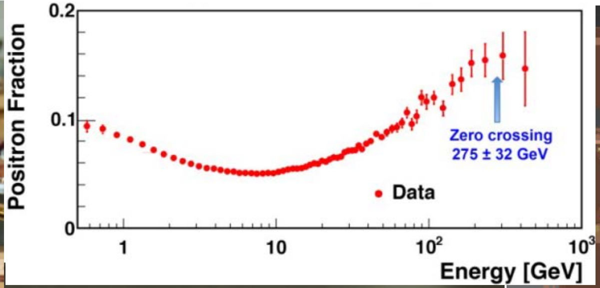
2015 SJTU-KIT Cooperative Research Workshop "Particles and the Universe"

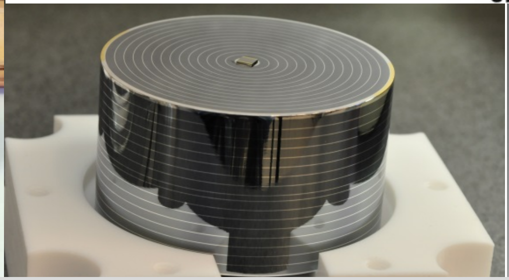
chaired by Thomas Müller (KIT/IEKP)

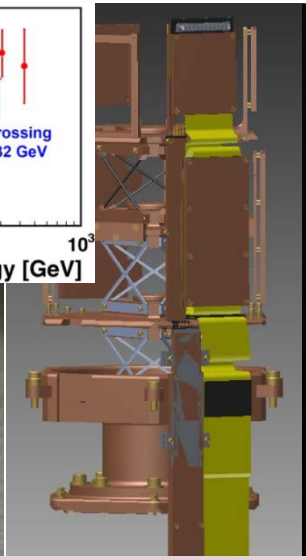
from Wednesday, November 4, 2015 at **08:00** to Friday, November 6, 2015 at **22:00** (Europe/Berlin)
at **Shanghai Jiao Tong University (Minhang) (Institute of Nuclear and Particle Physics(INPAC), room 417)**
800 Dongchuan Road Shanghai 200240

Dark Matter search at KIT with EDELWEISS, EURECA and AMS-02

Klaus Eitel, KIT Center Particle and Astroparticle Physics, KCETA

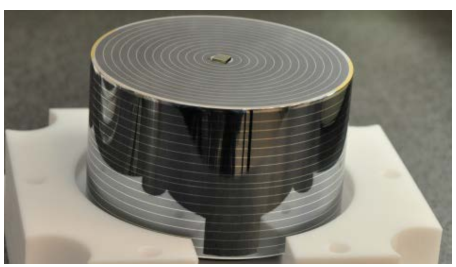






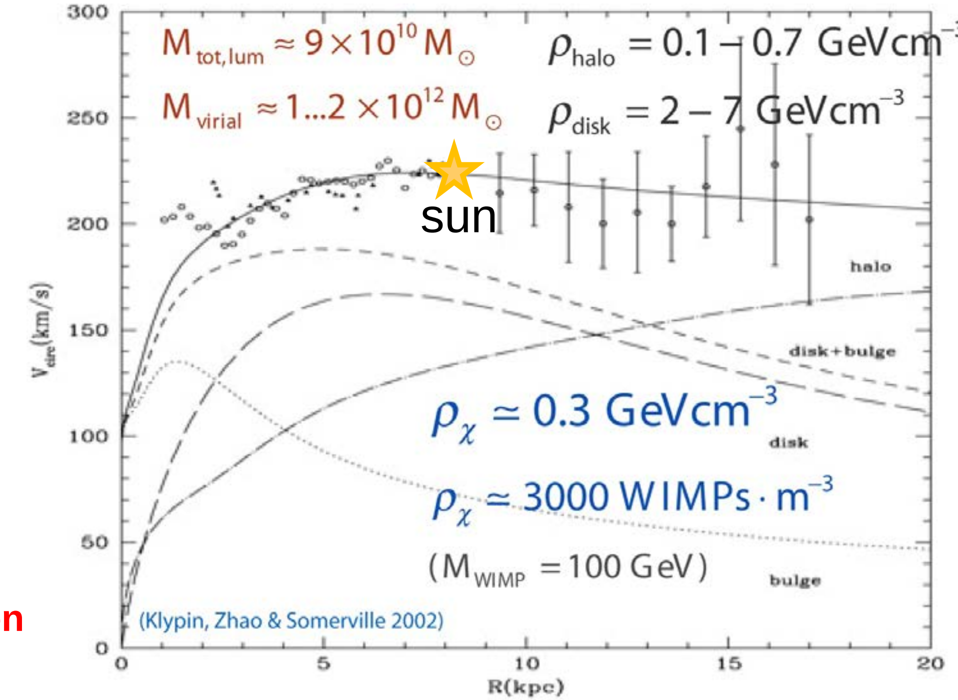
direct Dark Matter search principles

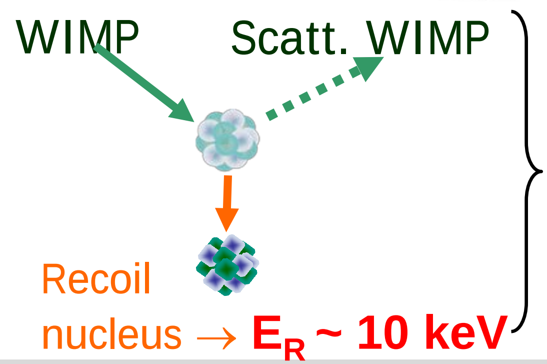
- Evidence for dark matter: galaxy rotation curves, clusters, CMB, nucleosynthesis, bullet cluster
- Candidates: WIMPs – supersymmetric neutralinos, KK particles, axions, technibaryons…
- Search for elastic scattering
  - **~ 10 keV nuclear recoil**
  - **< 1 event/kg/year**
  - **Need excellent background suppression**



- Cryogenic germanium phonon-ionization detectors

diffuse DM halo within our Milky Way
with ~ Maxwell-Boltzmann f(v), $\langle v^2 \rangle^{1/2}$ ~270km/s

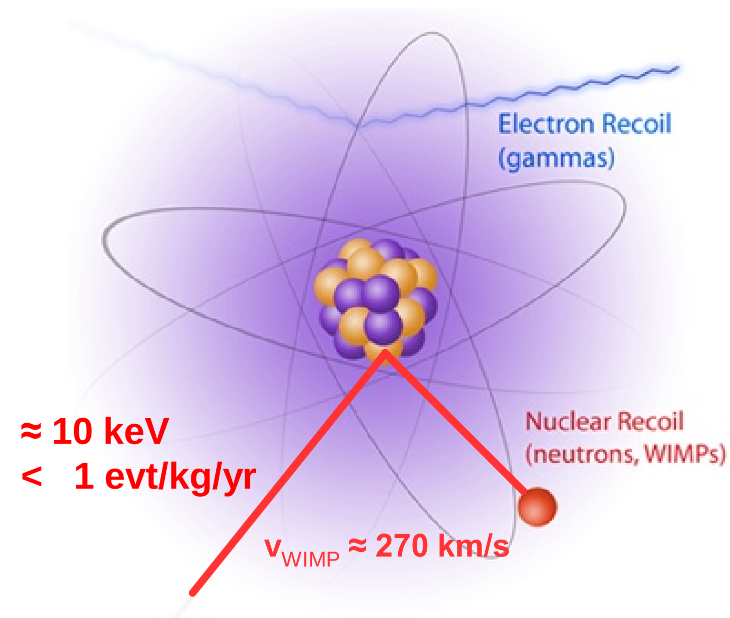




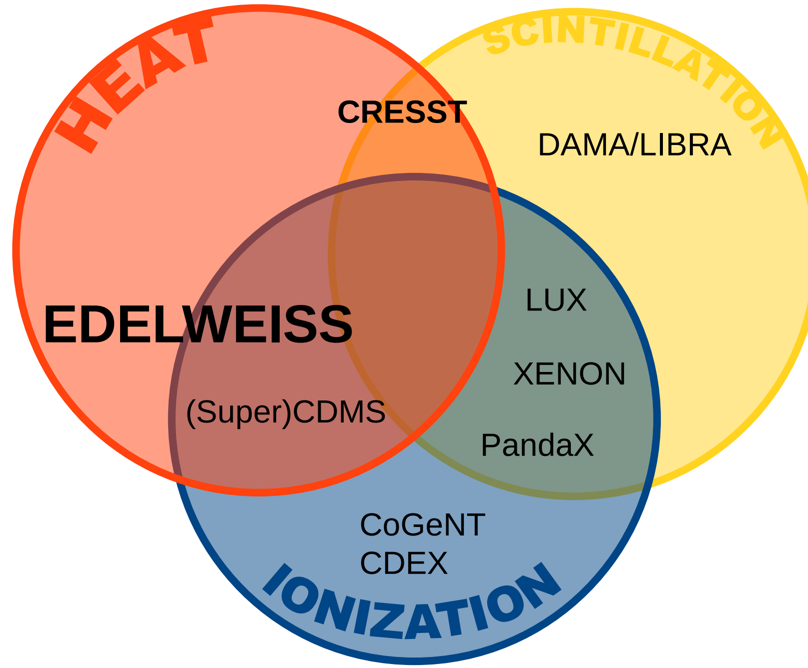
Count rate:

< 1evt/kg/year!

Direct Dark Matter detection with EDELWEISS



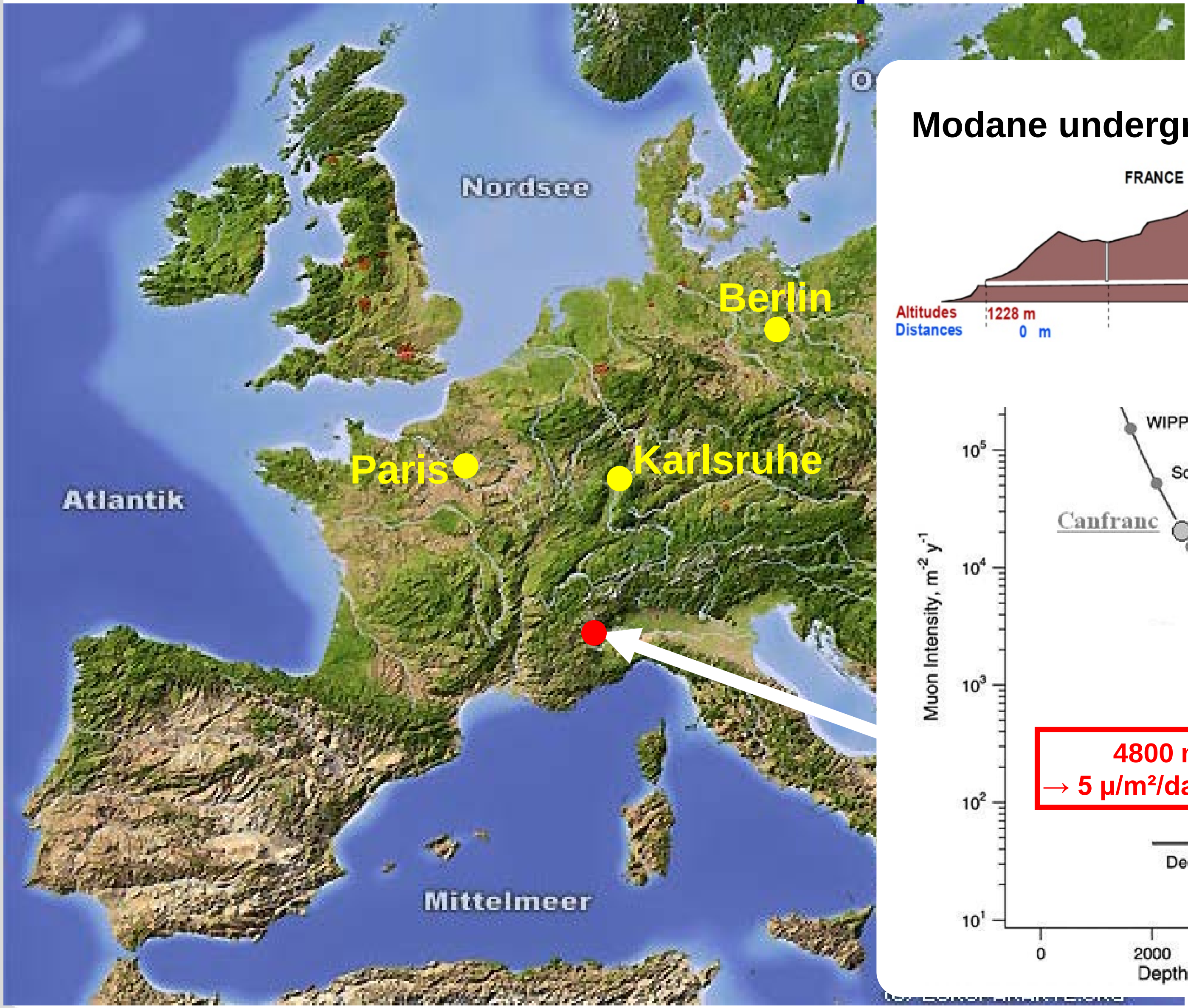
Ge monocrystal bolometer



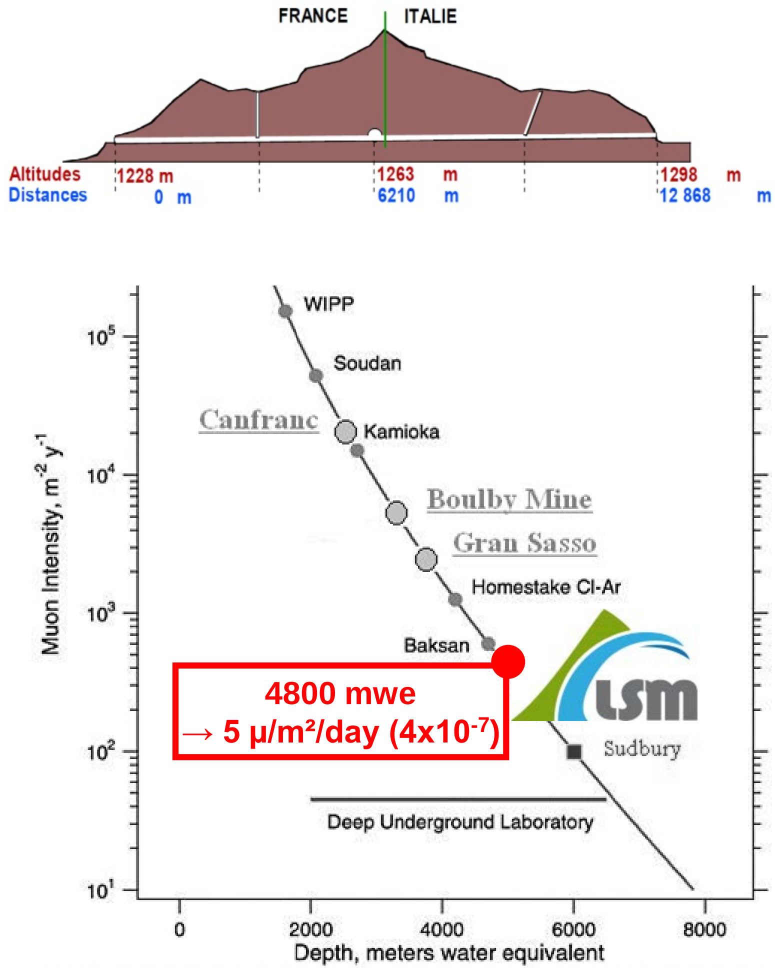
background discrimination:

- 2 *NTD* phonon sensors:
  → calorimetric measurement of total energy
  @ **T=18mK** → ΔT≈0.1 μK/keV
- 4 groups of *interleaved* Al ring electrodes:
  → ionization measurement

Location of the EDELWEISS experiment



Modane underground lab



The EDELWEISS collaboration

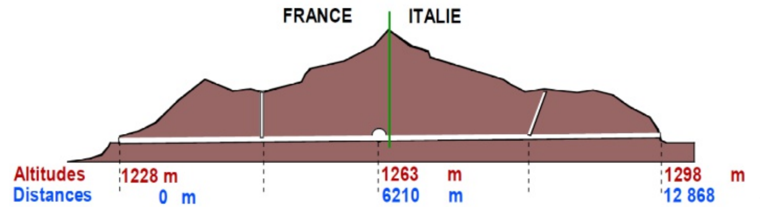
CEA Saclay (IRFU and IRAMIS)
CSNSM Orsay (CNRS/IN2P3, Paris Sud)
IPNLyon (CNRS/IN2P3)
Néel Grenoble (CNRS/INP)

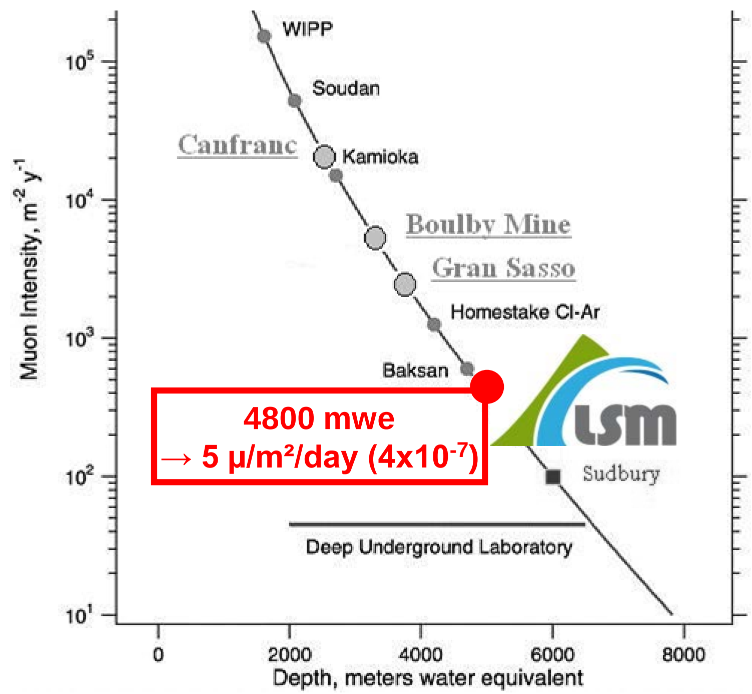
KIT Karlsruhe (IKP, EKP, IPE)

JINR Dubna

Oxford University
University of Sheffield

LSM @ *Fréjus* tunnel





The EDELWEISS shielding concept

clean room (Rn)
with derodanized air supply
(from 10 Bq/m³ → ≈ 30 mBq/m³)

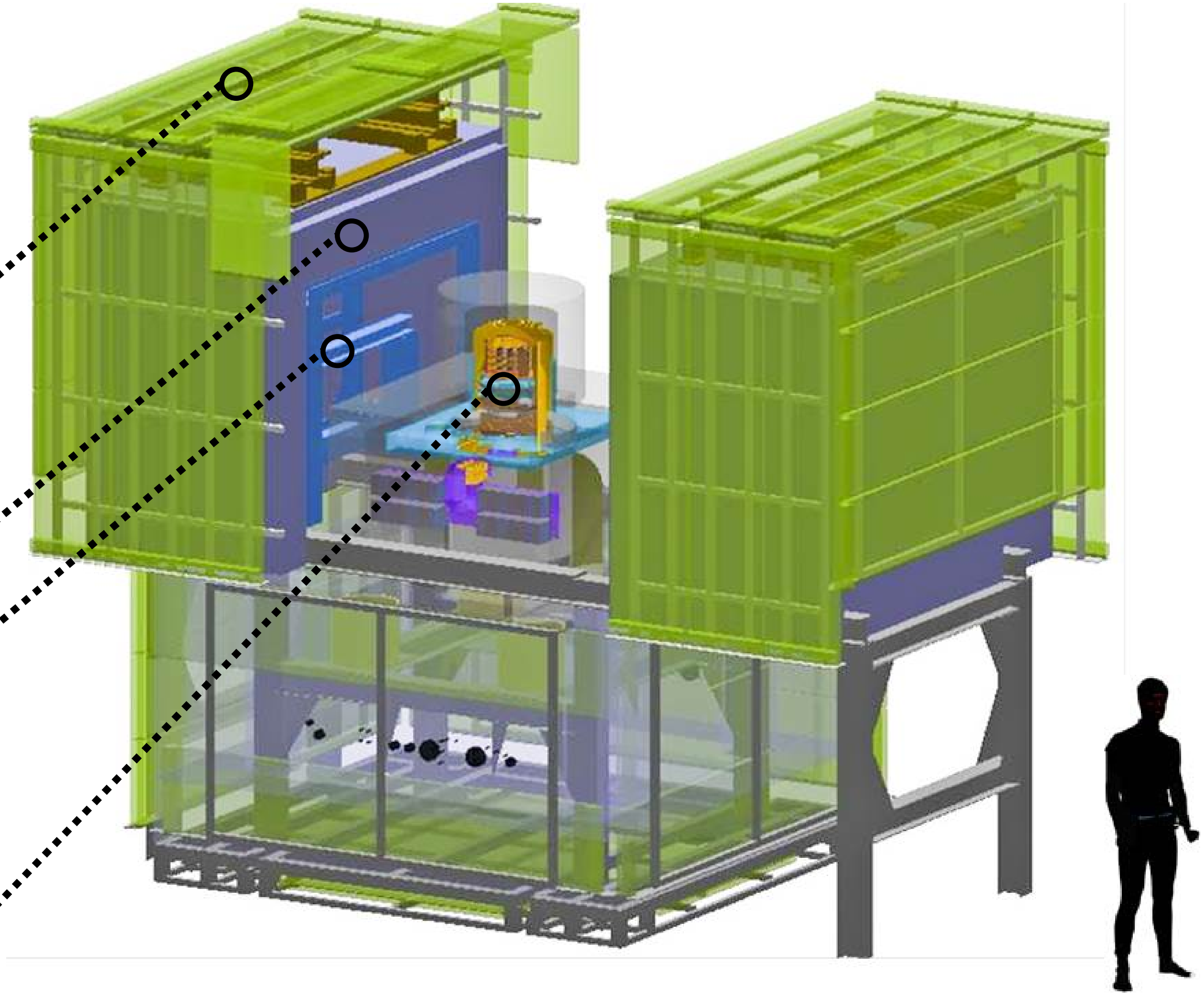
KCETA

active muon veto (μ)
98% geometric coverage

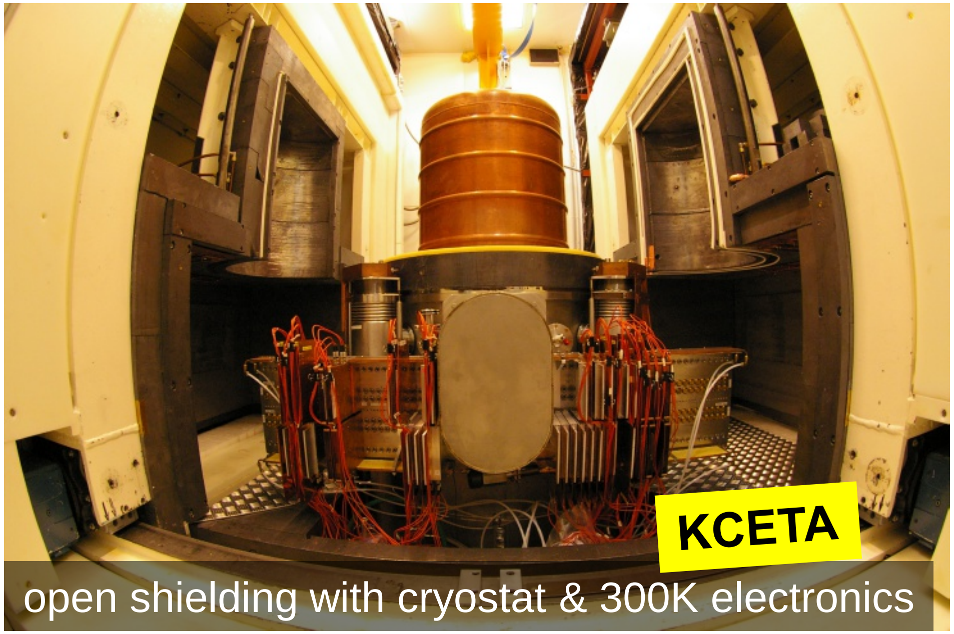
polyethylene shield (n)
50cm, for moderation

lead shield (β, γ)
18cm + 2cm roman lead

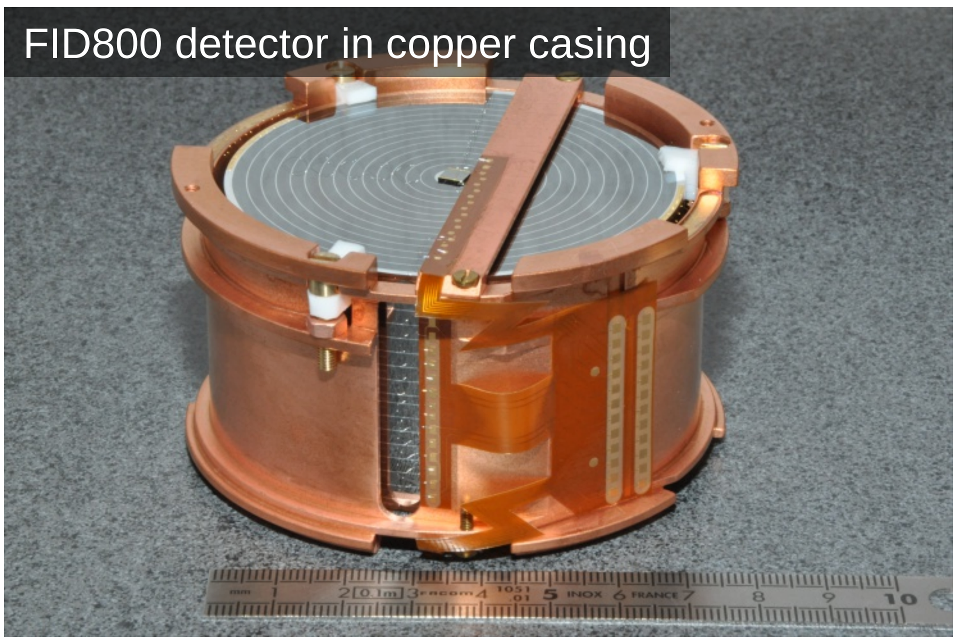
copper cryostat (β, γ)
with additional internal PE and Pb



KIT
Karlsruhe Institute of Technology

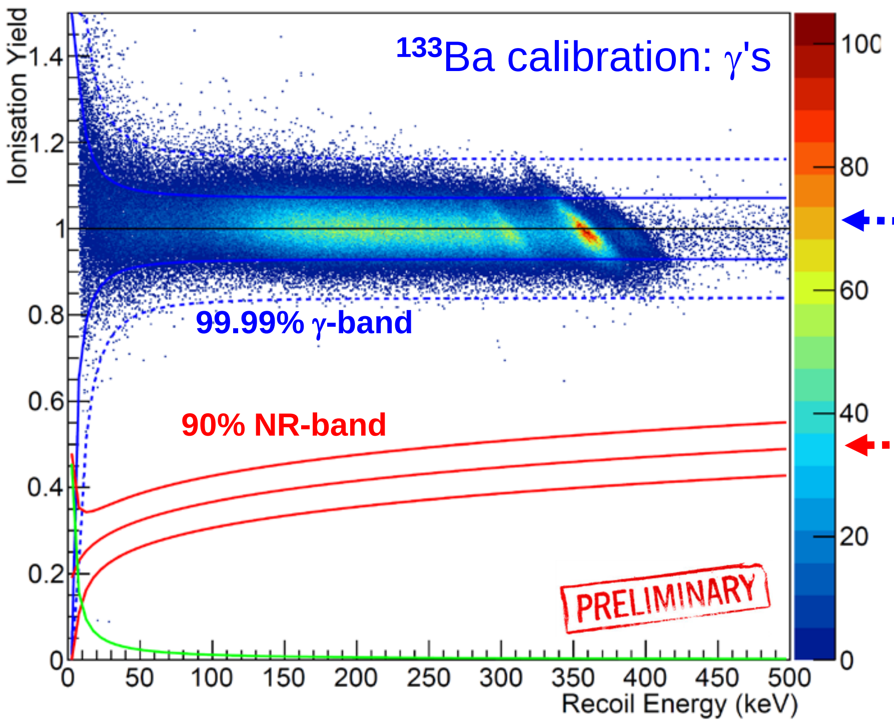


open shielding with cryostat & 300K electronics


FID800 detector in copper casing


open cryostat and bolometer plates

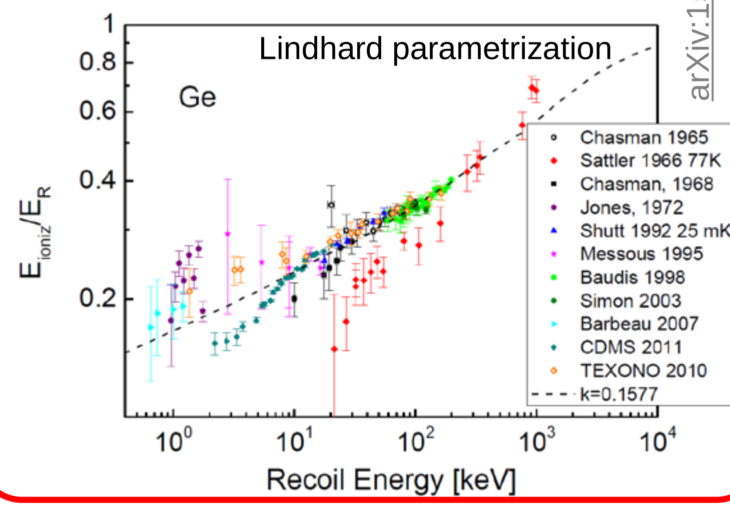
identification of nuclear recoils



Ionization yield $Q = E_{ion} / E_{recoil}$

Electron Recoils:
Q = 1
(by normalization)

Nuclear Recoils:
Q ≈ 1/3
("quenching")

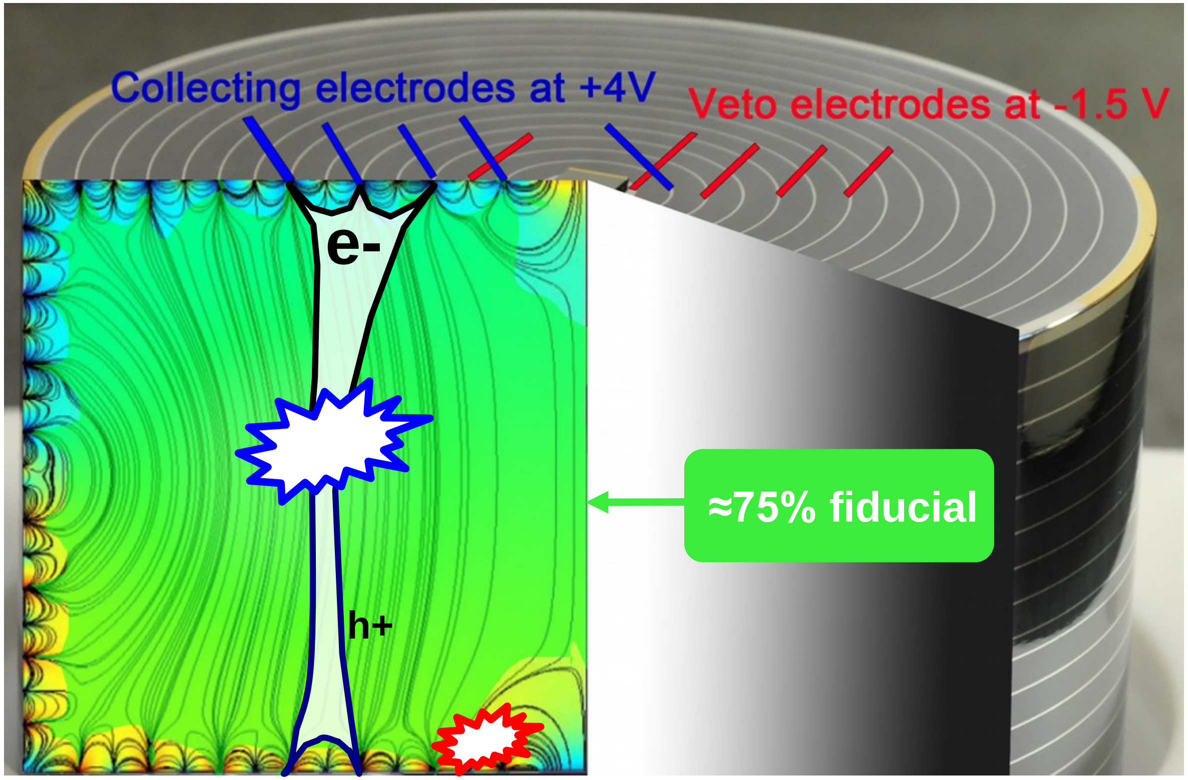


arXiv:1505.06340

- recoil type determination via ionization yield
- not possible if charge collection incomplete

→ need to reject surface events efficiently

Surface event rejection with the *Fully Inter-Digitized* (FID) electrode readout design

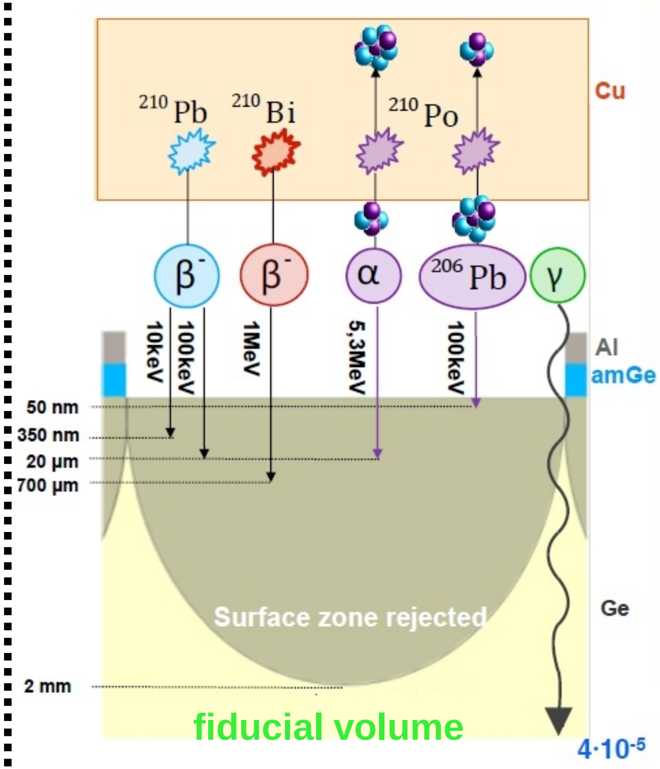


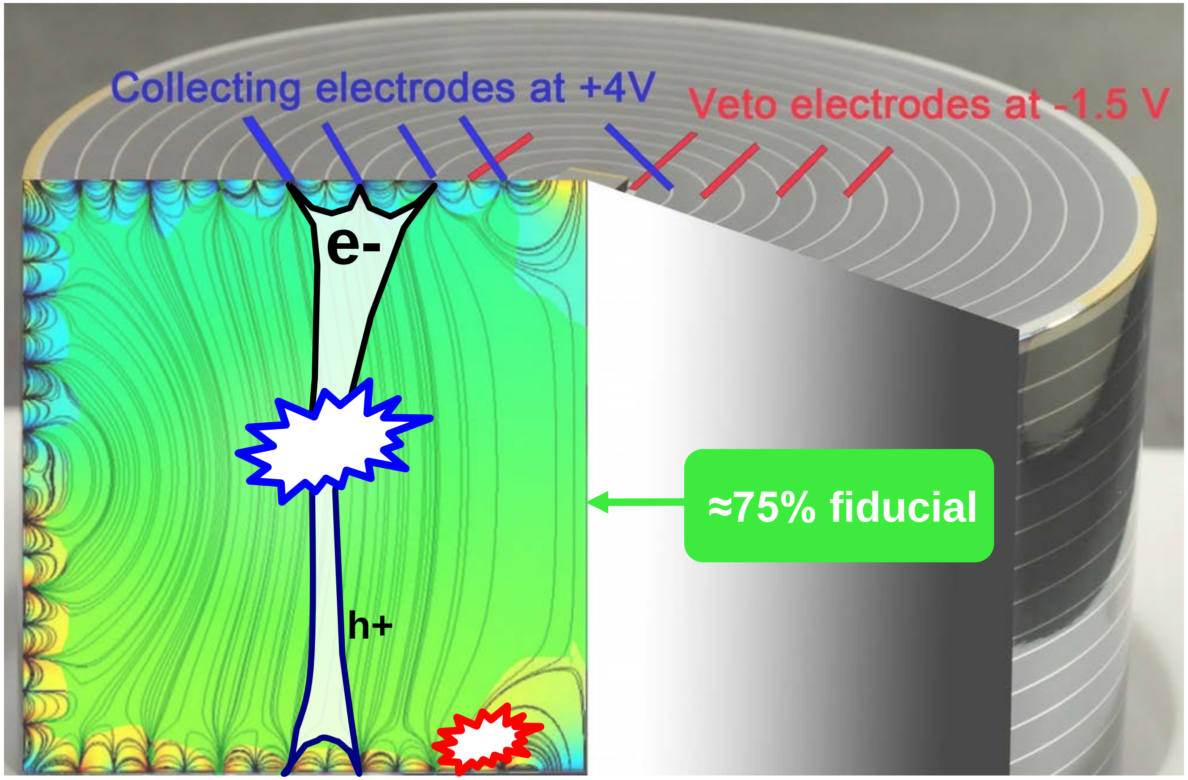
bulk event:
charge collection on
collecting electrodes

surface event:
charge collection on
veto electrodes

Surface event rejection with the *Fully Inter-Digitized* (FID) electrode readout design

From calibration measurement with implanted ^{210}Pb source:

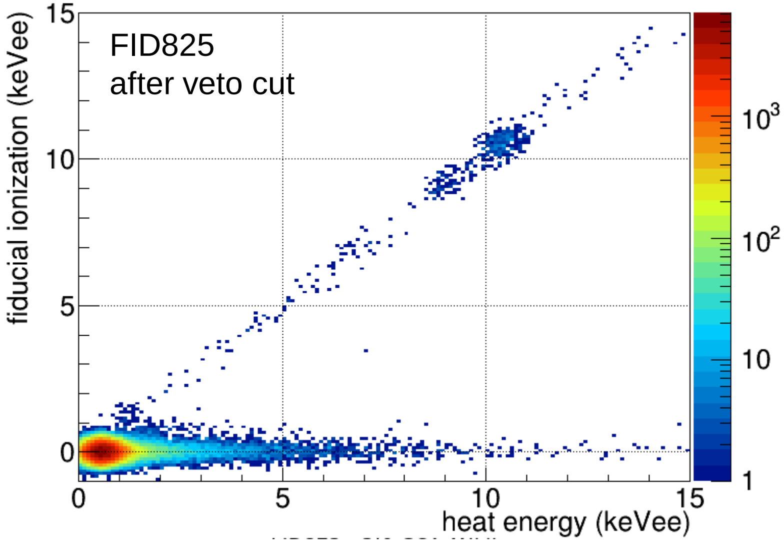




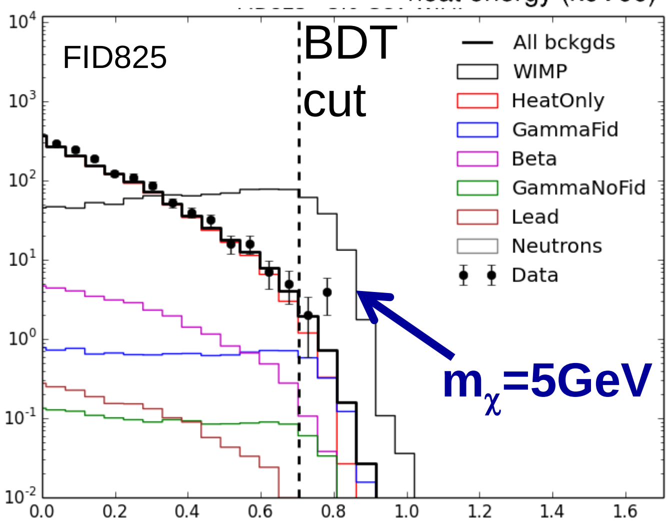
bulk event:
charge collection on
collecting electrodes

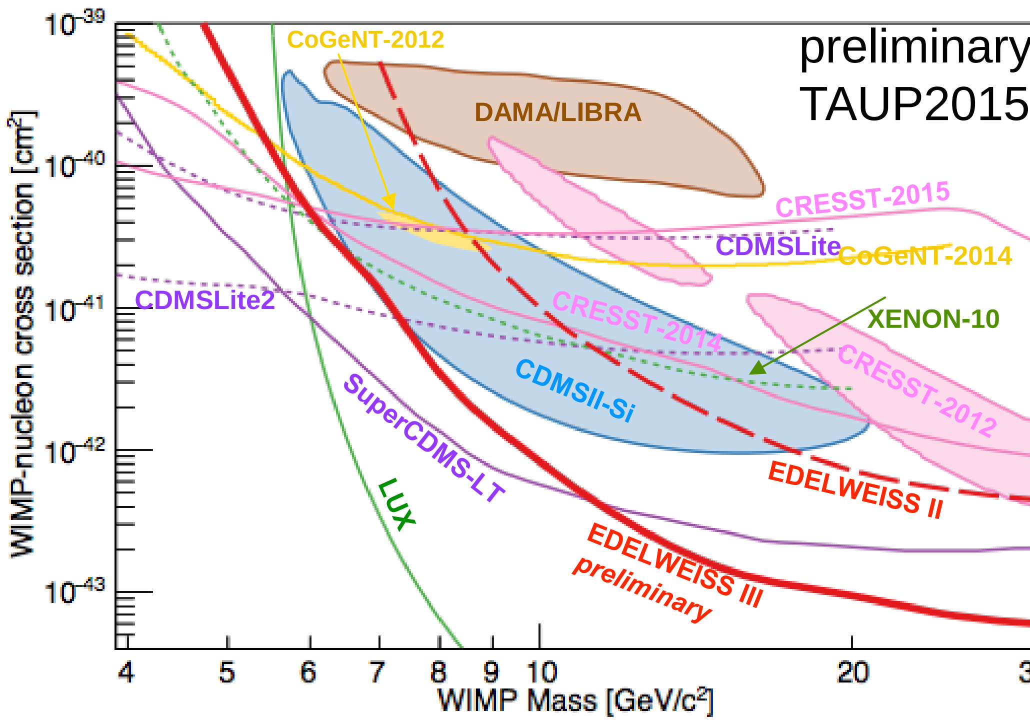
surface event:
charge collection on
veto electrodes

EDELWEISS 2014/205 campaign: improved low-mass WIMP sensitivity



- data taking 07/2014 — 04/2015
- blind analysis
- 8 detectors with $1keV_{ee}/1.5keV_{ee}$ threshold
- 582 kg·day (fiducial) exposure **KCETA**
- boosted decision tree (BDT) & profile LHD



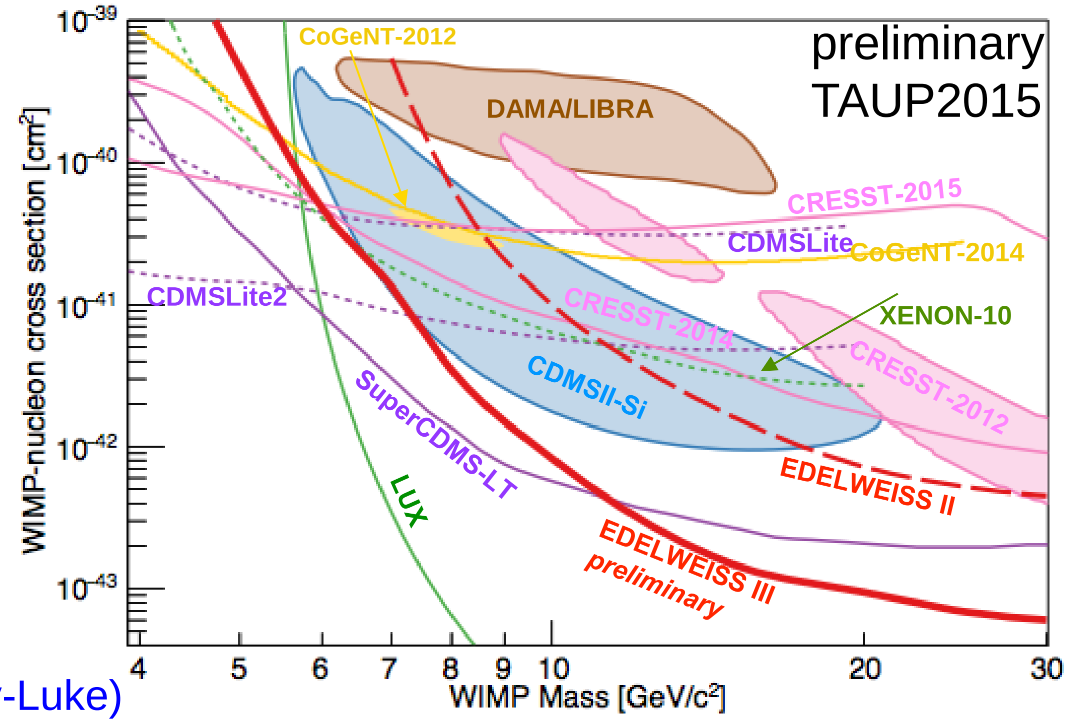


EDELWEISS-III perspective

- Poisson limits **w/o** background subtraction

→ **factor 40 improvement @ 7 GeV & new data down to 4 GeV**

- cross checks with 2d profile likelihood analysis (@KIT) ongoing and in good agreement



2015/2016 programme:

R&D on HEMT
to lower ionization threshold
down to σ_{ion} = 100 eV

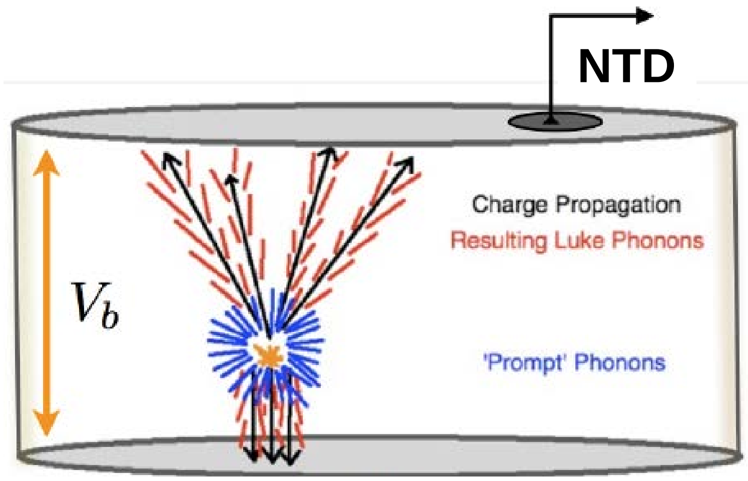
KCETA

R&D on heat sensors and HV (Neganov-Luke)
goal σ_{heat}= 100 eV and reduce recoil threshold
R&D to reduce heat-only events

aim in 2016/2017:

4-10 detectors in NL mode running for ~1year

voltage-assisted heat amplification aka Neganov-Luke mode



Heat signal amplitude: H = GE,
E = deposited energy from an impinging particle
G = (1+qU/ε) is the heat gain.
example :
U = 180V → heat gain G for γ interactions
(ε=3 eV/e.h. pair) : G = 61

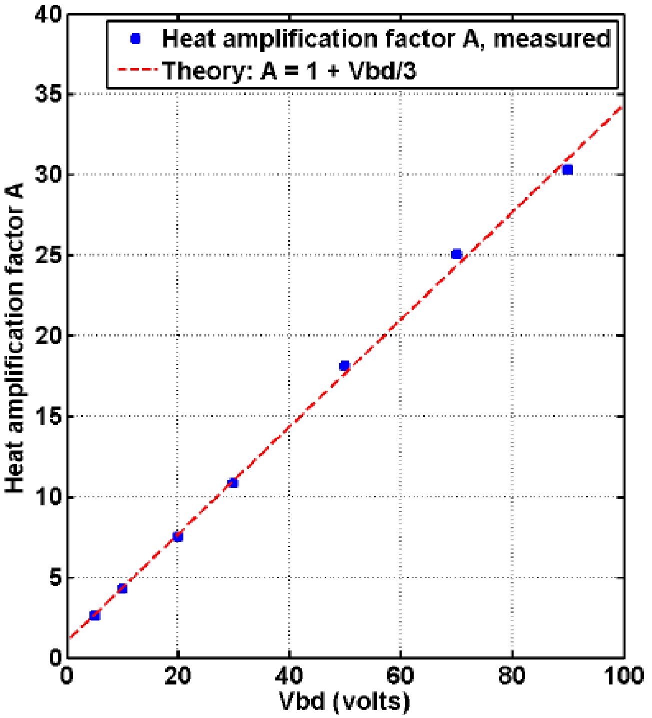
Ionization only, uses phonon instrumentation to measure ionization!

→ No event-by-event discrimination of NR

→ lower threshold ~100eV$_{NR}$

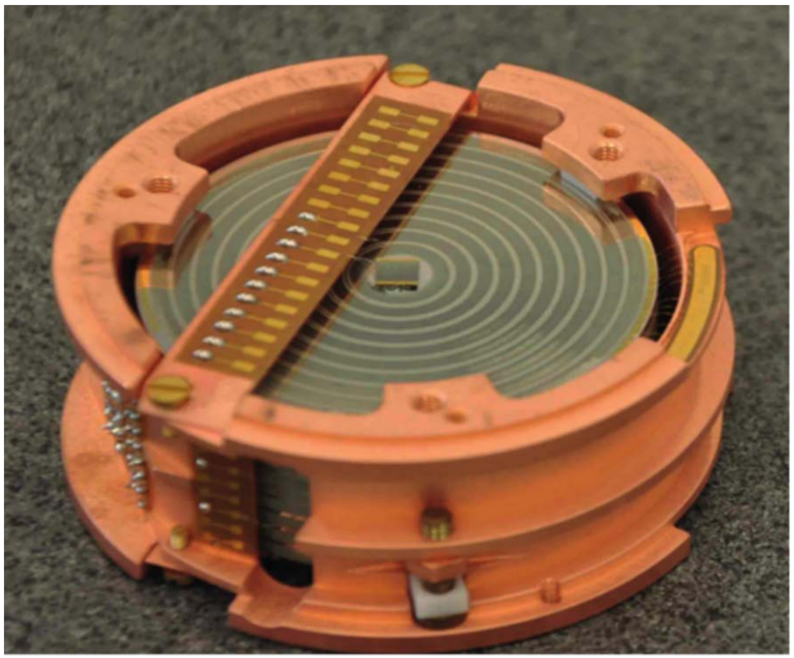
60keV bulk event
T=23mK

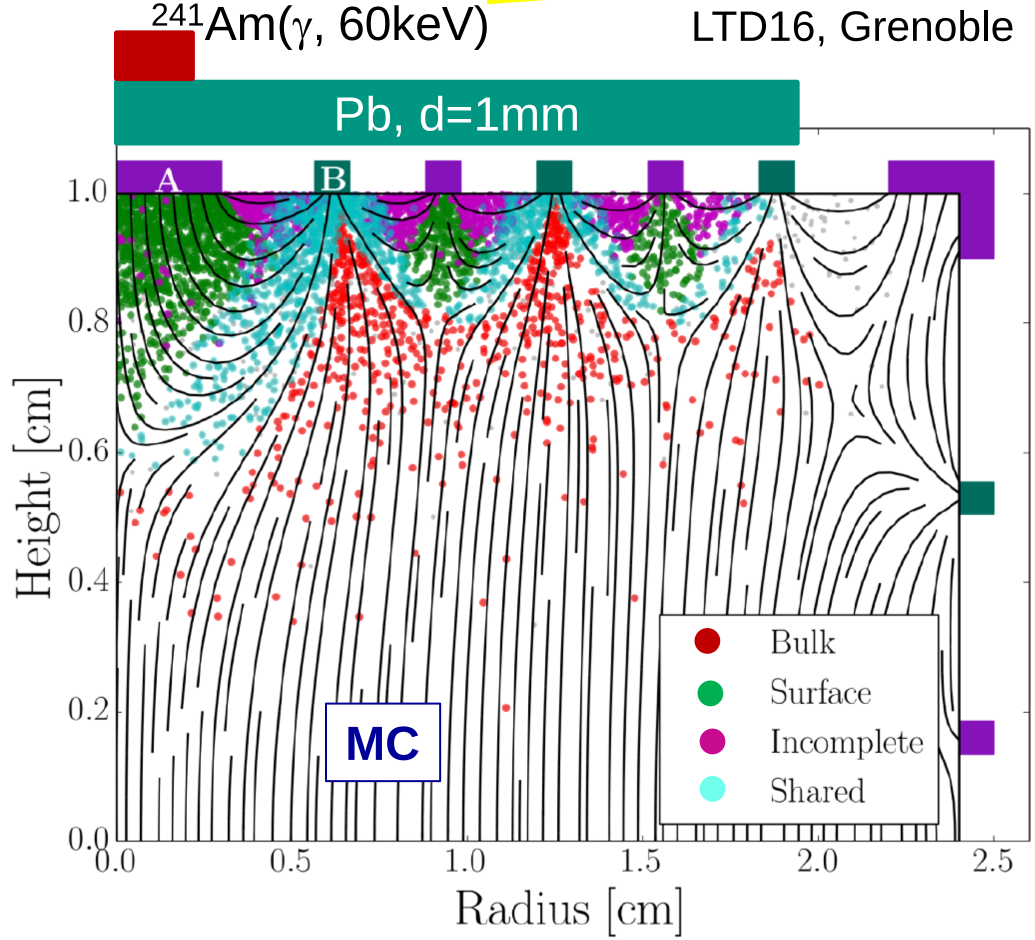
A. Broniatowski
CSNSM Orsay
LTD16 Grenoble



understanding charge collection: amplitude & shape (risetime)

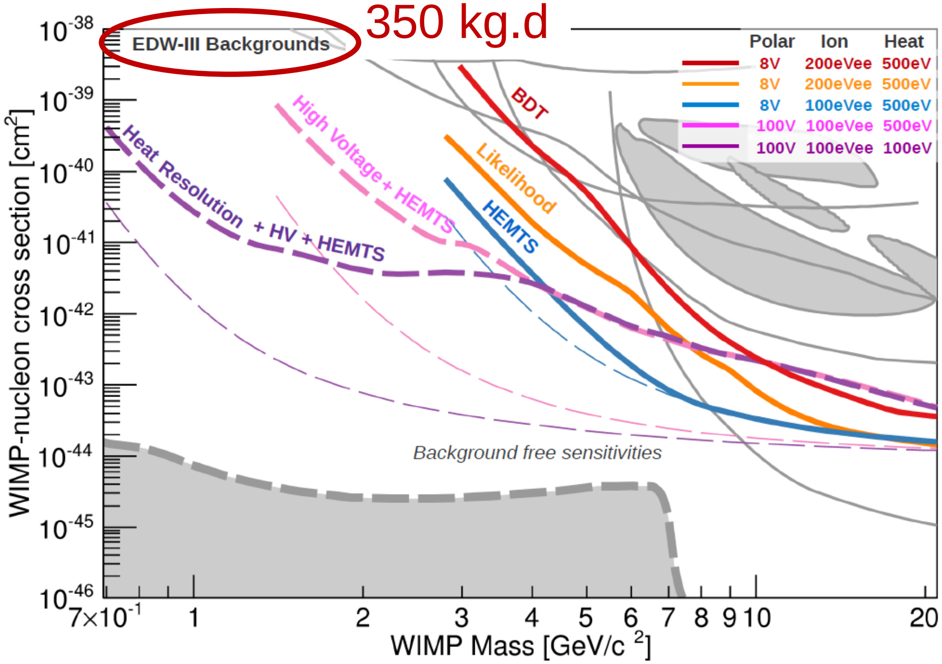
KCETA Nadine Foerster, LTD16, Grenoble

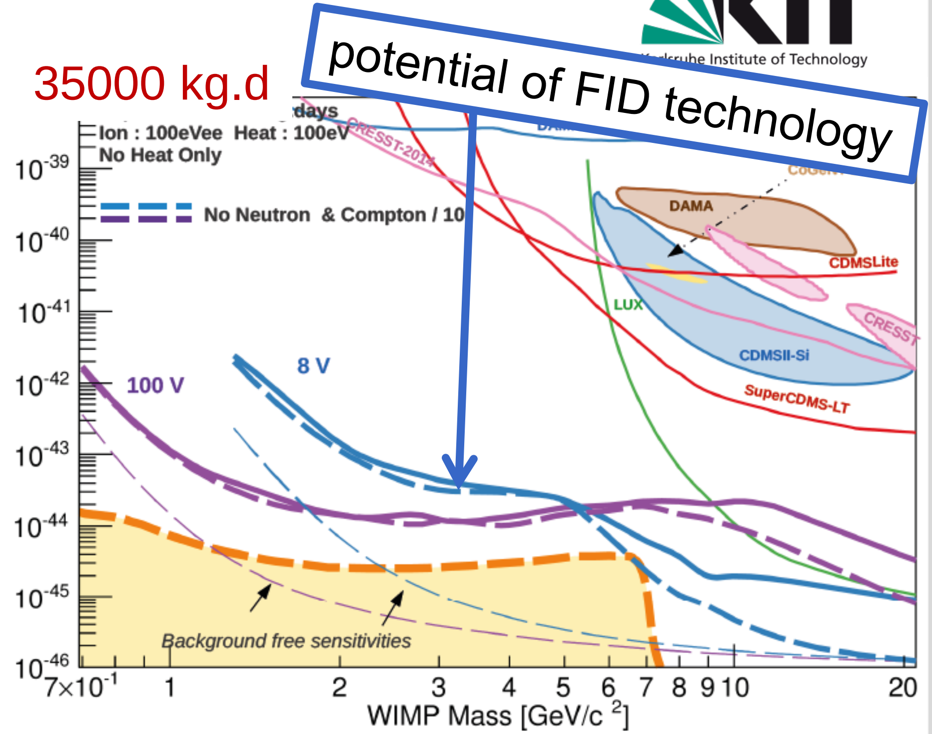




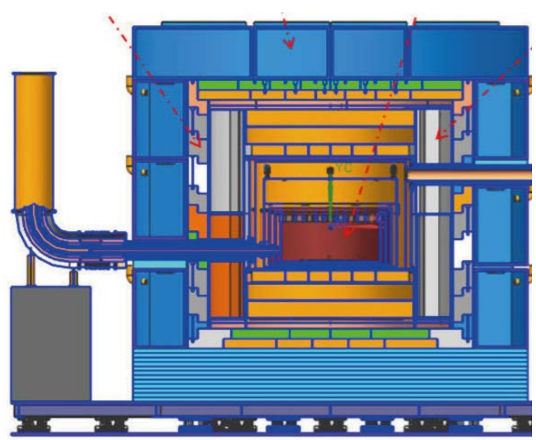
special measurements at CSNSM Orsay (together with KIT)
using a 200g n-type HP Ge crystal in planar mode, but separate readout (A,B,C,D)

EDELWEISS-III & beyond

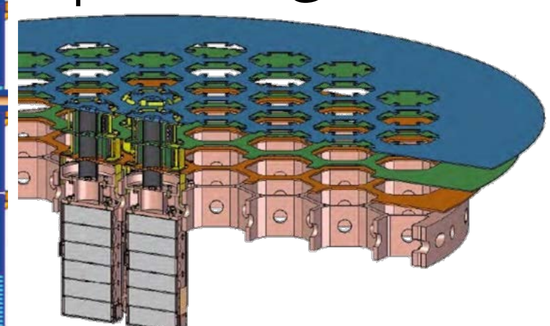




- cooperation with SuperCDMS → joint facility at SNOLAB (2019++) with common tower design for both detector technologies (SuperCDMS, EDELWEISS)
- CUTE project @ Queen´s: test cryostat @ SNOLAB by 2017

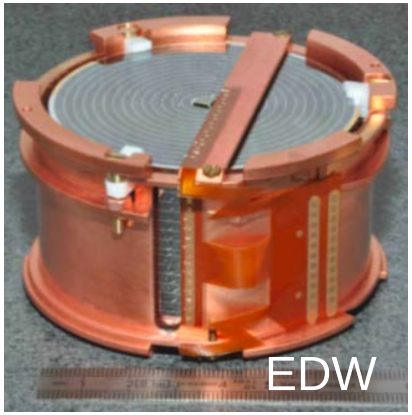


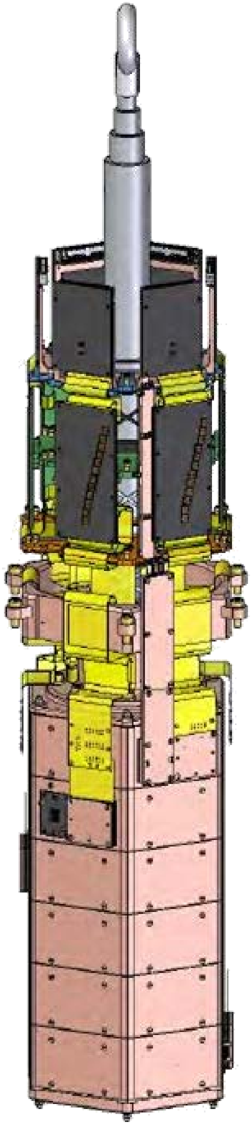
SuperCDMS@SNOLAB

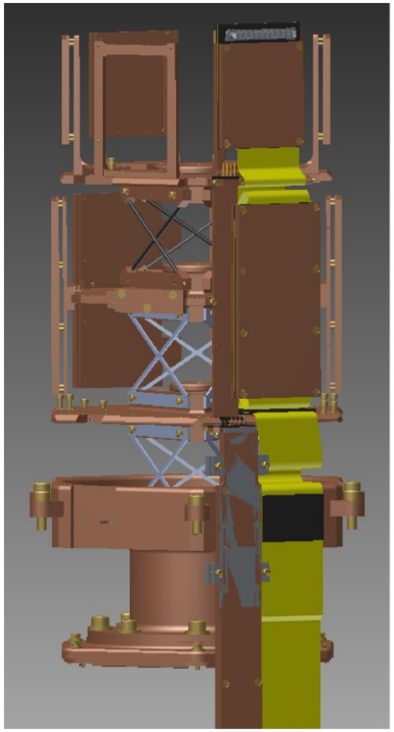


SuperCDMS/EURECA

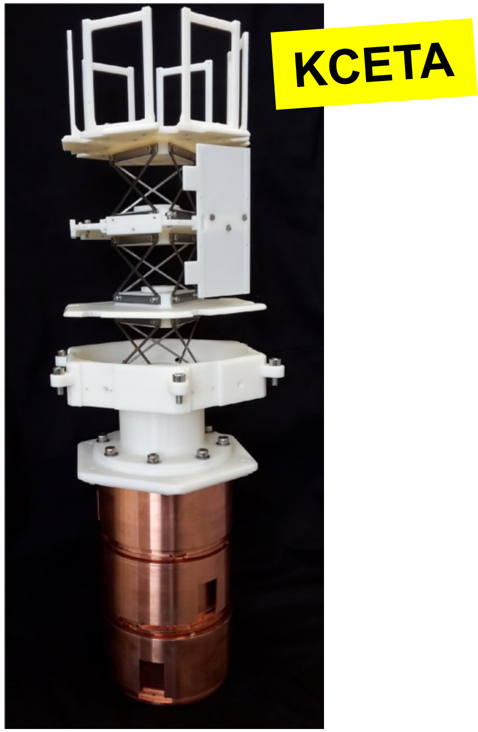
- common cryogenic infrastructure
- space for ~400kg of modular detectors
- compatible interface with tower design
- common cabling & readout electronics
- 1st phase: 50kg SCDMS + ≤50kg EURECA







SCDMS design



KIT mockup of tower

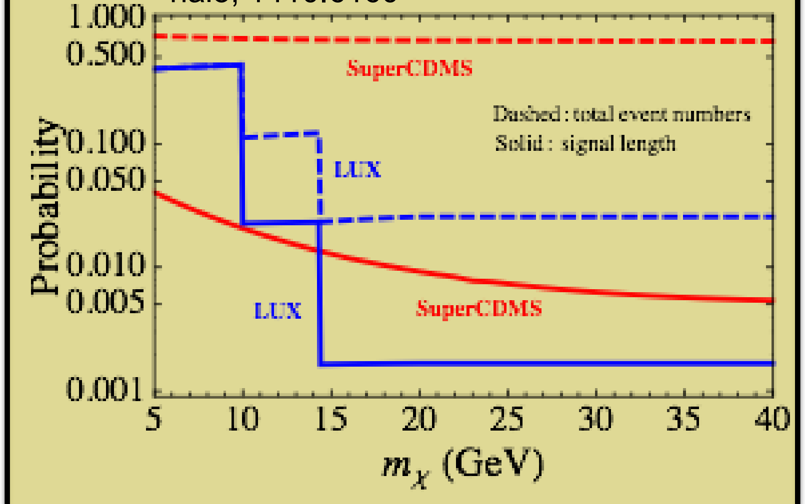
KCETA astroparticle theory group: DM theory & phenomenology

Prof. Dr. Thomas Schwetz-Mangold

Halo-independent methods for DM direct detection:

- comparison of different direct detection experiments
  Bozorgnia, Schwetz, 1410.6160
- comparison of direct detection with neutrinos from the sun
  Blennow, Herrero-Garcia, Schwetz,1502.03342
- comparison of direct detection with LHC and relic density
  Blennow, Herrero-Garcia, Schwetz, Vogl,1505.05710

prob. that CDMS-Si excess is compatible with LUX or SuperCDMS, irrespective of assumptions on the halo, 1410.6160



Simplified models for DM:

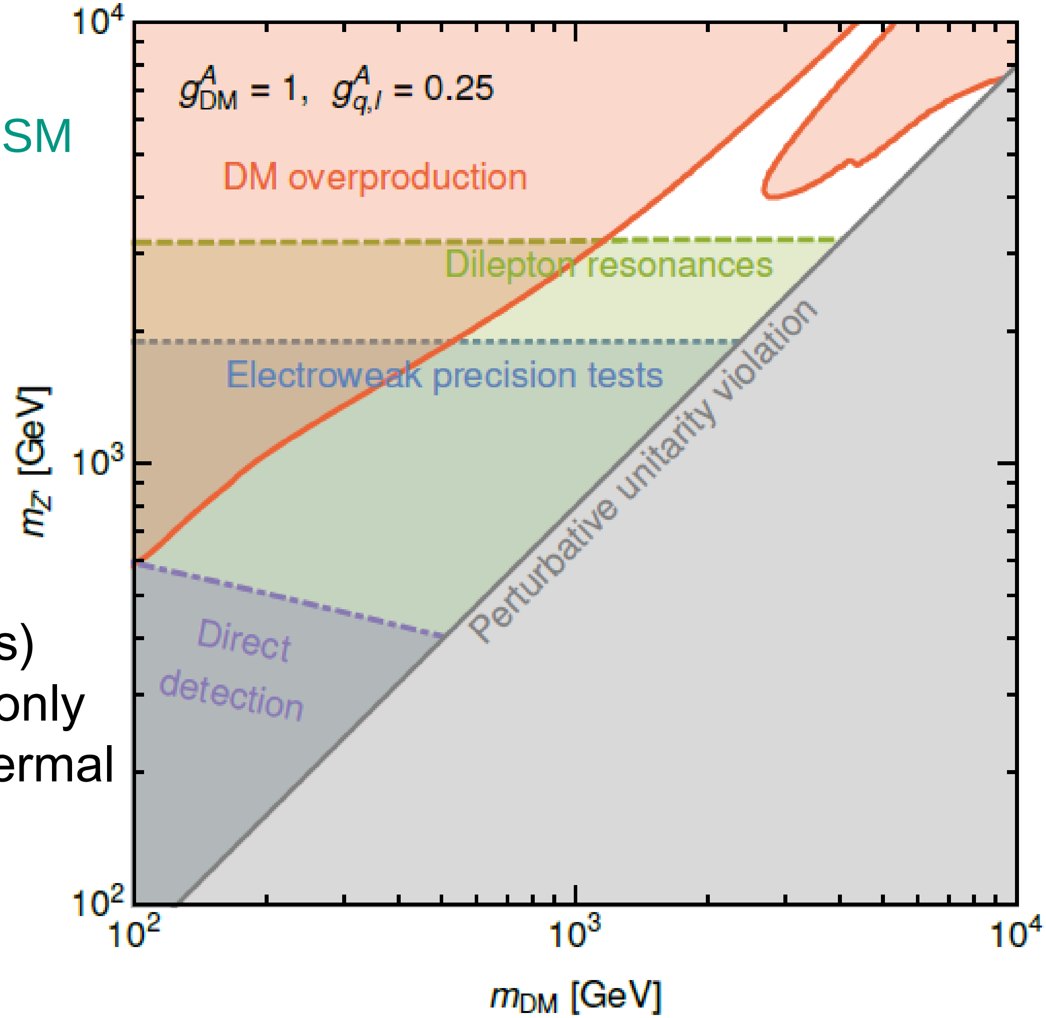
- Implications of unitarity and gauge invariance for simplified DM models,
  Kahlhoefer, Schmidt-Hoberg, Schwetz, Vogl, 1510.02110
- Flavored dark matter beyond Minimal Flavor Violation,
  Agrawal, Blanke, Gemmler, 1405.6709

KCETA astroparticle theory group: DM theory & phenomenology

Karlsruhe Institute of Technology

Simplified model for DM:
Majorana DM + Z' mediator with the SM

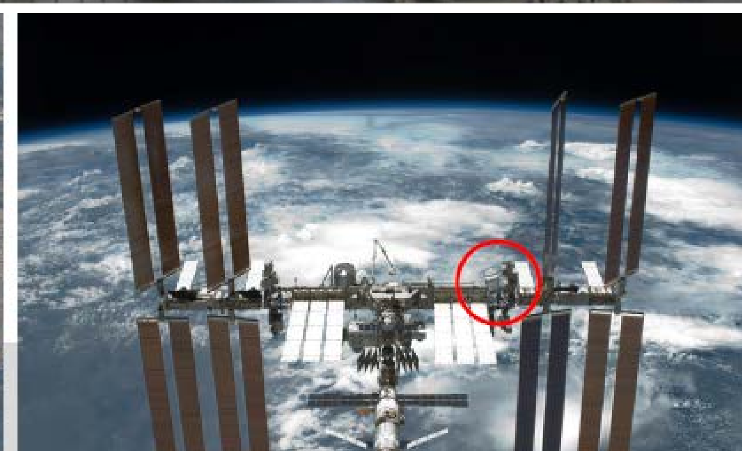
Imposing gauge invariance and perturbative unitarity leads to additional signatures (EWPT & dilepton resonances) which provide stronger constraints than traditional searches (monojets)
→ model gets highly constrained: only white region survives under the thermal WIMP hypothesis



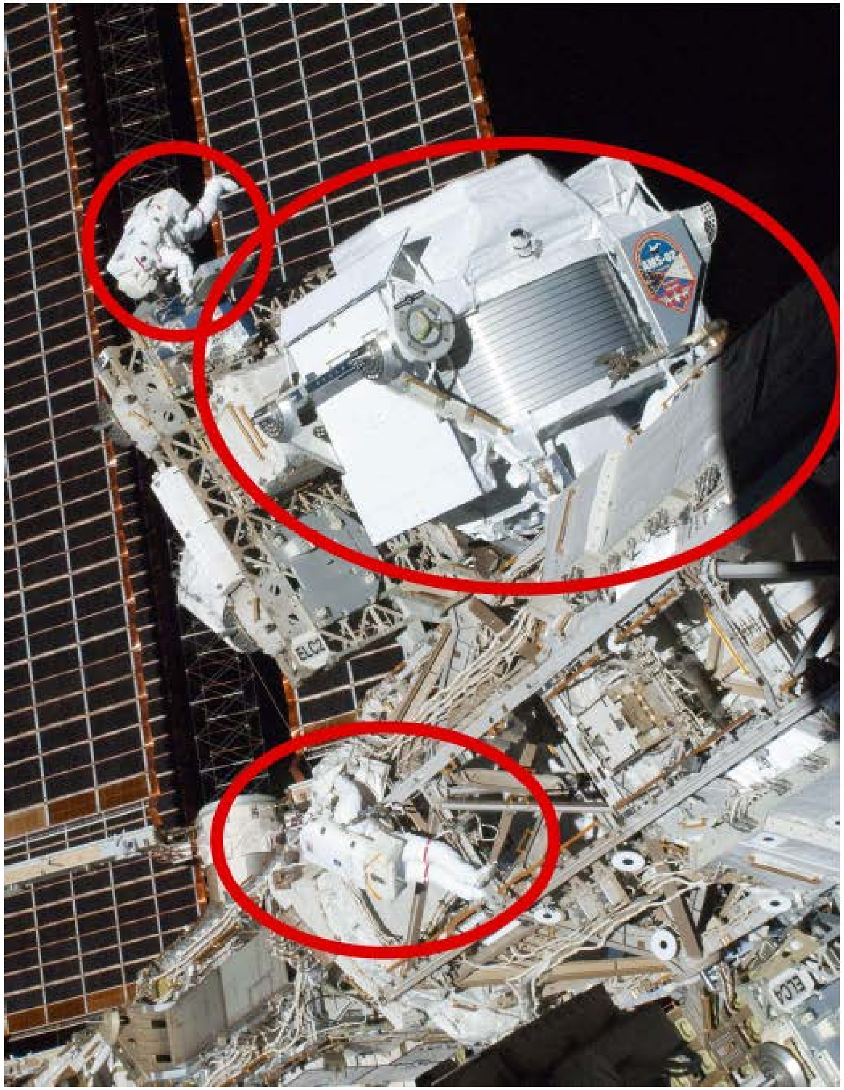
Kahlhoefer, Schmidt-Hoberg, Schwetz, Vogl, 1510.02110

AMS-02 team @ KCETA


Dr. Iris Gebauer



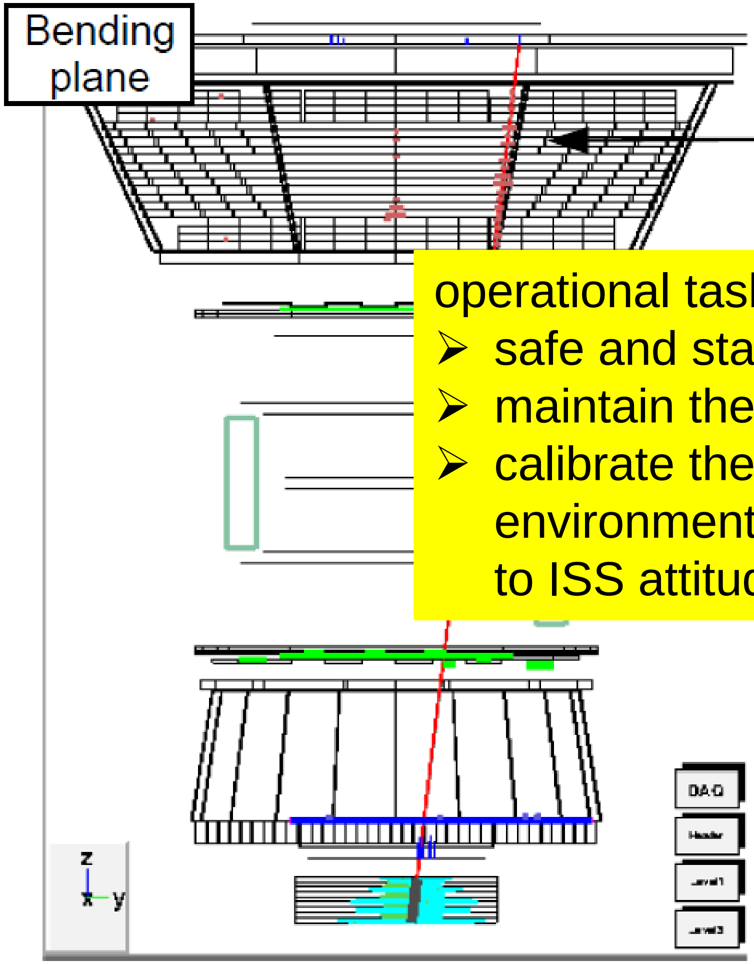
AMS-02: The Alpha Magnetic Spectrometer 02



- **Volume** 64 m^3, height 4 m
- **Weight** 8500 kg
- **Power** 2500 W
- **Data downlink** 9 Mbps (minimum)
- **Magnetic field** 0.15 T (400 x Earth, PAMELA: 0.4 T, but H=44.5 cm)
- **Launch** May 16th, 2011 (Endeavour)
- **Data taking** as of May 19th, 2011
- **Construction** 1999-2010 (>3 PhD generations)
- **Mission duration:** until the end of ISS operation (currently 2024)

AMS-02 collaboration

AMS-02 @ KCETA



320 GeV positron

Transition Detector Radiation TRD
Identifies e+/e- (Xrays)

operational tasks of KCETA group:

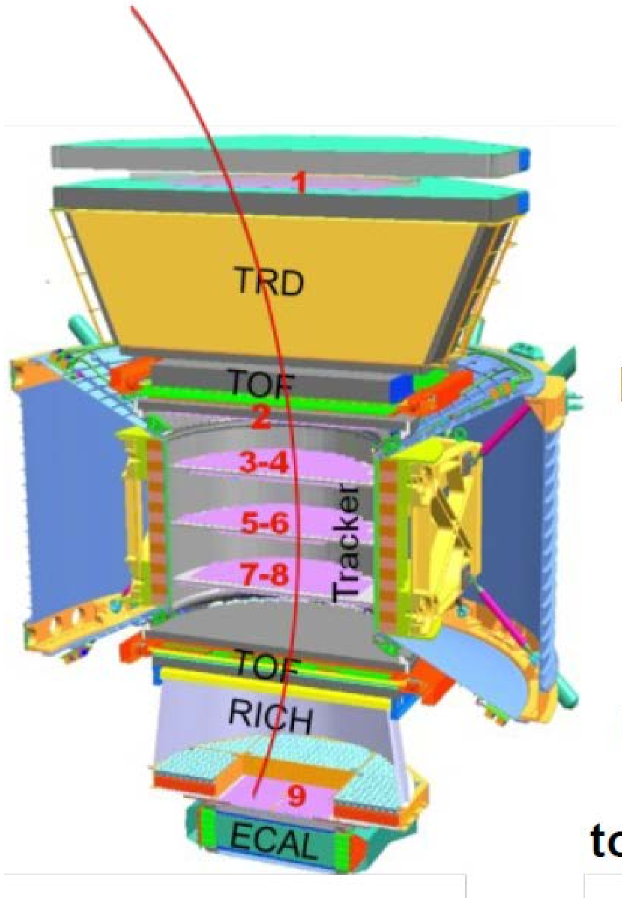
- safe and stable operation of the TRD from the ground
- maintain the detector in optimal science data taking conditions
- calibrate the detector gain response to time dependent environmental influences, such as temperature variations due to ISS attitude changes

Ring Imaging Cherenkov RICH
Velocity β / Charge Q /

Electromagnetic Calorimeter ECAL
Measure energy / Identifies e+/e- (shower shape)

Most particle properties are measured redundantly

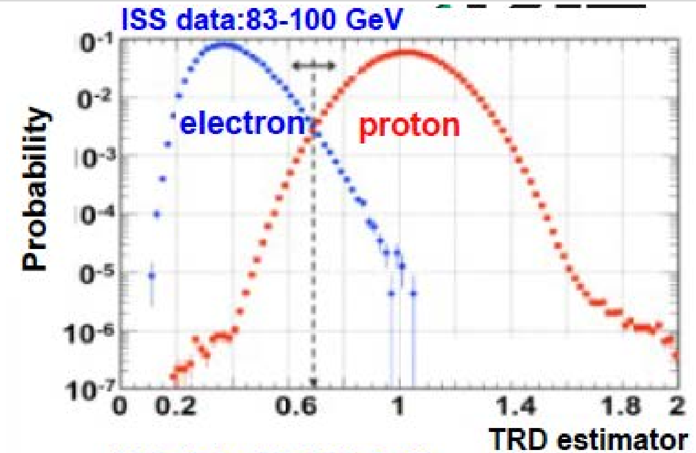
AMS-02 measuring electrons and positrons

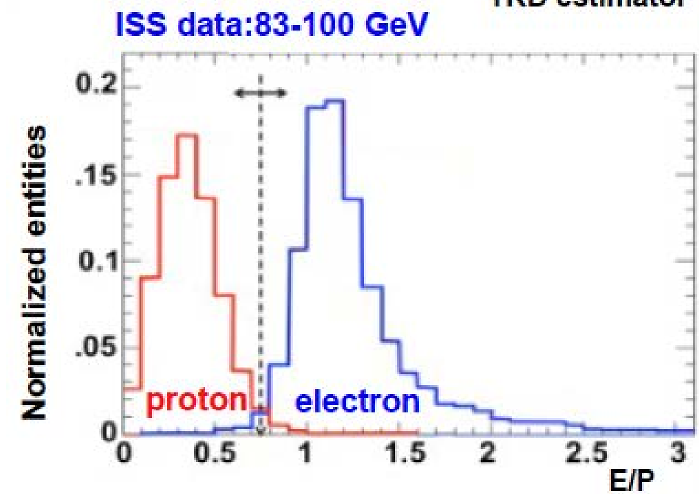


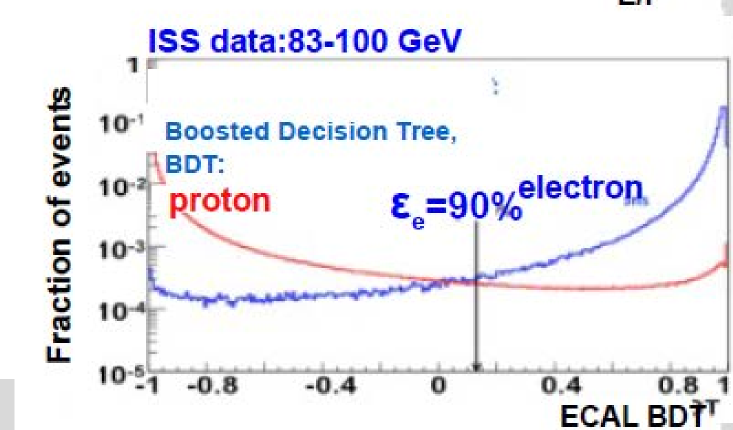
TRD
identifies e$^{\pm}$

TRACKER
measures P
ECAL measures E
e$^{\pm}$: E=P
proton: E<P

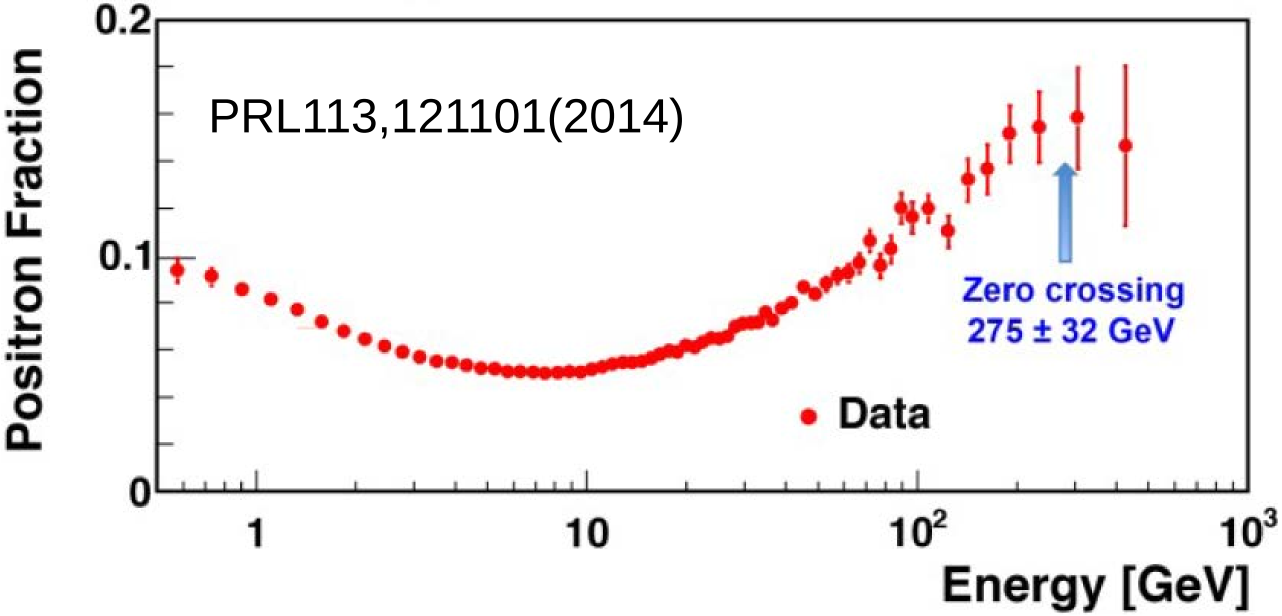
ECAL
measures E and shower shape
to separate e$^{\pm}$ from protons



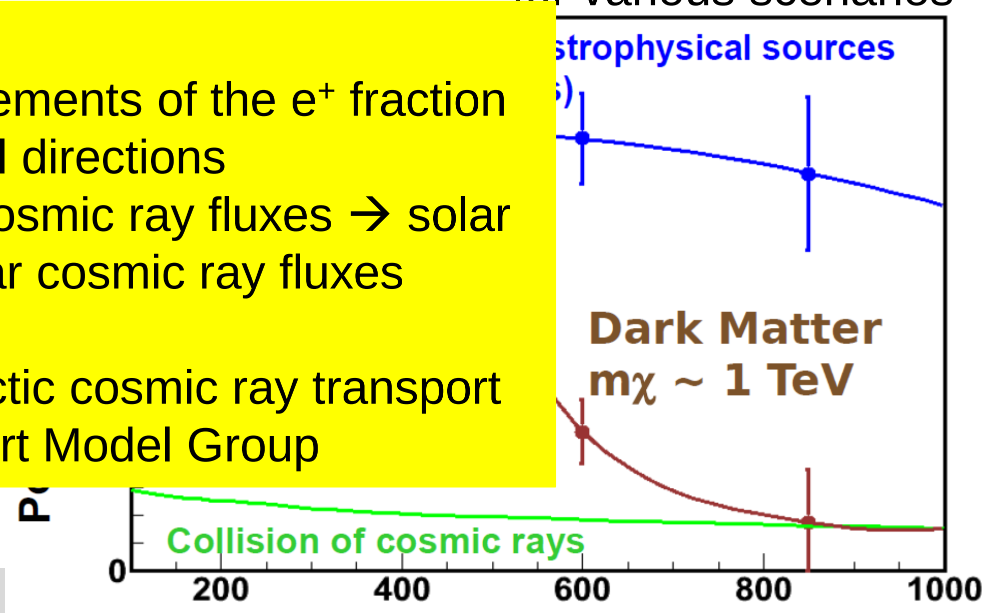




AMS-02 positron fraction



expectations
for various scenarios



KCETA group analyses:

- independent complementary measurements of the e^+ fraction
- anisotropies in the cosmic rays arrival directions
- time dependence in the low energy cosmic ray fluxes → solar wind effects modulating the interstellar cosmic ray fluxes

- numerical large scale studies of galactic cosmic ray transport
- IG leading AMS Cosmic Ray Transport Model Group

Vielen Dank! 谢谢