	→ huge getter pumps and TMPs

KATRIN, the film: http://www.youtube.com/watch?v=cnu79iC0C1M

Thanks C. Weinheimer

EPS-HEP2019 - 10-17 July 2019, Ghent, Belgium

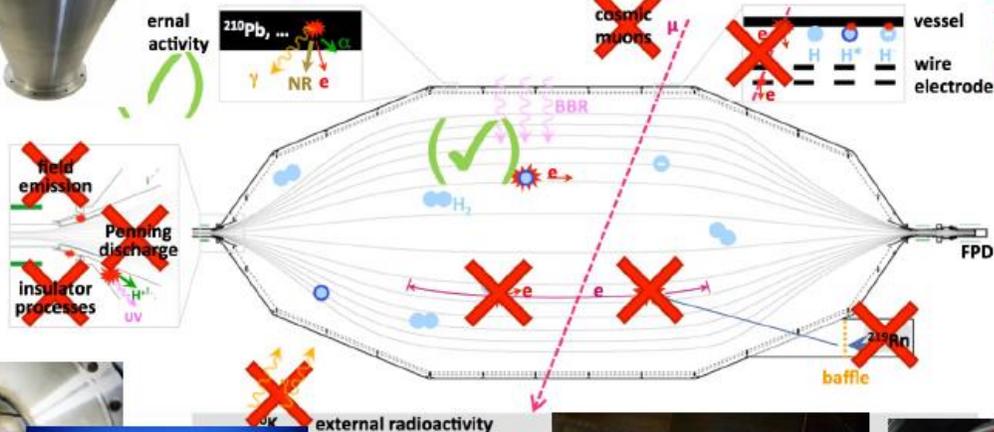*Ezio Previtali*

KATRIN – Background from the spectrometers

Penning trap at specrometer entrance/exit
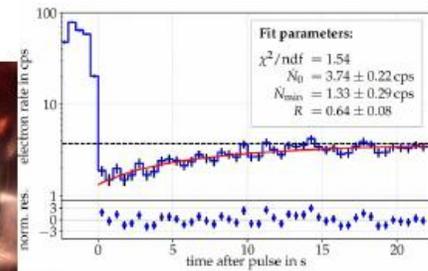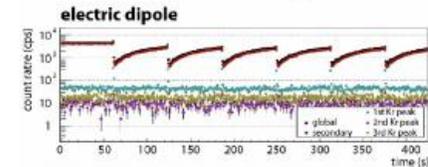Mitigation: „Colani-shaped" electrodes

Secondary electrons from walls
Mitigation: air coils
& wire electrodes

Rydberg atoms due to ^{212}Pb in wall
Mitigation: still working ...

Stored electrons in specs
Mitigation: electric dipole
& magnetic pulses

Intrinsic Penning trap between specs
Mitigation: 10^{-11} mbar backed up by „wiper"

Radon emanating from NEG pumps:
Mitigation: LN2-cooled baffles

Thanks C. Weinheimer

M. Beck et al., EPJ A44 (2010) 499
F. M. Fränkle et al., APP 35 (2011) 128
S. Mertens et al., APP 41 (2013) 52
N. Wandkowsky et al., J. Phys. G40 (2013) 085102
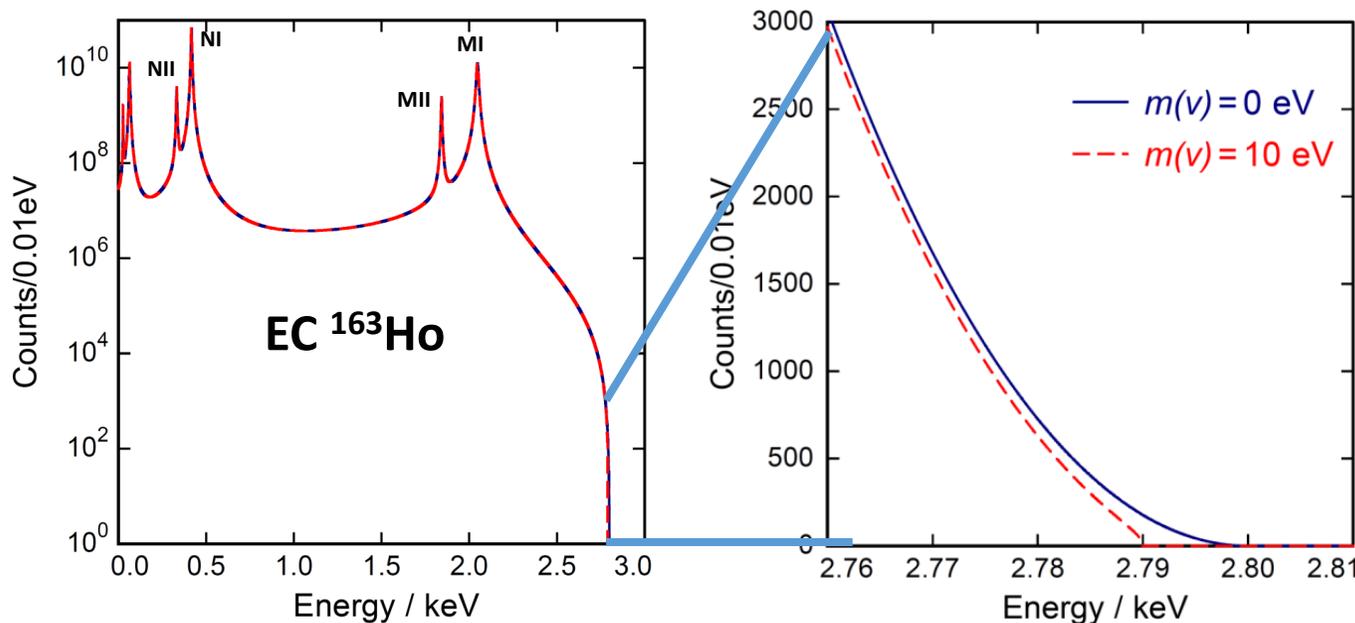F.M. Fränkle et al., JINST 9 (2014) P07028

G. Drexlin et al., Vacuum 138 (2017) 165
F.M. Fränkle and KATRIN Coll., J. Phys. Conf. S. 888 (2017) 012070
M. Arenz et al., arXiv:1805.01163
M. Arenz et al., arXiv:1805.12173

Criogenic detector for direct neutrino mass measurement

$$\frac{dW}{dE_C} = A(Q_{EC} - E_C)^2 \sqrt{1 - \frac{m_\nu^2}{(Q_{EC} - E_C)^2}} \sum_H B_H \varphi_H^2(0) \frac{\frac{\Gamma_H}{2\pi}}{(E_C - E_H)^2 + \frac{\Gamma_H^2}{4}}$$

Statistics in the end point region
- $N_{ev} > 10^{14}$ → **A ≈ 1 MBq**

Unresolved pile-up ($f_{pu} \sim a \cdot \tau_r$)
- $f_{pu} < 10^{-5}$
- $\tau_r < 1$ μs → $a \sim 10$ Bq
- 10^5 pixels

Precision characterization of the endpoint region
- $\Delta E_{FWHM} < 3$ eV

Background level
- **< 10^{-5} events/eV/det/day**

A. De Rujula and M. Lusignoli, *Phys. Lett.* **118B** (1982)

Thanks L. Gastaldo

Criogenic detector high energy resolution technologies

Low temperature microcalorimeters

H LMES

^{163}Ho

C_{tot}

G

Thermal bath

$$\Delta T \cong \frac{E}{C_{tot}}$$

T

ΔT

$\tau = \dfrac{C_{tot}}{G}$

t

Resistance at superconducting transition,TES

R

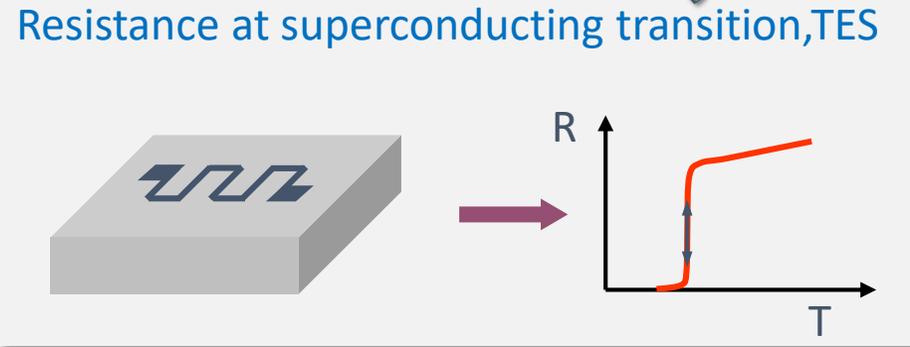T

K.D. Irwin and G.C. Hilton, Topics in Applied Physics 99 (2005) 63

ECHo

- Very small volume

- Working temperature below 100 mK

  small specific heat

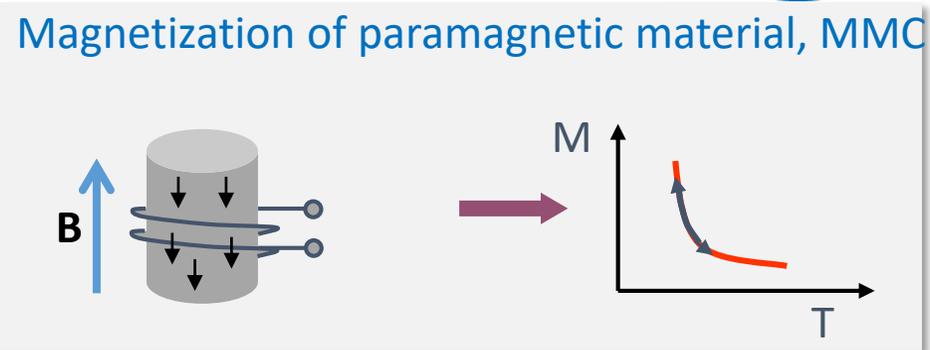 small thermal noise
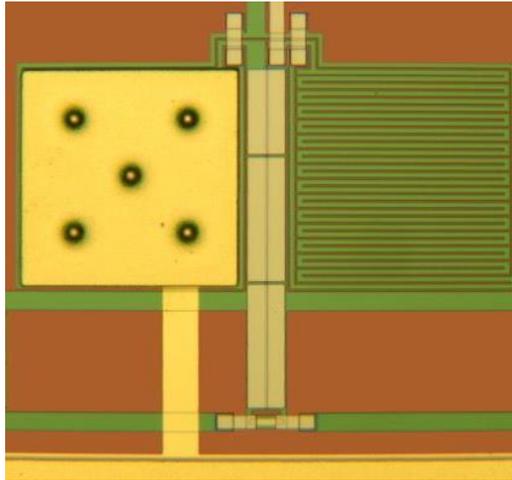
- **Very sensitive temperature sensor**

Magnetization of paramagnetic material, MMC

M

B

T

A.Fleischmann, C. Enss and G. M. Seidel,
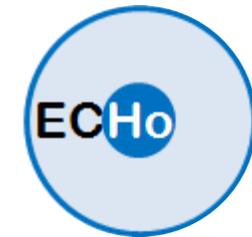Topics in Applied Physics 99 (2005) 63

Thanks L. Gastaldo
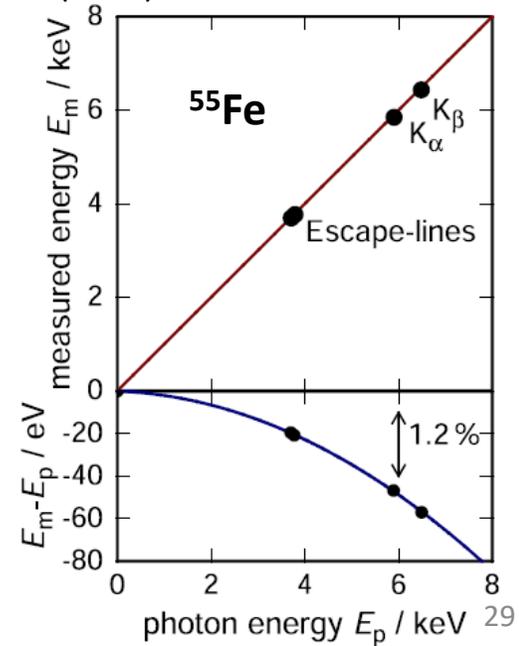
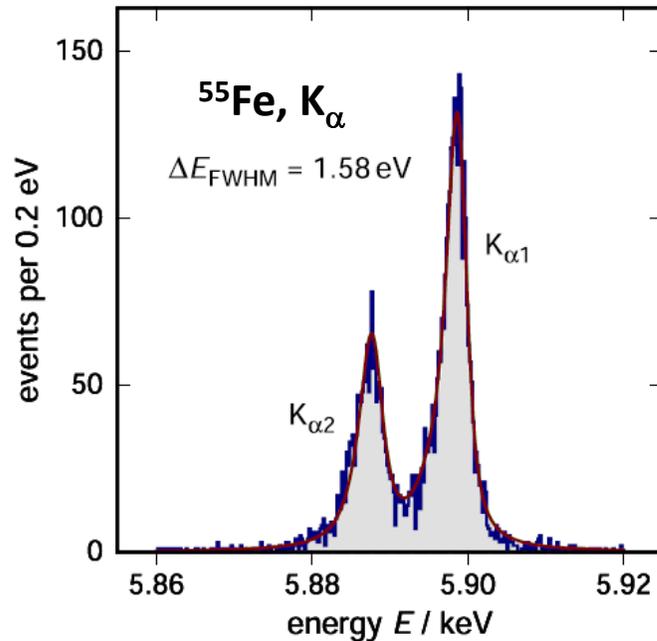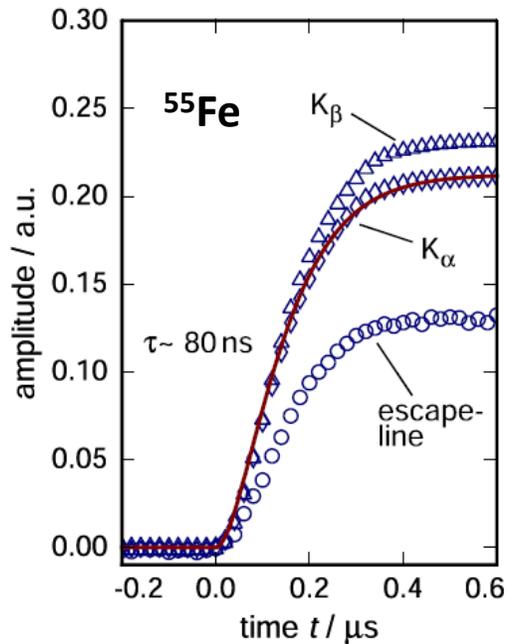# Criogenic detector performances

Fast risetime → Reduction un-resolved pile-up

Extremely good energy resolution → Reduced smearing in end point region
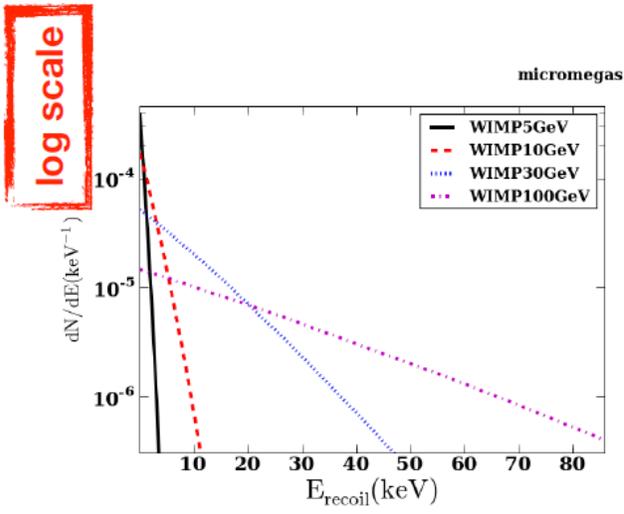
Excellent linearity → precise definition of the energy scale

A. Fleischmann et al., *AIP Conf. Proc.* **1185** (2009) 571

L. Gastaldo et al., Nucl. *Inst. Meth. A*, **711** (2013) 150

Thanks L. Gastaldo

DM – CRESST: scintillating bolometers for dark matter search

TES – Transition Edge Sensor

CaWO$_4$ iSticks
(with holding clamps & TES)

reflective and
scintillating housing

light detector (with TES)

block-shaped target crystal
(with TES)

log scale
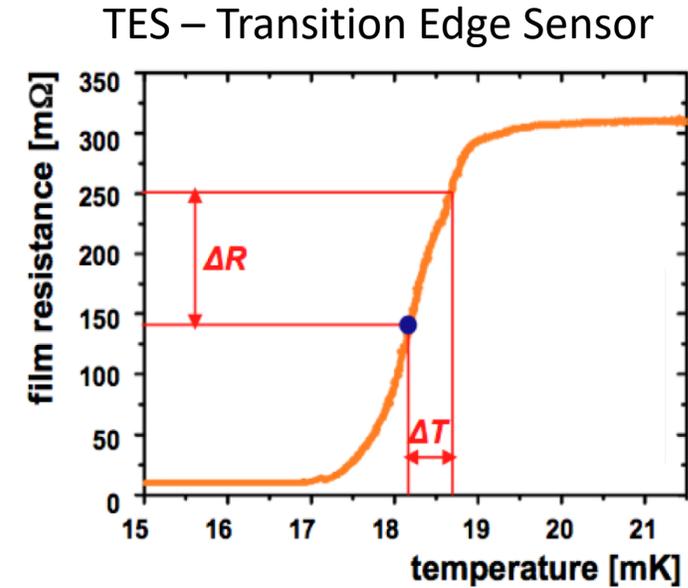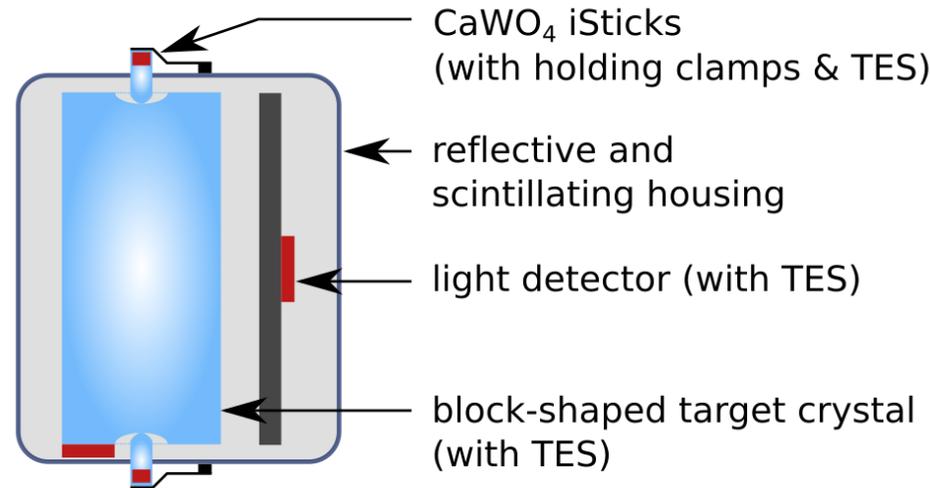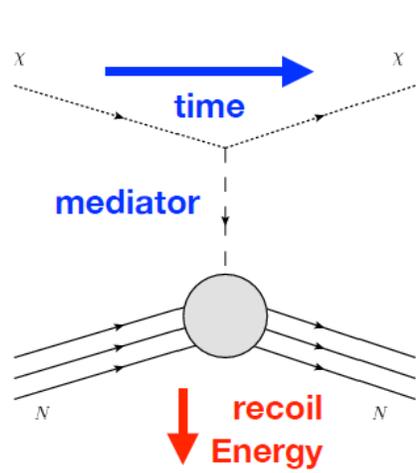
WIMP - ^{78}Ge nucleon scattering
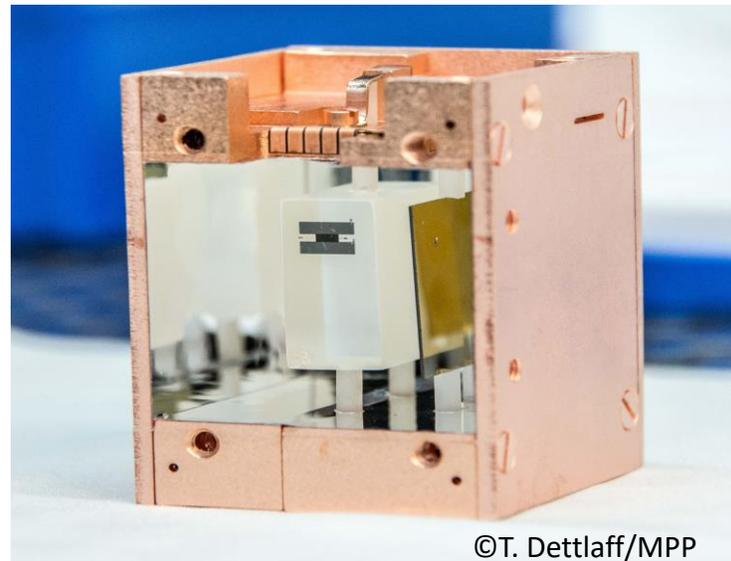
©T. Dettlaff/MPP

Talk J. Schieck
Thanks F. Petricca

Ezio Previtali

DM – CRESST: very low threshold scintillating bolometer

Eff. ≃ 65%

filter effect

arxiv:1904.00498

triggered events

selected events
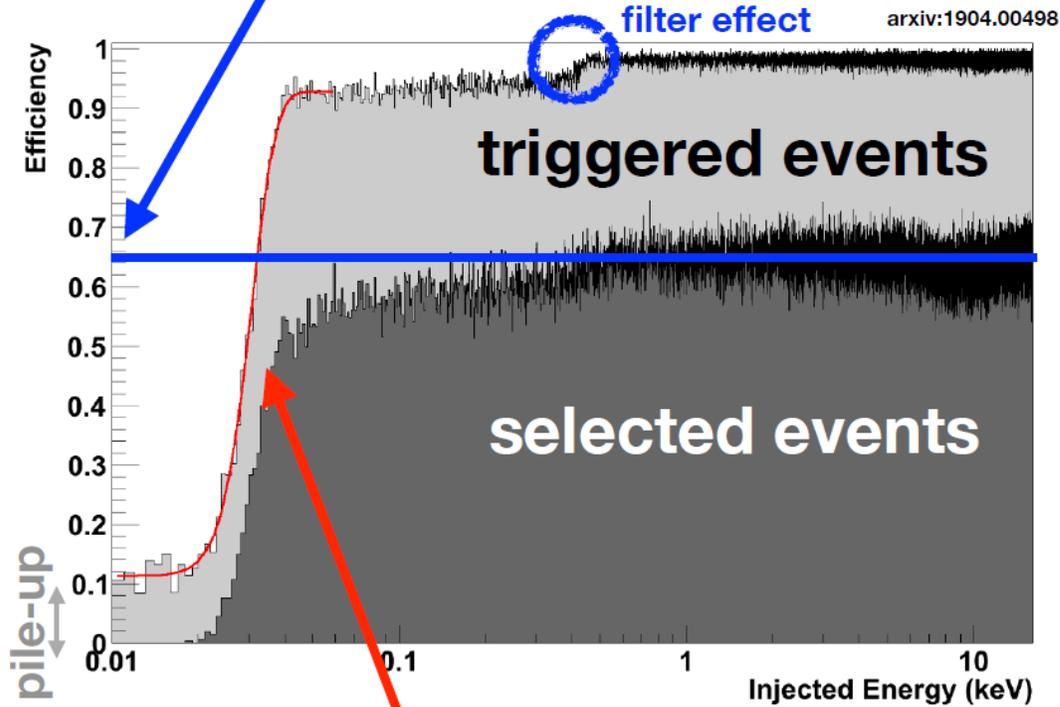
threshold E_{th} = 30.1 eV
(cross-check by fitting
error function)

pile-up

Detector layout optimized for low-mass dark matter
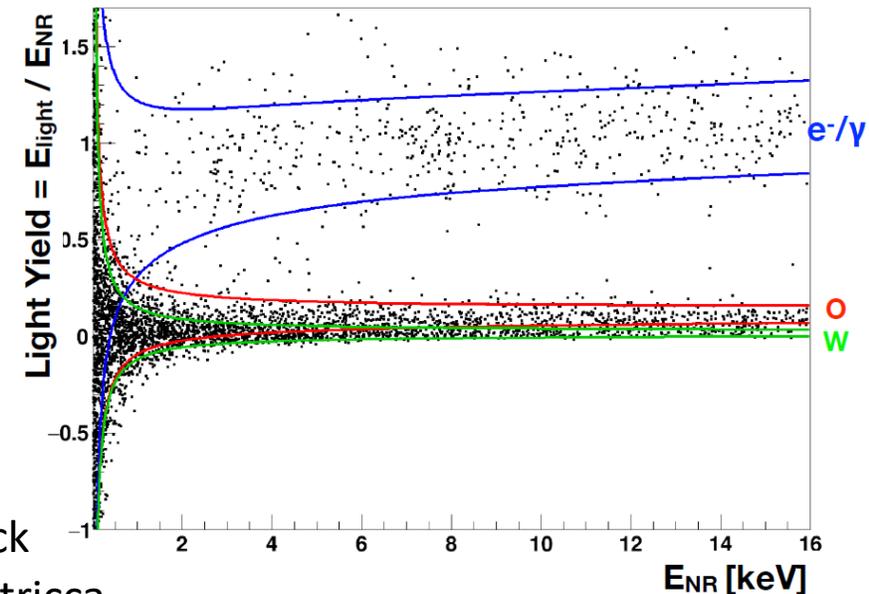**Radical reduction of dimension (300→25g)**
- Cuboid crystals of $(20 \times 20 \times 10)mm^3$ (**≈24g**)
- With self grown crystals **≈4 counts/(keV kg day)**
- Threshold design goal **<100 eV (best achieved 30 eV)**
- Fully scintillating housing
- Instrumented sticks

arxiv:1904.00498

β/γ-band

O-recoils

W-recoils

signal region

Talk J. Schieck

Ezio Previtali
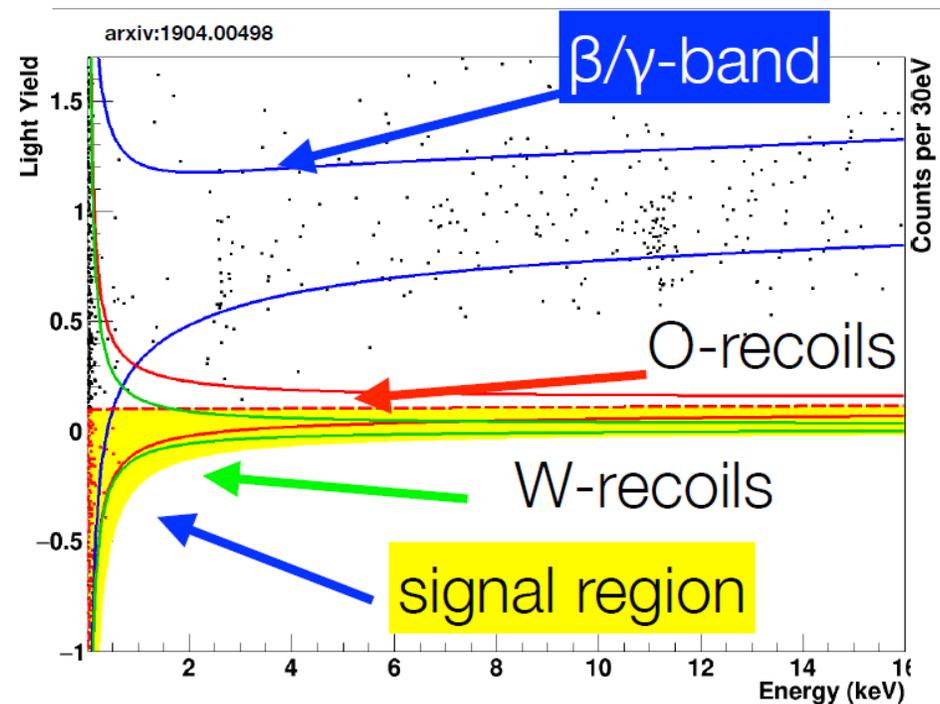
DM – XENON, dual phases LXe TPC
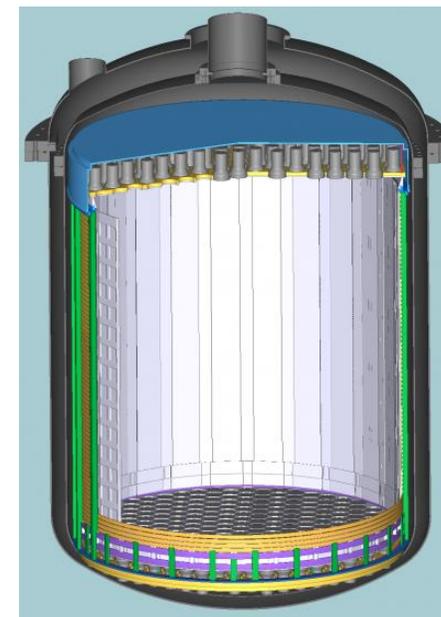
XENON10	XENON100	XENON1T	XENONnT
2005 - 2007	2008 - 2016	2012 - 2018	2019 - 2023
25 kg – 15 cm drift	161 kg – 30 cm drift	3.2 t – 1 m drift	8 t – 1.5 m drift
$\sim 10^{-43}$ cm²	$\sim 10^{-45}$ cm²	$\sim 10^{-47}$ cm²	$\sim 10^{-48}$ cm²

Talk A. Brown

Thanks C. Weinheimer

DM – XENON, dual phases LXe TPC

GXe

LXe

S2

S1

$E_{extraction}$

E_{drift}

e⁻ e⁻
e⁻ e⁻

particle

time
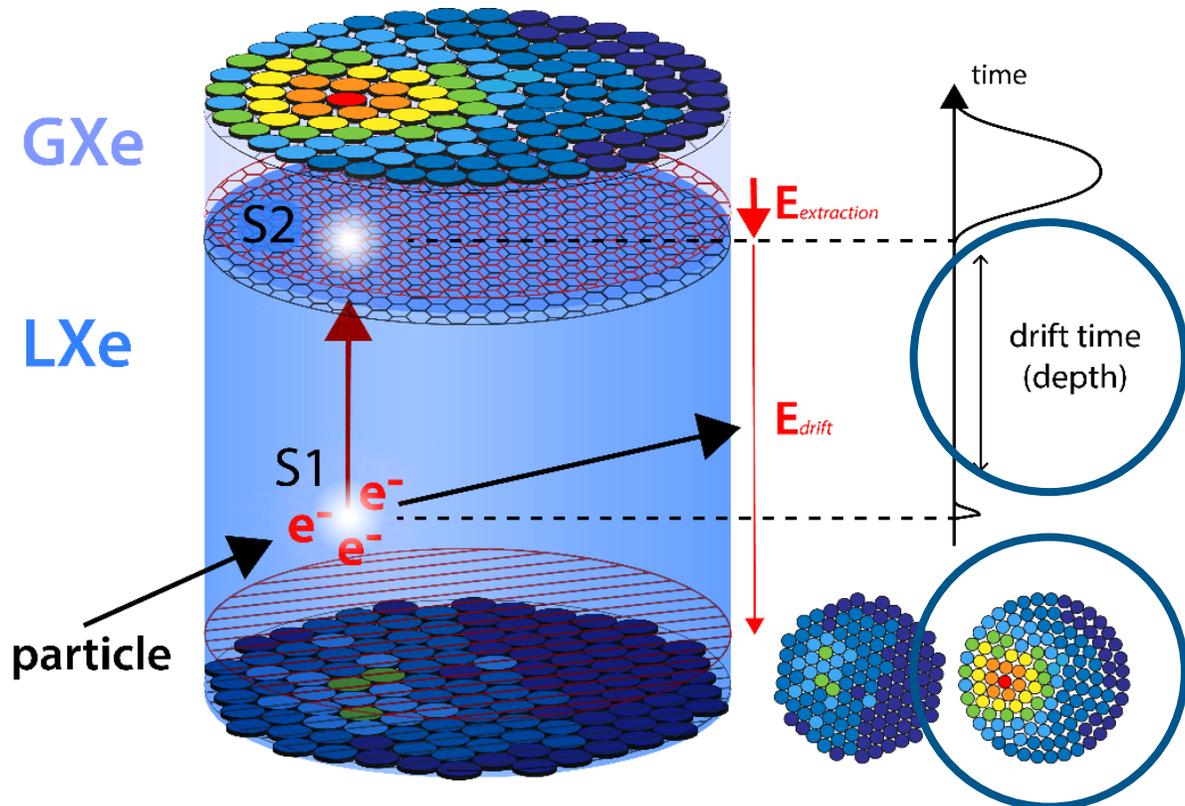
drift time
(depth)

Drift time:
$$\Delta t = t_{S2} - t_{S1}$$

Drift velocity:
$$v \approx 2 \; {}^{mm}/_{\mu s} \approx 7200 \; {}^{km}/_{h}$$

Depth (z - position):
$$z = v \cdot \Delta t$$

+

Concentric PMT array on top
→ S2 signal local
→ **x - and y - position**

=

→ **3D position reconstruction**
→ **Self - shielding**
→ **Inner + radio-pure volume**

Thanks C. Weinheimer
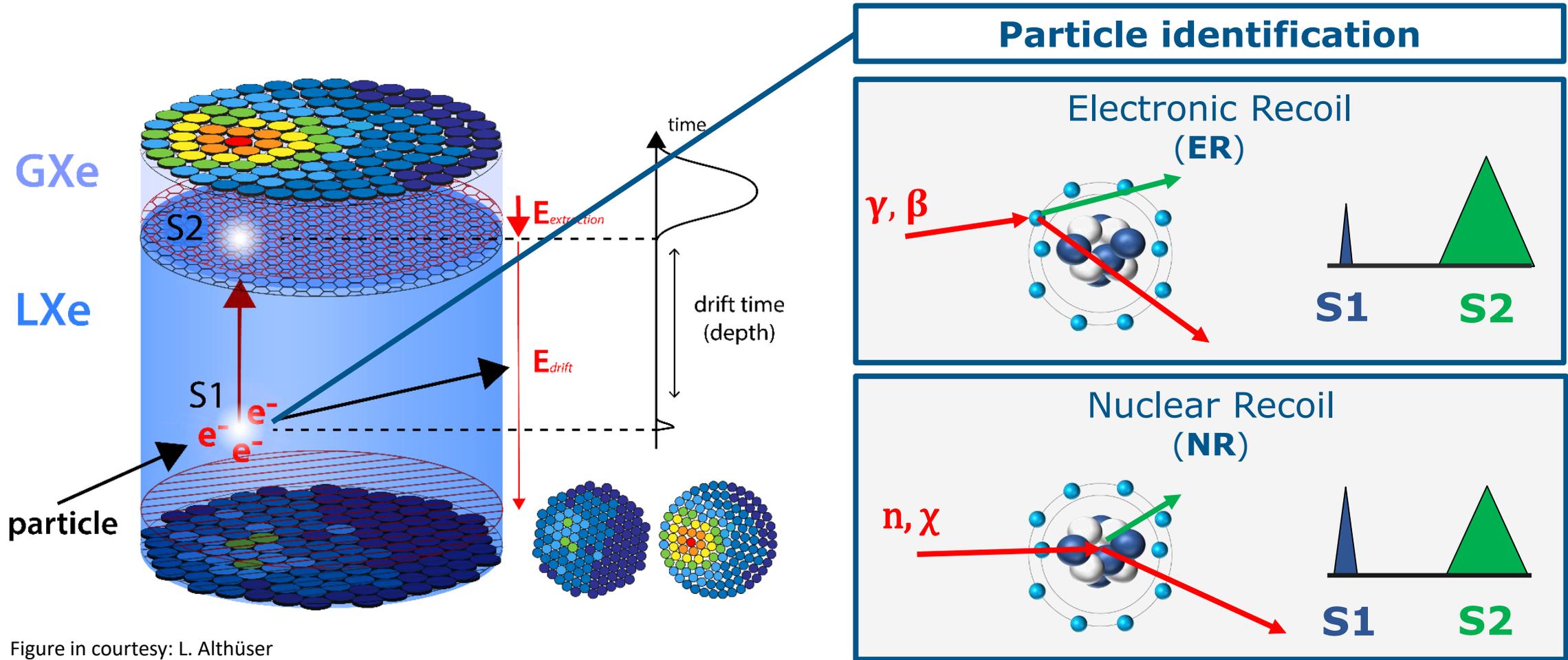
DM – XENON, dual phases LXe TPC

GXe

LXe

S2

$E_{extraction}$

S1

e^-
e^- e^-

E_{drift}

particle

time

drift time
(depth)

Figure in courtesy: L. Althüser

Particle identification

Electronic Recoil (**ER**)

γ, β

S1   S2

Nuclear Recoil (**NR**)

n, χ

S1   S2

Thanks C. Weinheimer

DM – XENON, dual phases LXe TPC

GXe

LXe

S2

S1

e⁻ e⁻ e⁻

$E_{extraction}$

E_{drift}

time

drift time (depth)

particle

Figure in courtesy: L. Althüser

Particle identification

Electronic Recoils

Nuclear Recoils

Charge

Corrected S2 [PE]

Corrected S1 [PE]

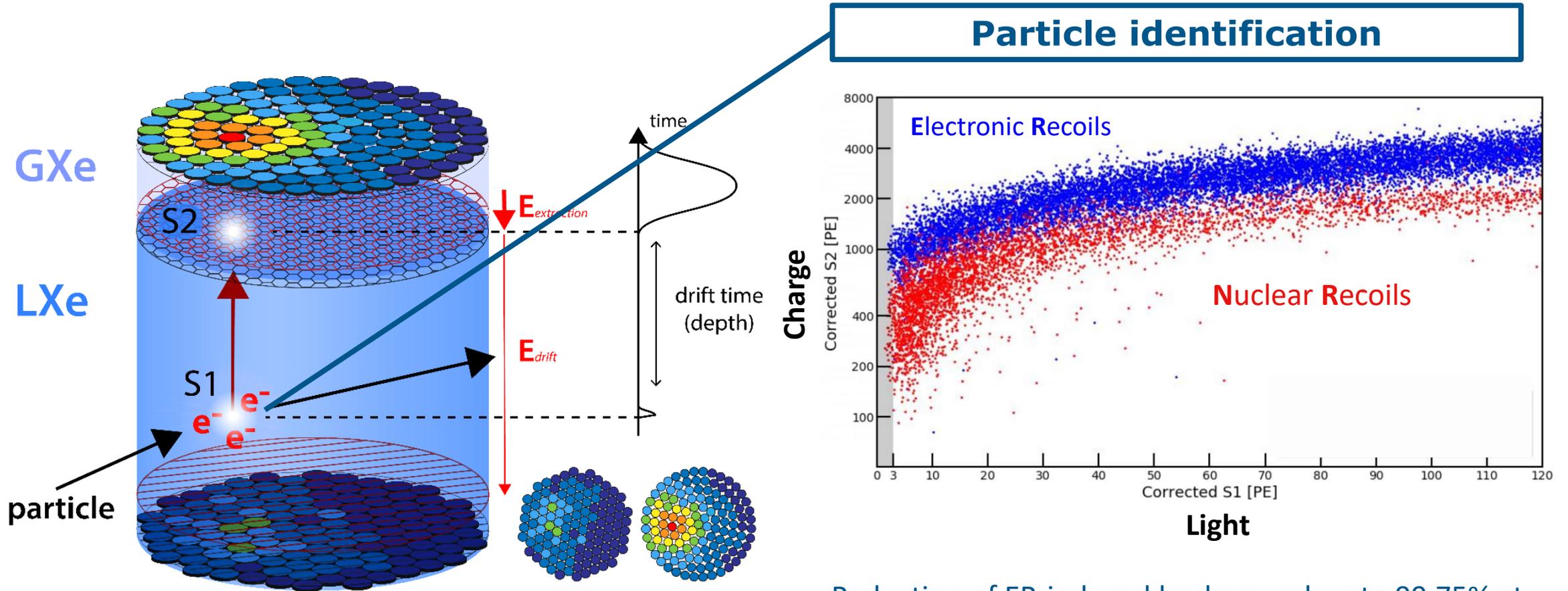Light

Reduction of ER-induced background up to 99.75% at 50% NR acceptance

Thanks C. Weinheimer

DM – Online krypton removal for XENON1T

Event Rate in TPC (ER): Data give direct „online" insight to innermost 700 kg of LXe

Eur. Phys. J. C (2014) 74:2746

Rare Gas Mass Spectrometer (RGMS): Samples extracted from LXe for off-site analysis at MPIK Heidelberg

First RGMS point scaled to ER rate
→ Direct comparison at all times possible
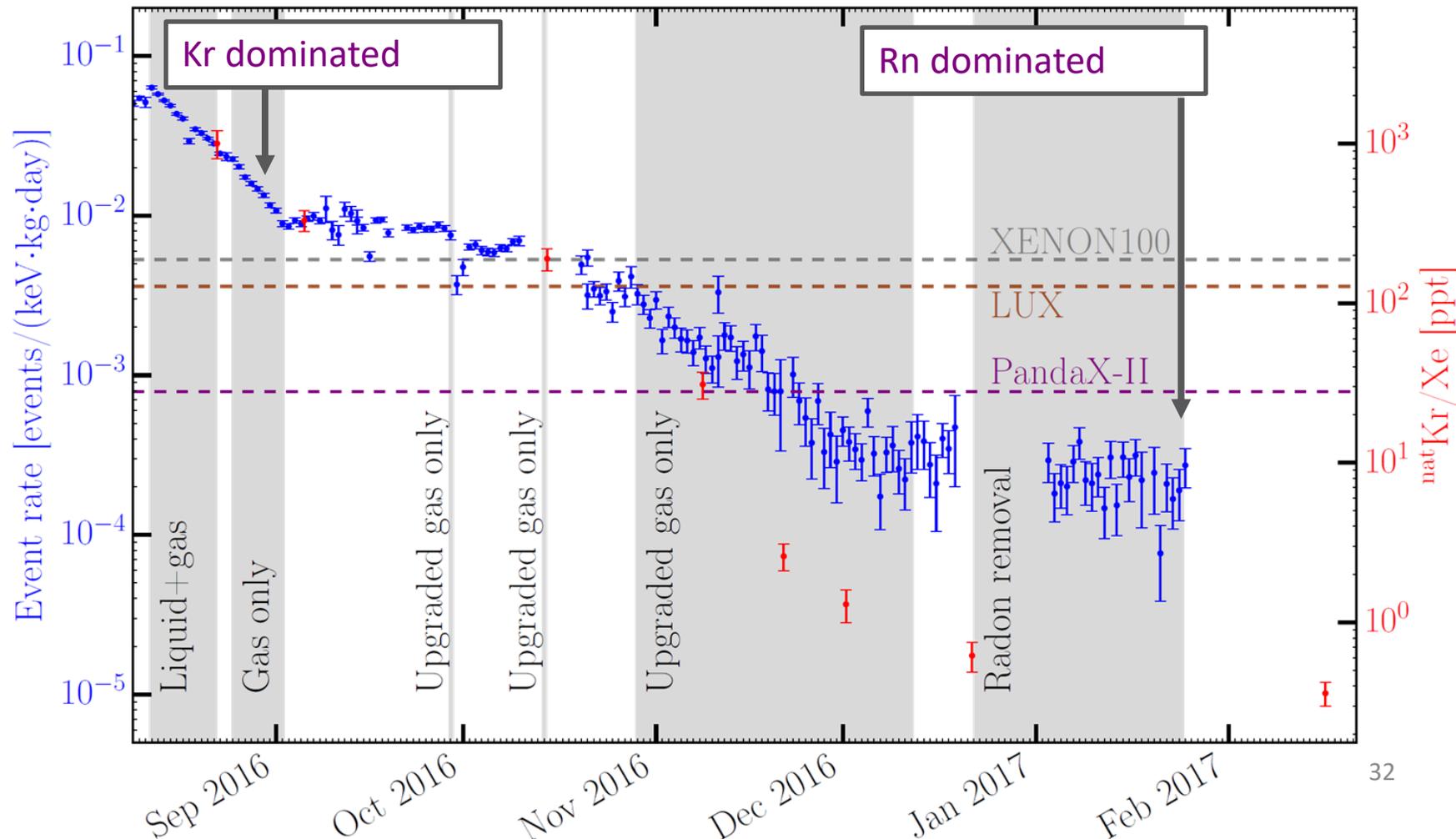→ Allows for absolute calibration of ER

At the beginning:
Krypton dominated

At the end:
Radon dominated

→ Reached sufficient krypton concentration for first science run
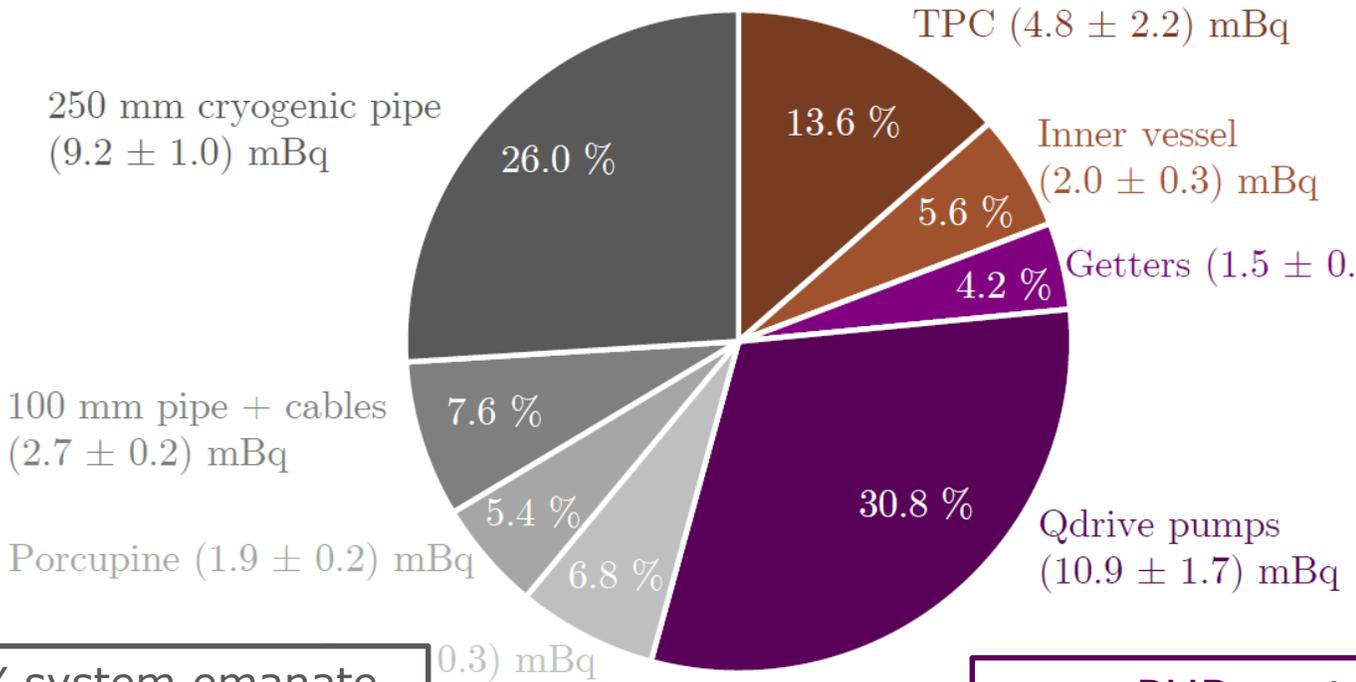→ **Lowest background so far**

^{nat}Kr/Xe = (360 ± 60)ppq

M. Murra, PhD thesis, 2019

Ezio Previtali

DM – XENONnT Radon mitigation

TPC + Cryostat emanate 19% of total budget
→ **Reduce with a new Radon Distillation System**
→ **Expect less radon due to lower surface to volume ratio by factor $3^{(1/3)} \sim 1.4$**

250 mm cryogenic pipe (9.2 ± 1.0) mBq — 26.0 %

TPC (4.8 ± 2.2) mBq — 13.6 %

Inner vessel (2.0 ± 0.3) mBq — 5.6 %

Getters $(1.5 \pm 0.$ — 4.2 %

100 mm pipe + cables (2.7 ± 0.2) mBq — 7.6 %

Porcupine (1.9 ± 0.2) mBq — 5.4 %

$0.3)$ mBq — 6.8 %

Qdrive pumps (10.9 ± 1.7) mBq — 30.8 %

Cryo-pipe/cables/CRY system emanate 46% of total budget
→ **Reduce with online distillation**

PUR system emanates 35% of total budget
→ **Reduce by pump exchange**

Thanks C. Weinheimer
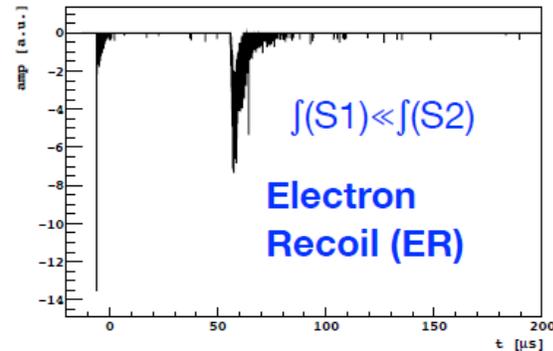
DM – LAr TPC

background-like
(electron-recoil event)
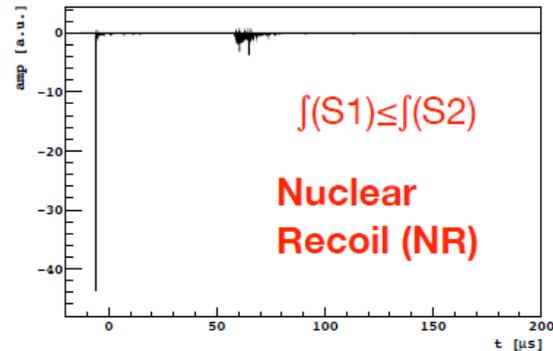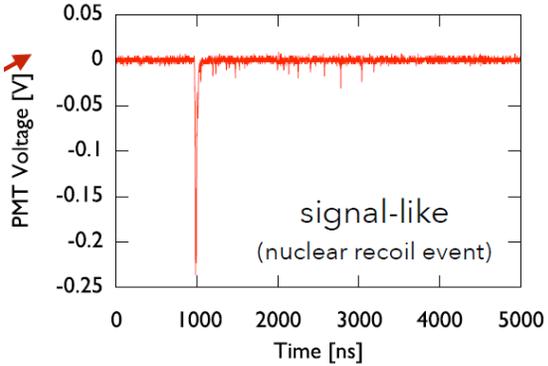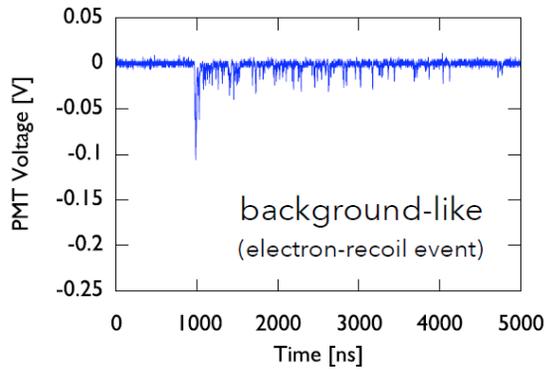

signal-like
(nuclear recoil event)

For LAr TPC

Pulse shape discrimination on S1
signal shape (Talk T. Pollman – DEEP)

Electroluminescence of S2:
- Additional γ/n discrimination (S2/S1)
- Radial fiducialization
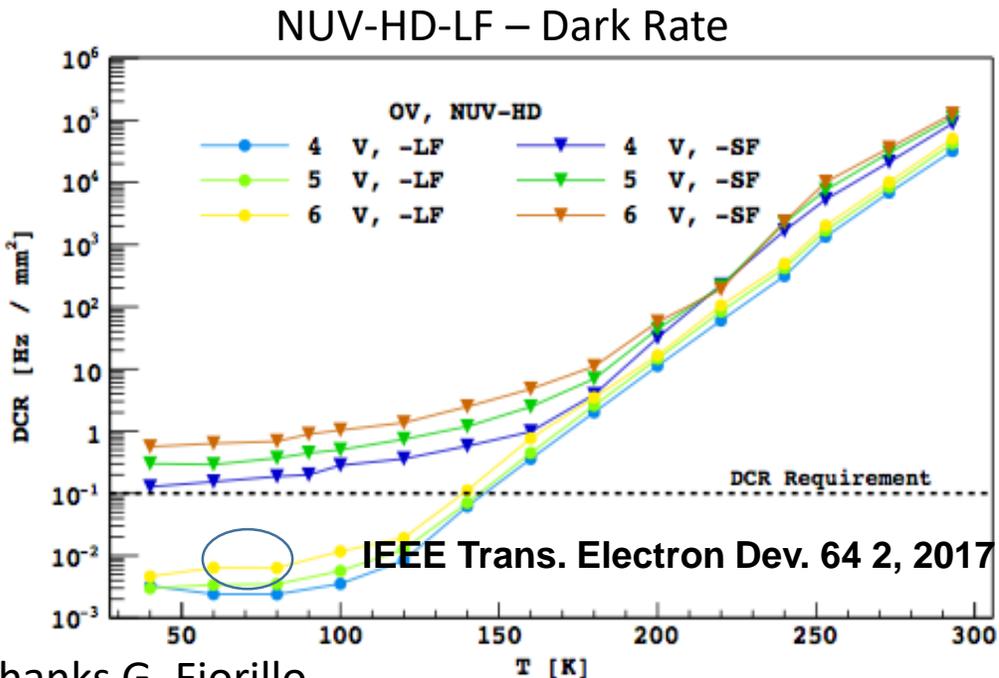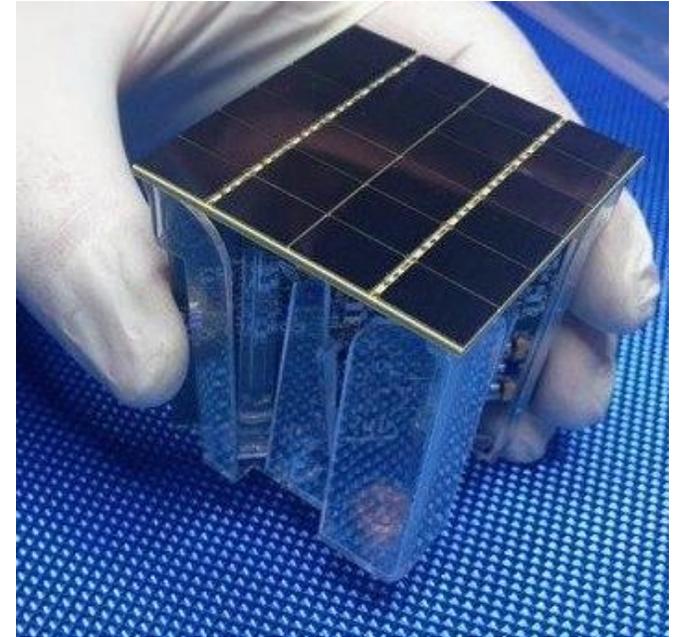(Talk A. Caminata – Dark Side)

$\int(S1) \leq \int(S2)$
Nuclear Recoil (NR)

$\int(S1) \ll \int(S2)$
Electron Recoil (ER)
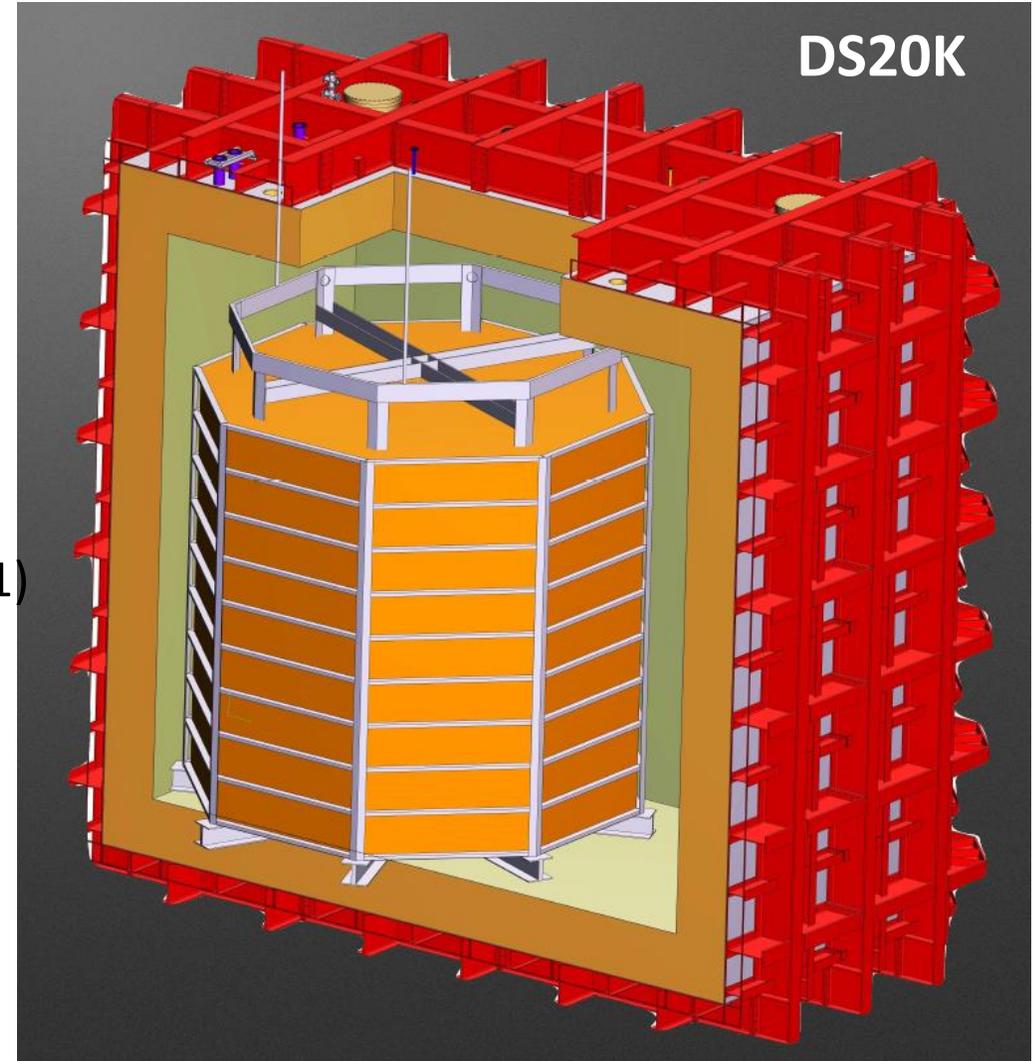
DS20K

DM – DS20k development on SiPM

- **Silicon-based 3" PMT** equivalent

- The basic photo-detector element in DS-20k

  - One read-out analog channel per PDM

    - Aggregating **24x 1cm² SiPM**

- Integrates the SiPMs and the electronics in a plastic cage

NUV-HD-LF – Dark Rate

OV, NUV-HD
- 4 V, -LF   4 V, -SF
- 5 V, -LF   5 V, -SF
- 6 V, -LF   6 V, -SF

DCR Requirement

IEEE Trans. Electron Dev. 64 2, 2017

Thanks G. Fiorillo
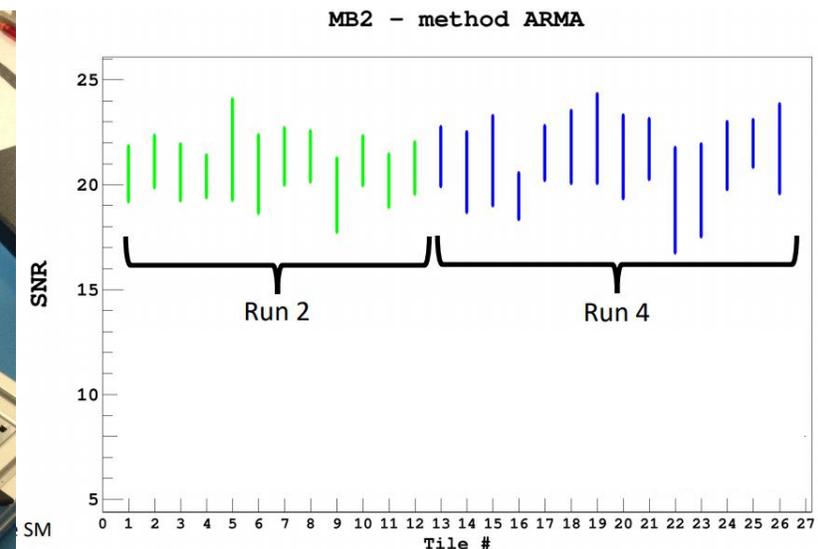
The NUV-HD technology was selected
- Peak sensitivity **at ~ 420 nm**
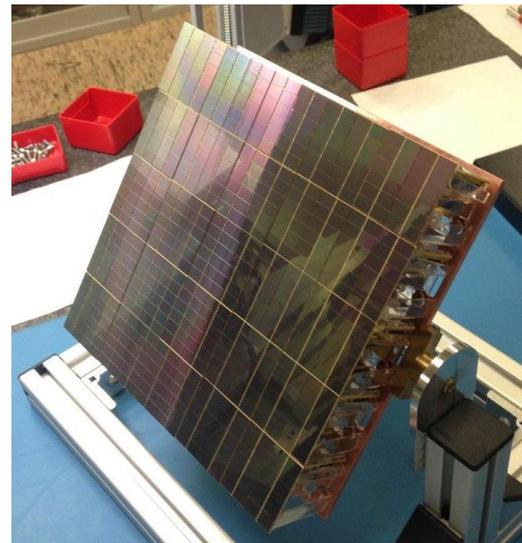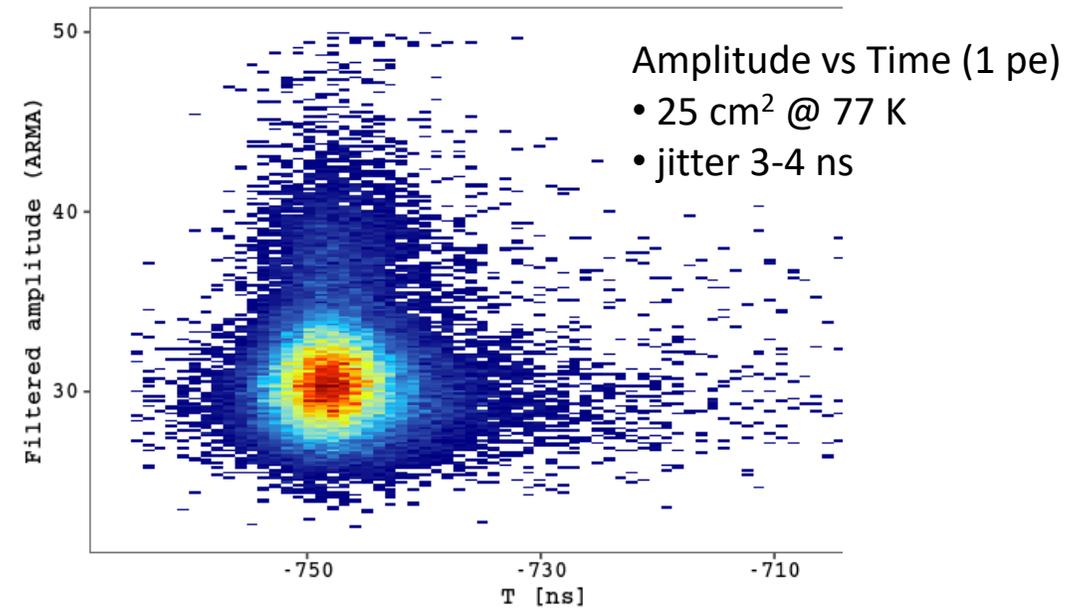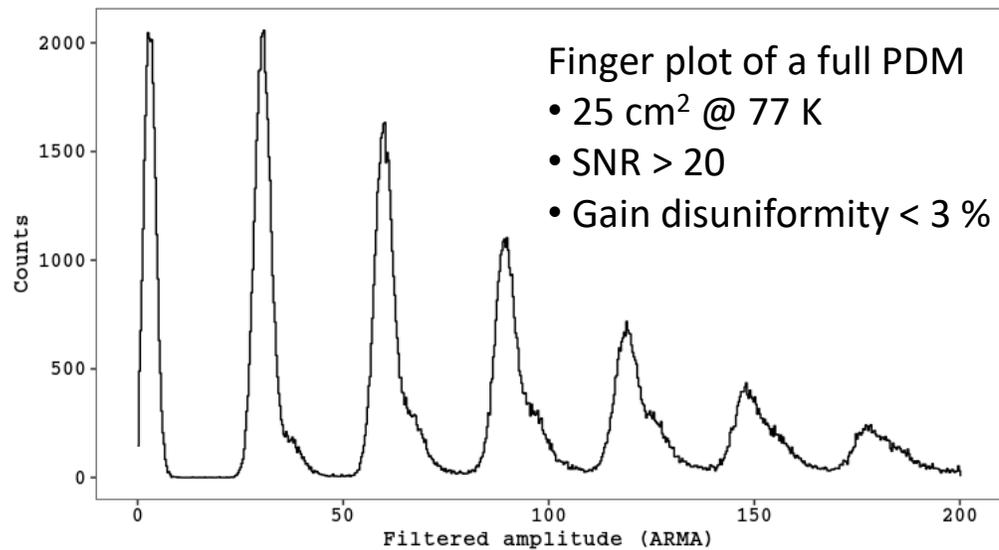- High density SPAD with high PDE

NUV-HD Low field variant:
- **DCR ~ 5 10^{-3} cps/mm² at 80 K**

FBK developed the NUV-HD-Cryo variant for extended gain at cryogenic temperature
- It is based on NUV-HD-LF with different (higher) doping
- It allows operation of NUV-HD at 14 Volt over-voltage

DM – DS20k SiPM performances

Finger plot of a full PDM
- 25 cm^2 @ 77 K
- SNR > 20
- Gain disuniformity < 3 %

Amplitude vs Time (1 pe)
- 25 cm^2 @ 77 K
- jitter 3-4 ns

- 2 Motherboards were produced and tested

- A motherboard **25 PDM = 600 SiPM 1 cm^2** large

  - For a total gross surface of **625 cm^2**

- The tests demonstrated a very high uniformity of the signal-to-noise ration of the PDMs
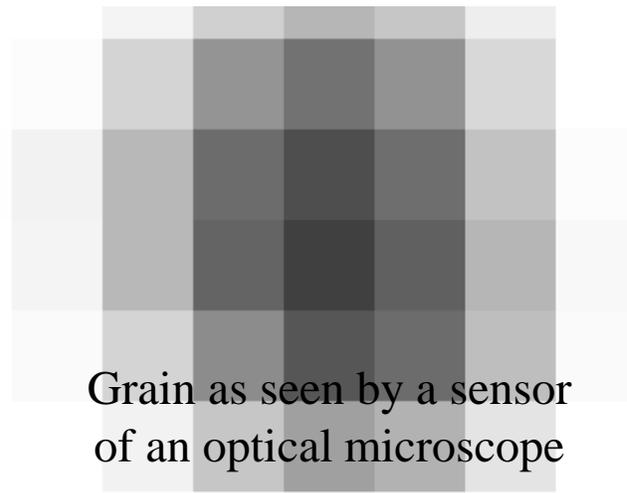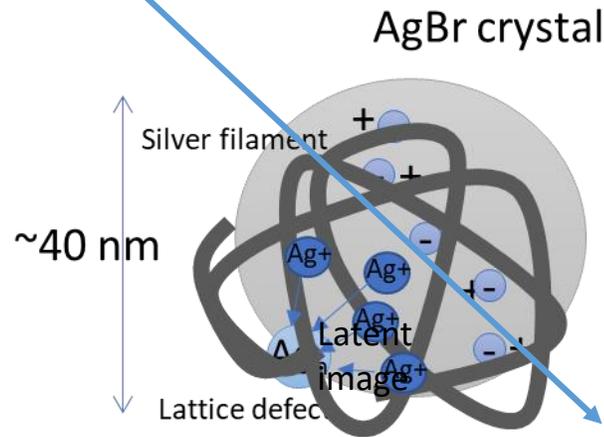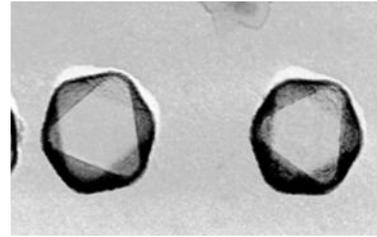
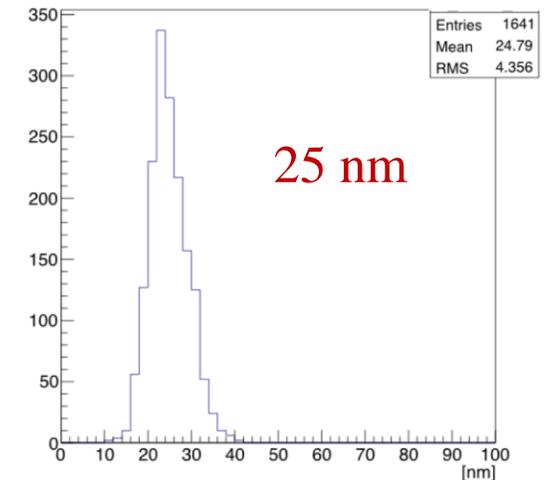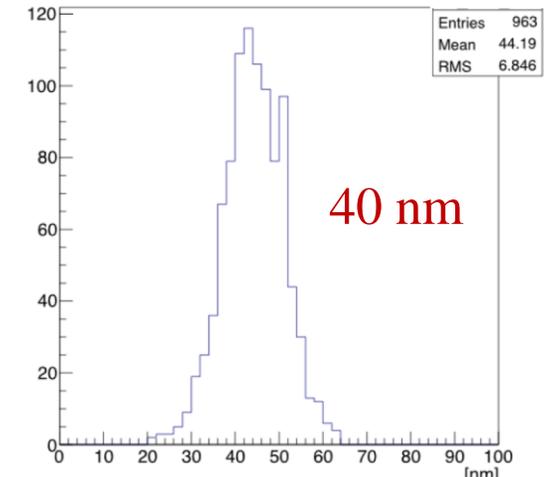Thanks G. Fiorillo

Thanks G. Fiorillo

DM - Directional search NEWs - Nuclear Emulsion

Detection principle

1. Ionization induced by a particle
   - 2.6 eV band gap

2. Electrons trapped at a lattice defect on the crystal surface
   - Attract interstitial silver ions
   - Produce a "latent image" = Ag_n

3. Chemical amplification of signal
   - Development → silver filaments
   - 10^7 - 10^8 amplification

4. Dissolve crystals

5. Observe it at optical microscopes
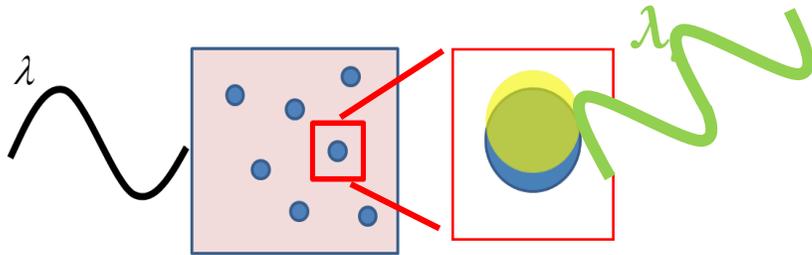
Thanks G. Galati

AgBr crystal

~40 nm

Silver filament

Ag+   Ag+   Latent image   Ag+

Lattice defect

Grain as seen by a sensor of an optical microscope

	Entries	963
	Mean	44.19
	RMS	6.846

40 nm

	Entries	1641
	Mean	24.79
	RMS	4.356

25 nm
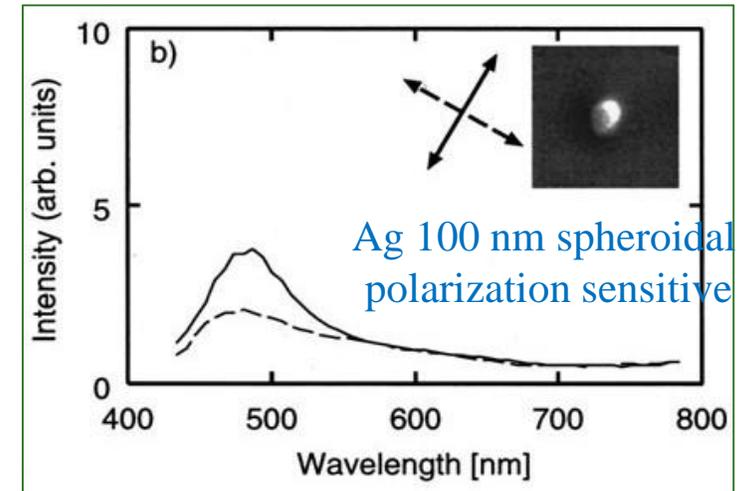
DM – NEWs, Plasmon resonance, nanometric imaging

Applied Phys Letters 80, 1826 (2002)

Ag 100 nm spheroidal polarization sensitive
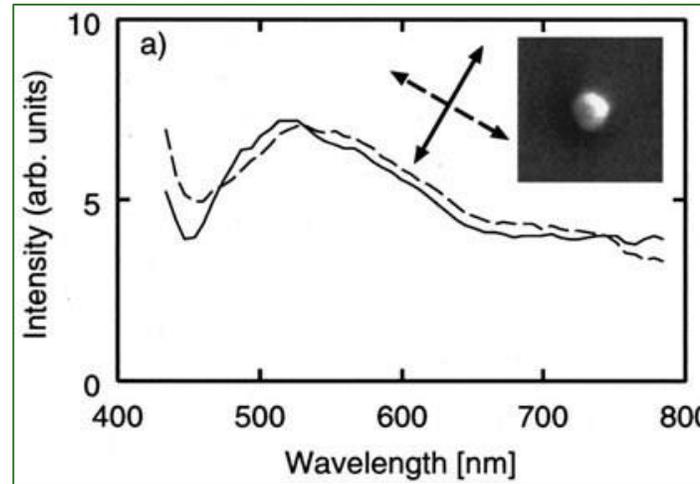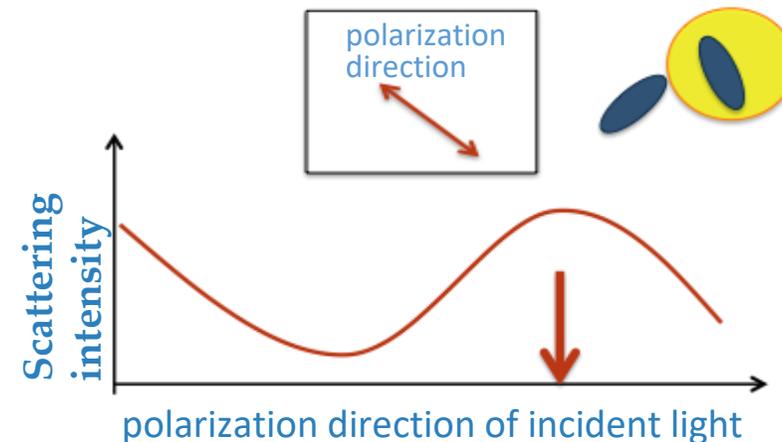
- Sensitive to the shape of nanometric grains: being silver grains **non-spherical**, the resonant response depends on the polarization of the incident light.
- Each grain is emphasized at different polarization values
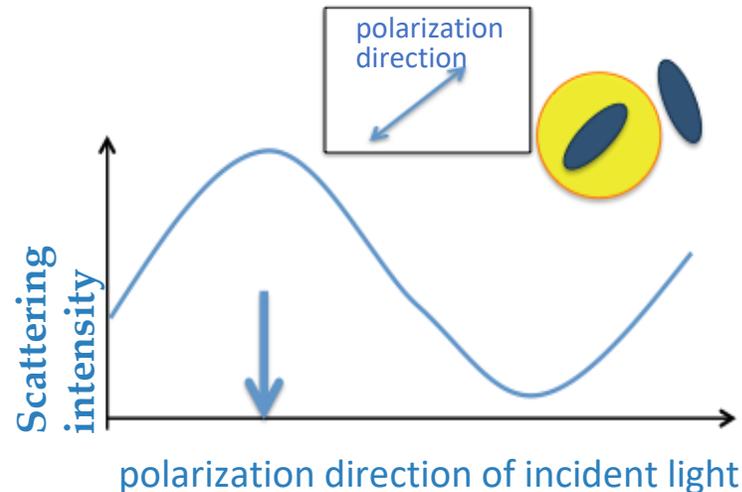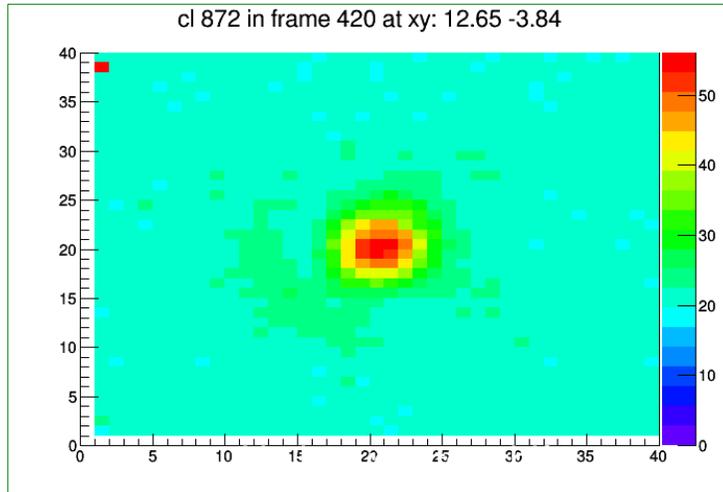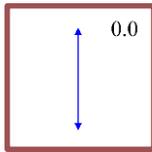

Thanks G. Galati

DM – NEWS, Very high resolution analysis

Taking multiple images over the whole polarization range produces a displacement of the barycentre of the cluster

Single grain
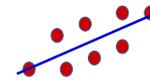
Signal-like events (100 keV C ion)
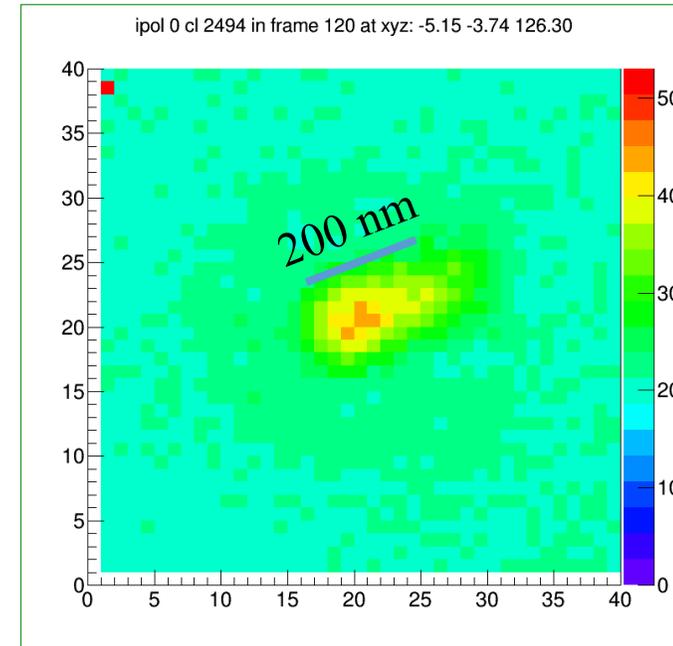
Barycenter of the cluster

Max barshift

PTEP (2019) 063H02

cl 872 in frame 420 at xy: 12.65 -3.84

Polarization angle

ipol 0 cl 2494 in frame 120 at xyz: -5.15 -3.74 126.30

200 nm

Talk G. Galati

DM – NEWs, very high position accurancy

- 10keV C-ions vertical ⇒ single clusters → no displacement → position accuracy

3D system
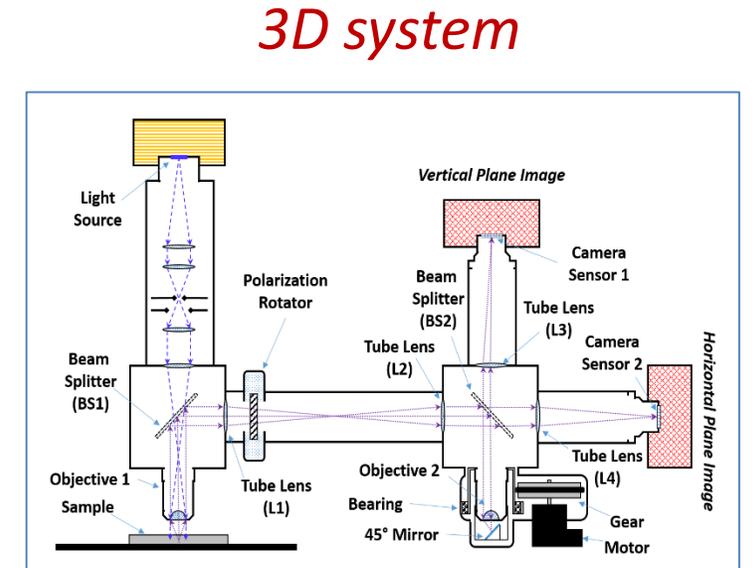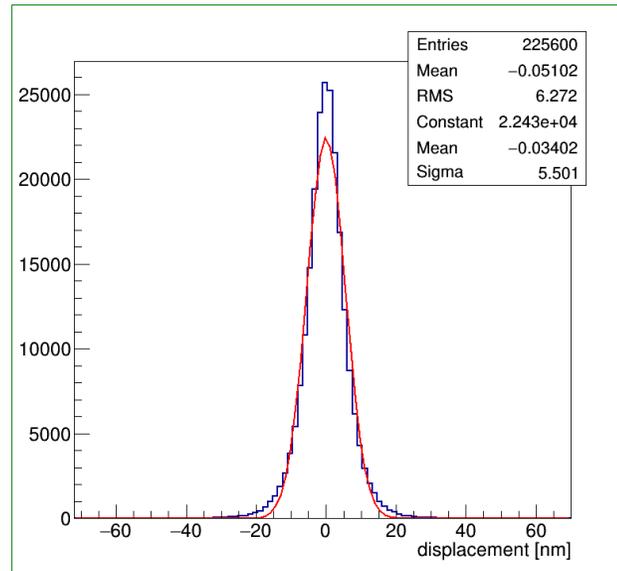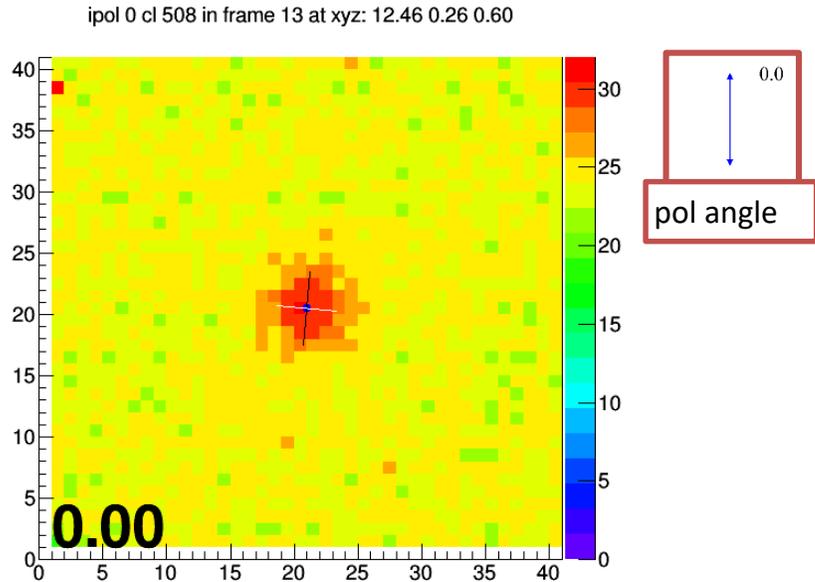
Unprecedented accuracy of **6 nm** achieved on XY coord

Future R&D will demonstrate if a large detector mass will be realizable

Talk G. Galati

JUNO – High sensitive neutrino oscillation experiment

700 m

**20 kt
Liquid Scintillator**

**Acrylic Sphere
~18000 20" PMTS
~25000 3" PMTS**

a huge liquid scintillator detector

2 Key parameters:

LARGE & PRECISE

	DETECTOR TARGET MASS	RESOLUTION
KamLAND	1000 t	$6\%/\sqrt{E}$
Double Chooz	8 t	
RENO	16 t	$8\%/\sqrt{E}$
Daya Bay	20 t	
Borexino	300 t	$5\%/\sqrt{E}$
JUNO	20000 t	$3\%/\sqrt{E}$

Talk M. Grassi

JUNO – High sensitive neutrino oscillation experiment

QE=25% → QE=30% → QE=35%

CE=70% → CE=100% → CE=100%

DE=17% → DE=30% → DE=35%
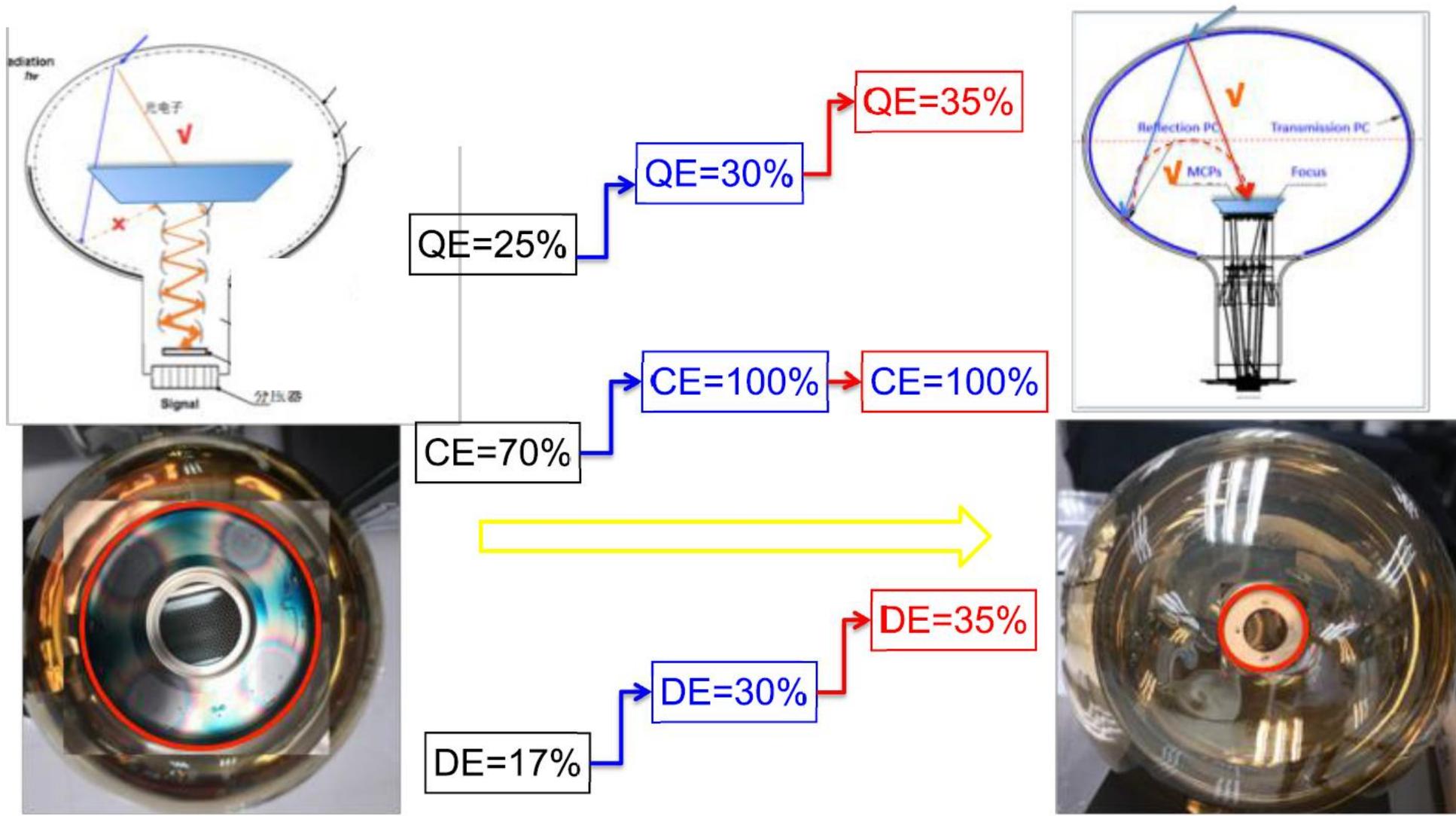
Talk M. Grassi

LiquidO – Opaque-liquid-scintillator

novel opaque-liquid-scintillator technology
(unprecedented ν detection potential)

e+ ⇔ anti-ν(e)   e- ⇔ ν(e)   p-recoil

[IBD interaction]   [^{12}C/new interaction] [cosmogenic background]

LiquidO PRELIMINARY

full Geant4 simulation

LiquidO PRELIMINARY

LiquidO PRELIMINARY

e^+ 30MeV e^- 30MeV   p-recoil 30MeV

(MIP-track⊕annihilation)   (MIP-track)   (Bragg peak)
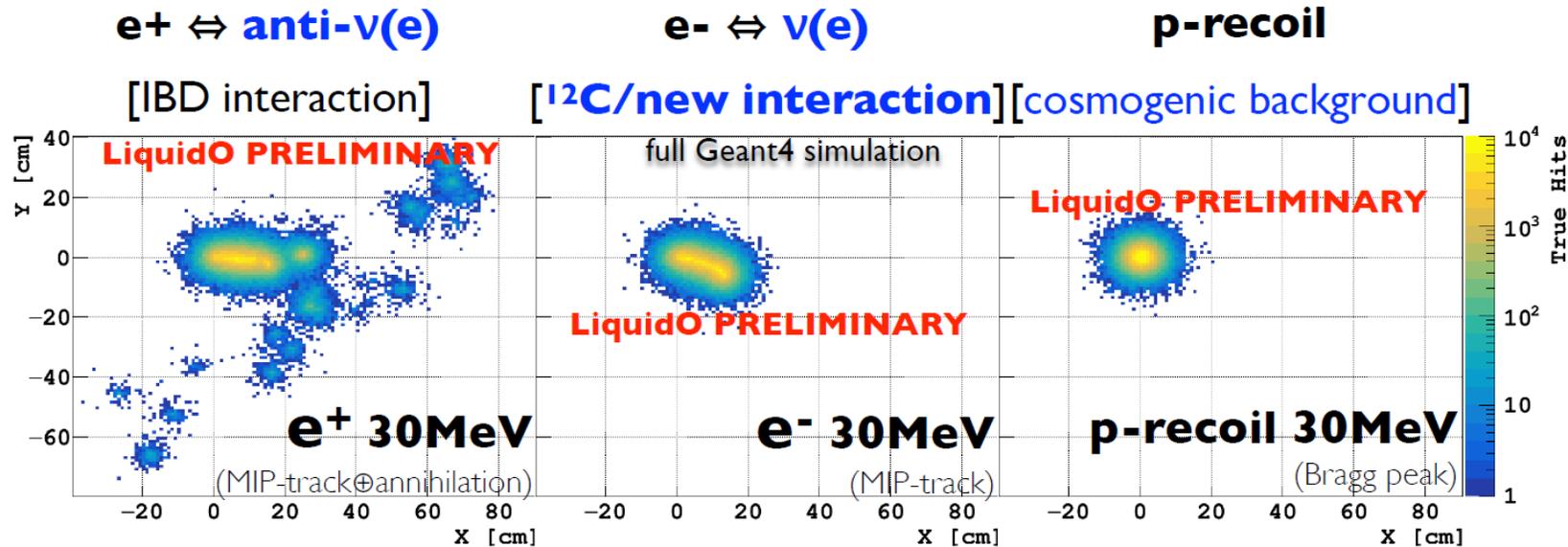
powerful PID capability (i.e. imaging) ⊕ large loading
⇒ new physics capabilities?

CERN seminar (https://indico.cern.ch/event/823865/) **& publication** (within days!!)

LiquidO...

Collaborators+Cooperators
(Brasil, Chile, France, Germany, Italy, Japan, Spain, UK, USA)
[contact: anatael@in2p3.fr & suekane@awa.tohoku.ac.jp]

Conclusions

- **Many R&Ds** on non-accelerator detectors are ongoing

- **Different technologies** were developed with the aim of
  - Increasing the **detector masses**
  - Lowering the **detector backgrounds**
  - Improving the **detector performances**

- **New generation detectors** is under design/construction

- *Specific efforts will be needed to*
  - ***Enriched isotope** productions (00νββ decay)*
  - *Very pure **material selections***
  - *Suitable **underground infrastructures***

- Strong **improvements in the experimental sensitivities** is expected soon

…and what else…

Neutrino physics

> *SNO+*
>
> *SuperNEMO*
>
> *AMoRE*
>
> *Project8*
>
> *........*

Direct Dark Matter Search
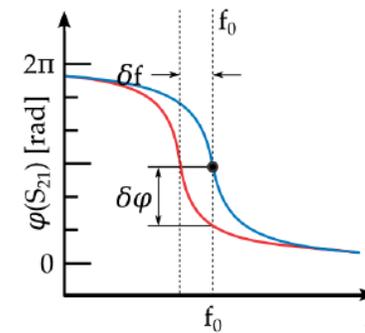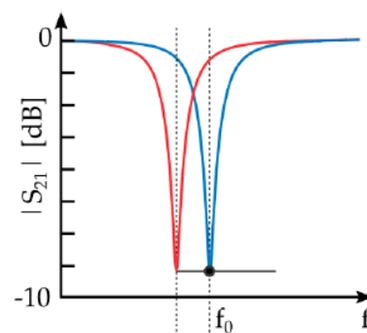
> Edelweiss
>
> LZ
>
> COSINE
>
> COSINUS
>
> ....

… thank you …

Criogenic multiplexing readout
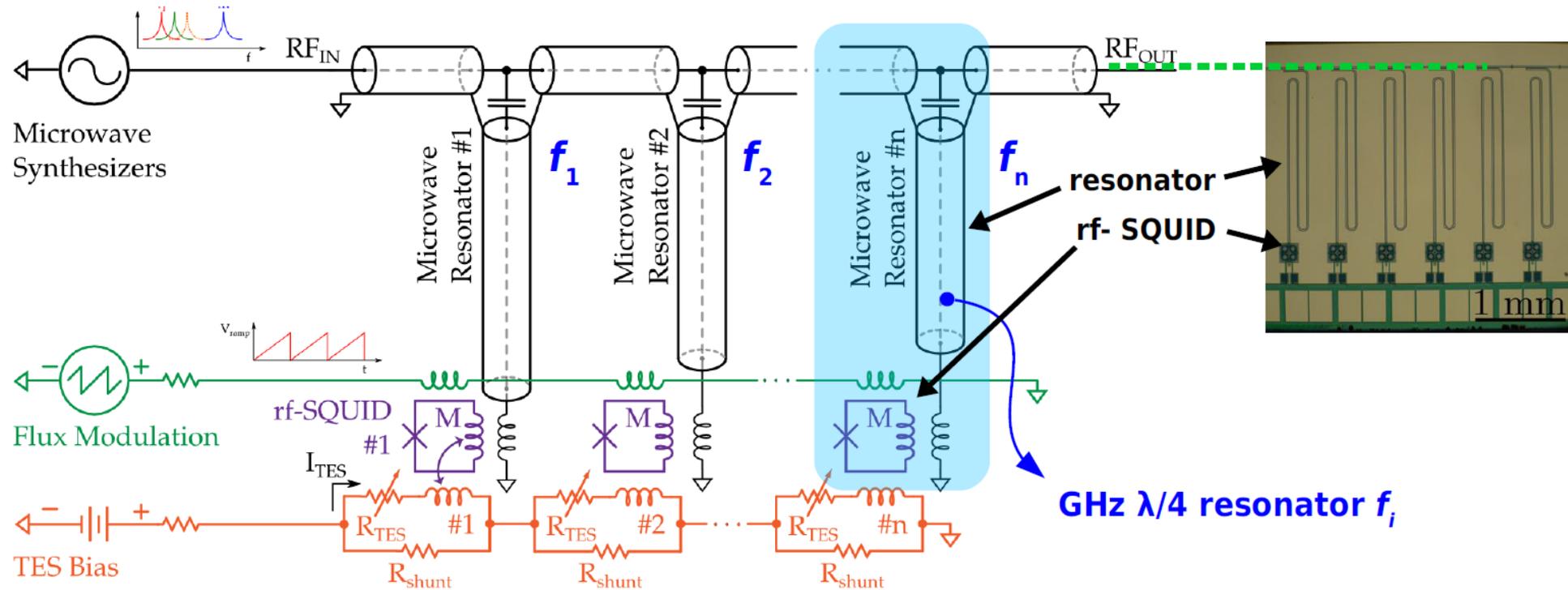
$$\dots \to \Delta\Phi \to \Delta L \to \Delta f_0 \to (\Delta A, \Delta\varphi) \to (\Delta I, \Delta Q)$$
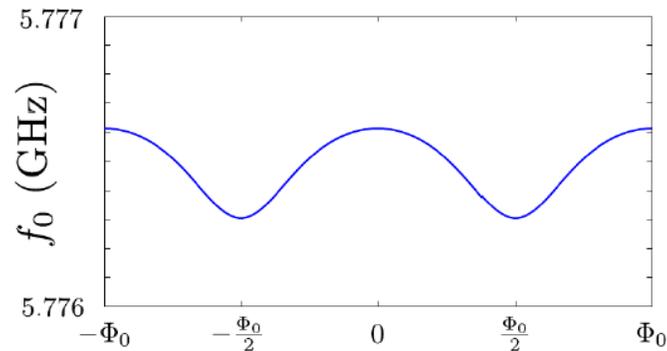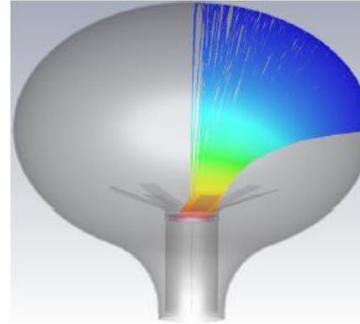
Thanks A. Nucciotti

# JUNO – High sensitive neutrino oscillation experiment
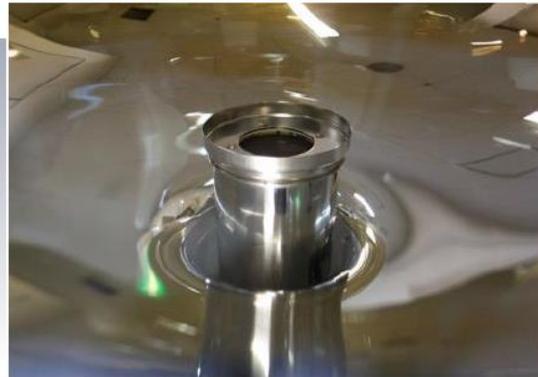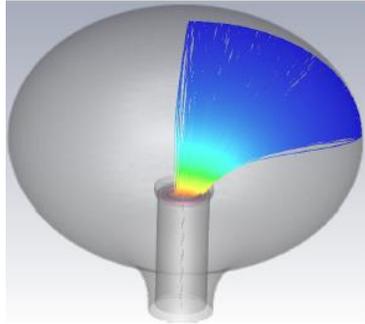
Normal focusing electrode → Flower-like focusing electrode

— By changing the constructer of the focusing electrode, using the flower-like one, the TTS of the PMTs is improving from 20ns to 5ns, but the CE of the prototype is decreasing to 85%,

— By decrease the area of the photocathode for better TTS, the dark rate of the PMT also much better than the normal one, from 40KHz to 20KHz.
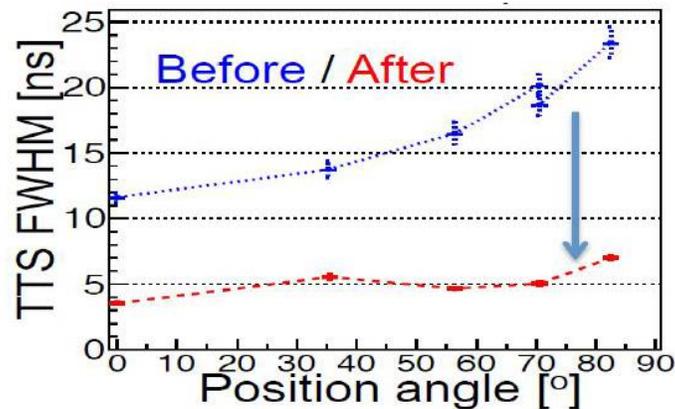
Characteristics	Normal focusing electrode		Flower-like focusing electrode
QuantumEfficiency (400nm)	~30%		~30%
Relativity Detection Efficiency	~ 100%	↓	85%
P/V of SPE	~ 7	↓	~ 5
TTS on the top point	~20ns	↑	5 ns
Anode Dark Count	~40KHz	↑	~20KHz

Thanks M. Grassi