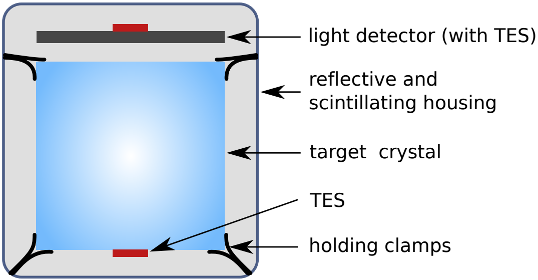
Status of the CRESST Dark Matter Search

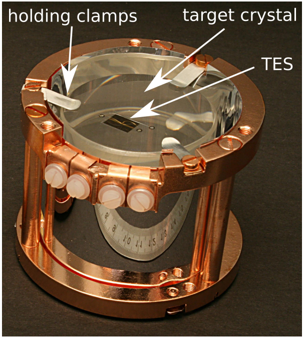
Anja Tanzke

Max-Planck-Institute for Physics

YSW Ringberg 2015, 7.7.2015

Detector Module

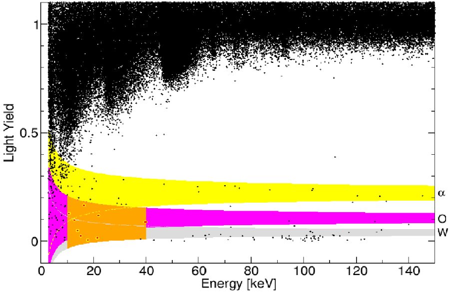




Non-scintillating surfaces on reflective bronze holding clamps!

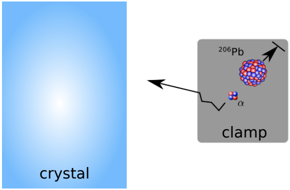
Background from surface contamination with ^{210}Po

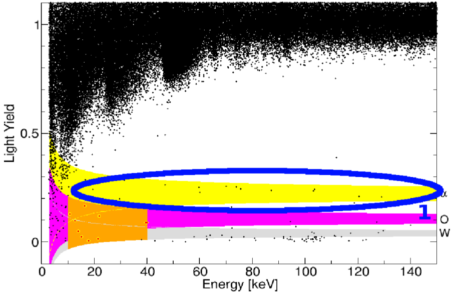
$$^{210}\text{Po} \rightarrow {}^{206}\text{Pb}(103\,\text{keV}) + \alpha\ (5.3\,\text{MeV})$$



Background from surface contamination with ^{210}Po

$$^{210}\mathrm{Po} \rightarrow {}^{206}\mathrm{Pb}(103\,\mathrm{keV}) + \alpha\ (5.3\,\mathrm{MeV})$$

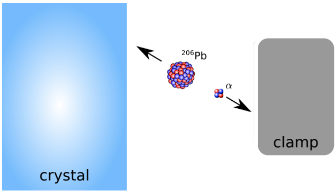


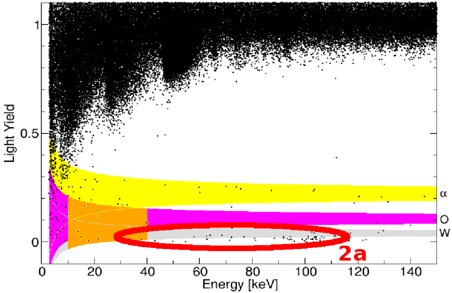


1. Decay inside clamp material

Background from surface contamination with ^{210}Po

$$^{210}\text{Po} \rightarrow {}^{206}\text{Pb}(103\,\text{keV}) + \alpha\ (5.3\,\text{MeV})$$

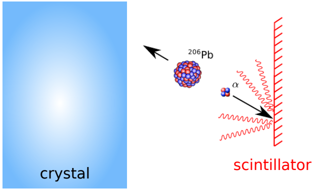


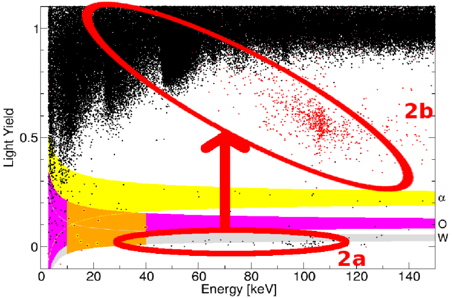


1. Decay inside clamp material
2. Decay on or slightly below surface of clamp
   (a) α hitting clamp $\rightarrow$ no scintlillation light

Background from surface contamination with ^{210}Po

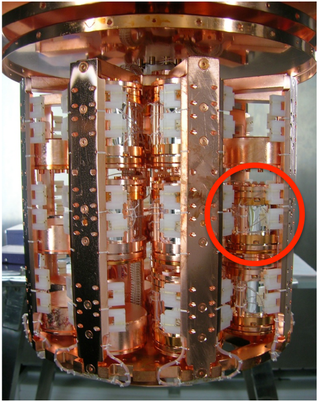
$$^{210}\text{Po} \rightarrow {}^{206}\text{Pb}(103\,\text{keV}) + \alpha\ (5.3\,\text{MeV})$$





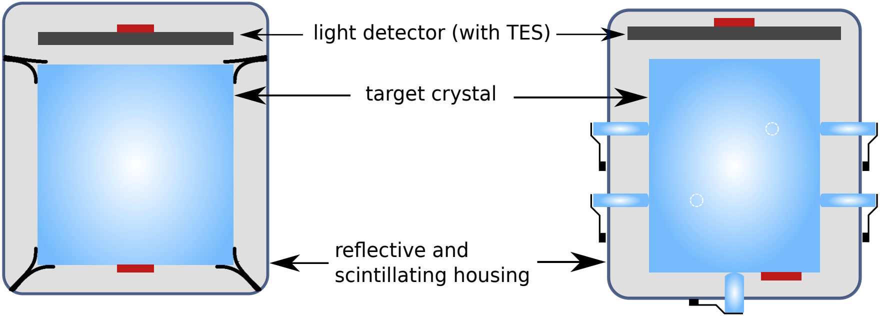
1. Decay inside clamp material
2. Decay on or slightly below surface of clamp
   (a) α hitting clamp → no scintlillation light
   (b) α hitting scintillating material → additional scintlillation light (with different pulse shape)

CRESST-II Phase 2



- Data-taking since July 2013
- 18 detector modules (5 kg target mass)
- Upgraded Detector Modules: 3 new detector designs
- Focus on one detector module TUM40
  - 29 kg days of data
  - nonblinded data set from August 2013 to December 2013

TUM40



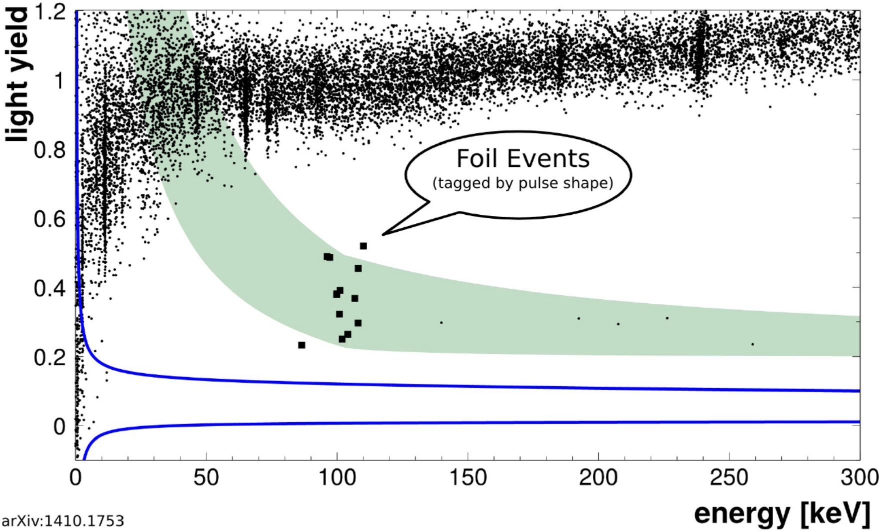
conventional module

crystal held by non-scintillating reflective bronze clamps

TUM40

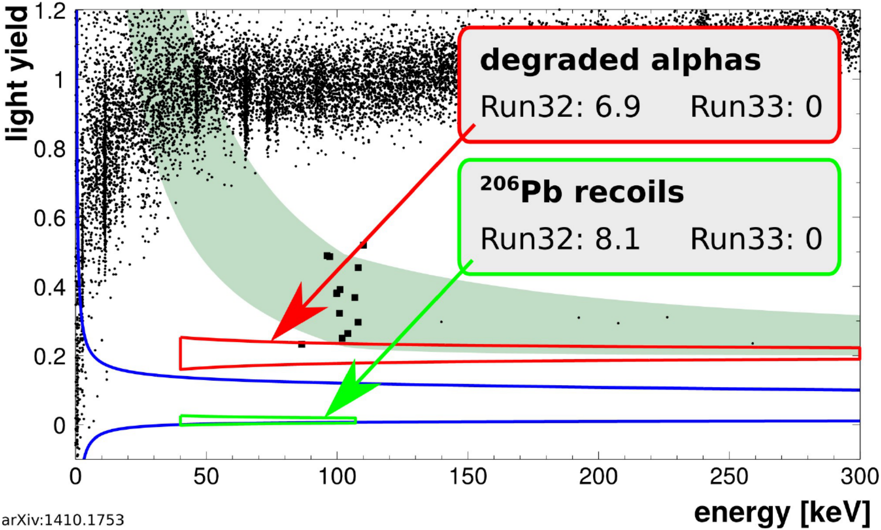
crystal held by $CaWO_4$ sticks pressed by clamps outside the reflective housing
→ fully-scintillating housing

Veto of Surface Events



arXiv:1410.1753

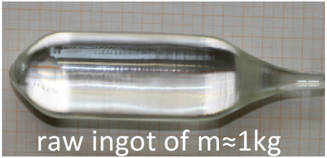
Veto of Surface Events

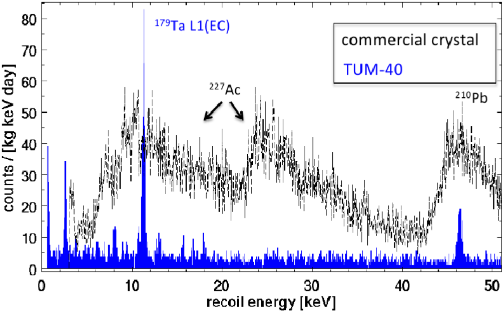


arXiv:1410.1753

TUM40: Radiopurity

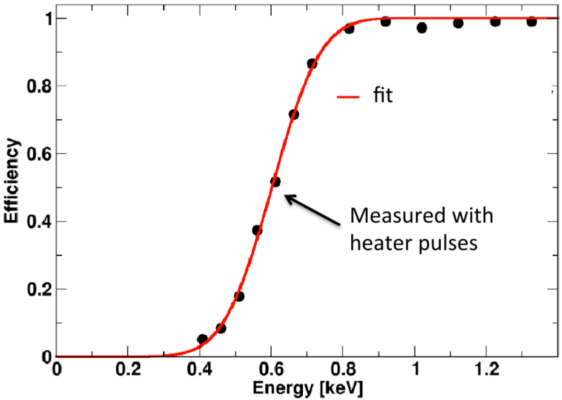
- $CaWO_4$ crystal production at TUM
- improvement of e^-/γ background below 50 keV by a factor of 2-10
- TUM40: average rate 3.44/(kg keV day)





- γ-lines caused by cosmogenic activation
- Energy resolution $\sigma \sim$100 eV
- all lines agree within <5 eV to tabulated values

TUM40: Trigger Threshold

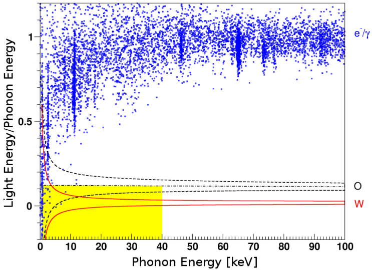


extremely low trigger threshold of $E_{th} \sim 603\,\text{eV}$

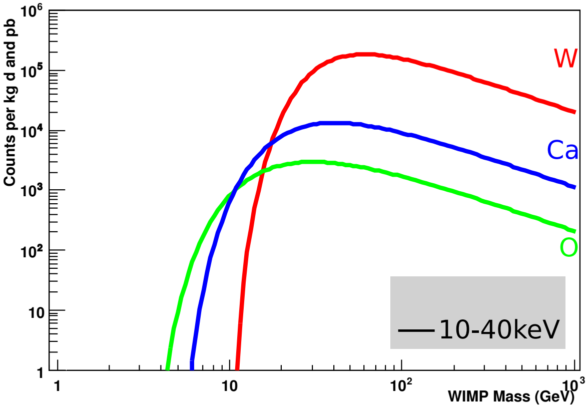
TUM40: Results after 29 kg days

- Fully-efficient veto of surface backgrounds
- Unprecedented radiopurity
- Very low trigger threshold of $\sim$600 eV
- Excellent resolution of $\sim$100 eV

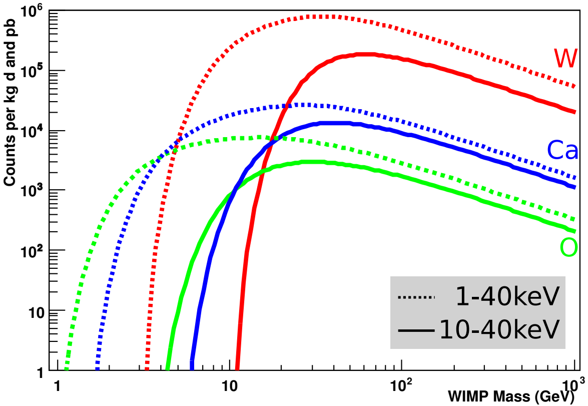
$\rightarrow$ Low-threshold Dark Matter analysis



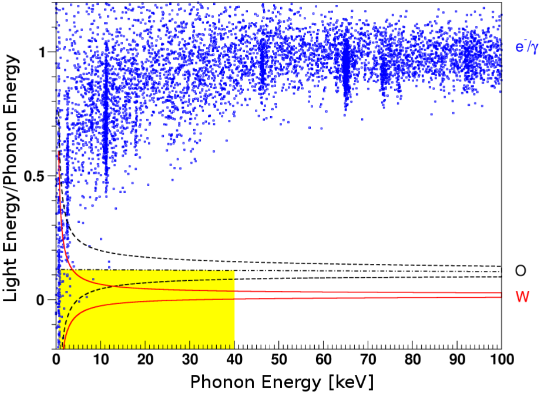
Low Threshold Analysis - Motivation

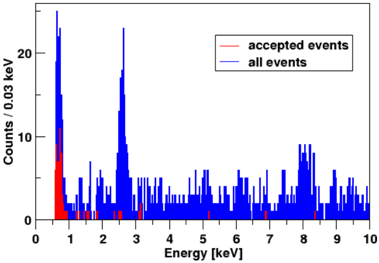


Low Threshold Analysis - Motivation



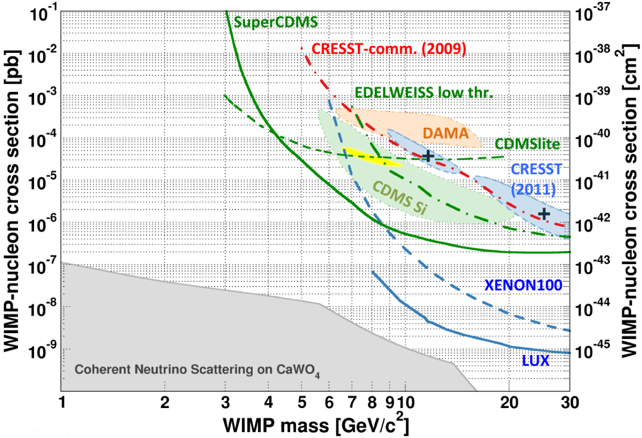
TUM40: Acceptance Region



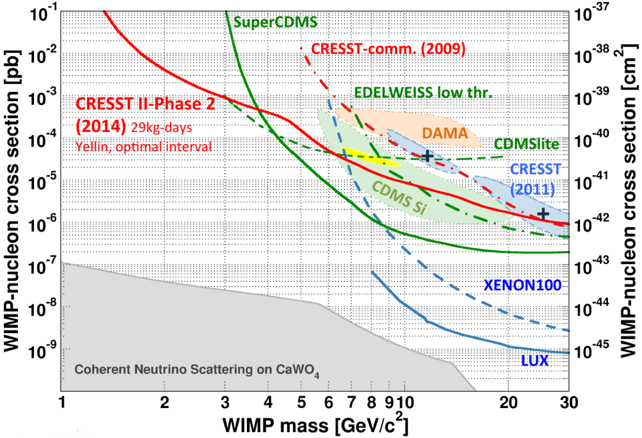


- WIMP-Acceptance region:
  - $600\,\text{eV} < \text{E} < 40\,\text{keV}$
  - LY < 50% O-band
- all events are considered as WIMP scatters

WIMP-Landscape Summer 2014

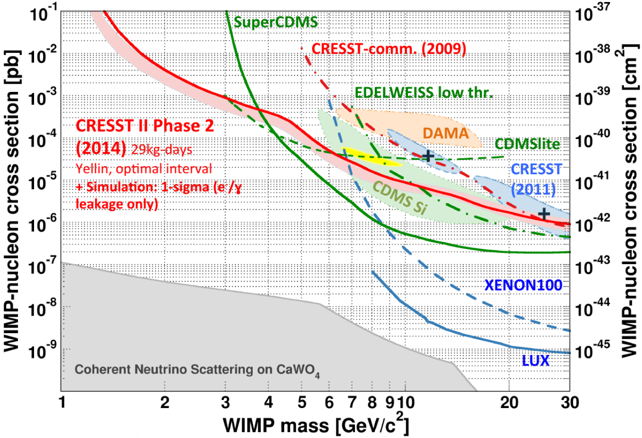


Results from 29 kg days of TUM40



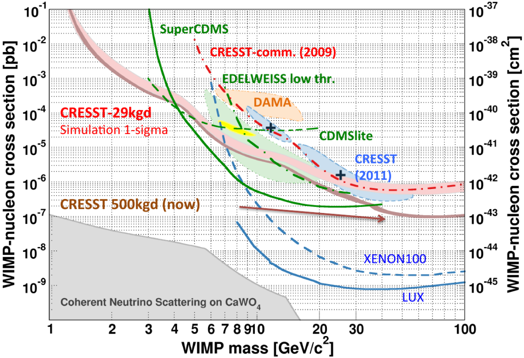
- M2 completely ruled out
- New parameter space explored for WIMP masses below 3 GeV/c^2

Data vs. Simulation



- M2 completely ruled out
- New parameter space explored for WIMP masses below 3 GeV/c^2
- Events in acceptance region can be explained with e^-/γ background only

Goal for CRESST II Phase 2

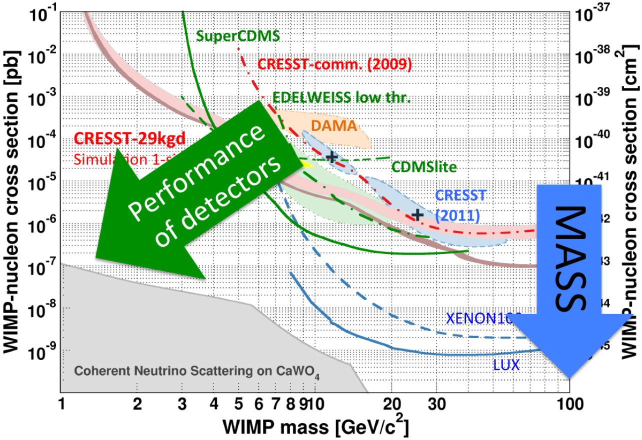


- 500 kg days reached end of May
- threshold of several detectors lowered <400 eV $\rightarrow$ further improvement in low mass WIMP region possible

Analysis strategy:

- use non-blinded data set (115 live days) for definition of data quality cuts, trigger efficiencies and selection of detectors
- Apply to blinded data set (since January 2014)

Future Strategy for CRESST III



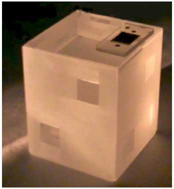
CRESST proved high potential for low-mass WIMP search

→ Increase Performance of detectors

CRESST III: Low-mass WIMP search

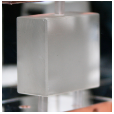
Increase performance of detectors with small crystals (m$\sim$24 g) with at least TUM40 quality

TUM40
m=250g



scale down size by a factor of 10

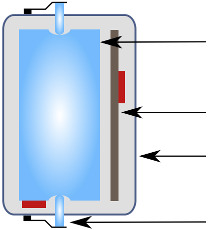
m=24g

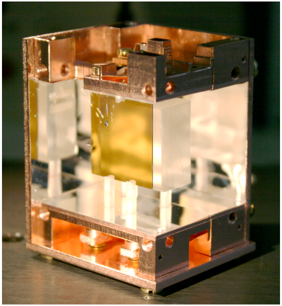


phonon detector threshold $\sim$ 400 eV — **improvement by factor of 5**

light detector resolution $\sim$ 5 eV — **improvement by factor of 2**

CRESST III: Detector modules for low-mass WIMP search

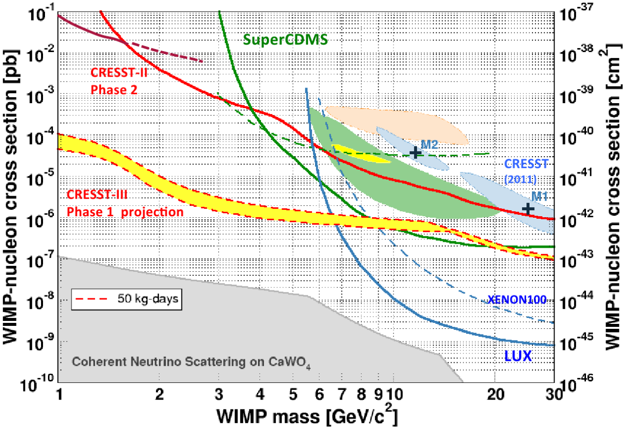




- Prototype successfully tested (threshold of 100 eV reached)
- Production of detector modules ongoing

CRESST III will start end of this year

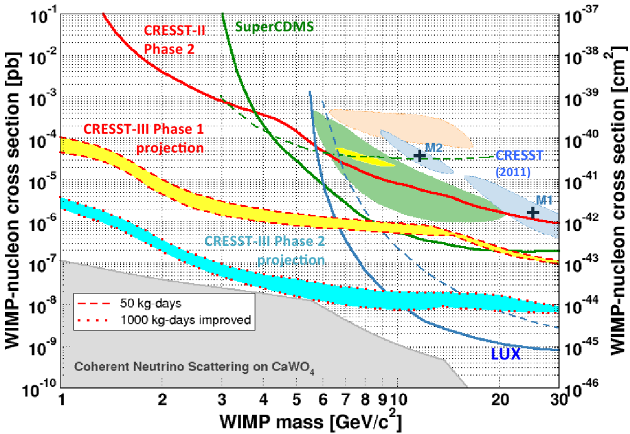
Projection for CRESST III Phase 1



CRESST III Phase 1

50 kg days: 10 small crystals (m=24 g) operated for 1 year

Projection for CRESST III Phase 2



CRESST III Phase 2

- 1 tonne days: 100 modules, 2 years
- crystal radiopurity improved by a factor of 100

Conclusions

CRESST II Phase 2

- CRESST technology proved high potetial for low-mass WIMP search
- CRESST II Phase 2 probed new region of parameter space below $3\,\mathrm{GeV}/c^2$

CRESST III

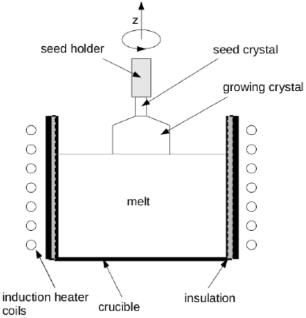
- Potential to explore low-mass WIMP region
- Starting end of 2015

Backup Slides

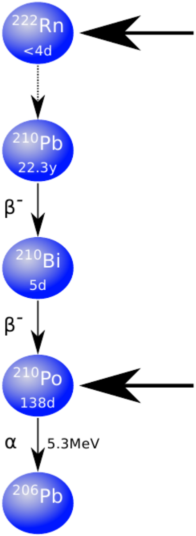
Crystal Growth via Czochralski Method

- Production of $CaWO_4$ powder via solid state reaction: $CaCO_3 + WO_3 \rightarrow CaWO_4 + CO_2$

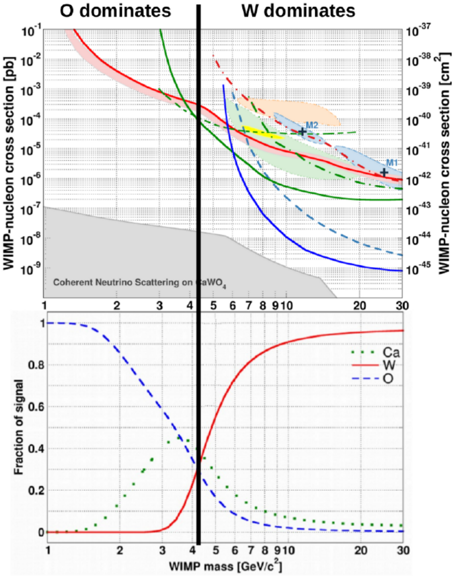
- Melting of $CaWO_4$ powder in Rh crucible of Czochralski furnace
- Lowering of seed crystal into $CaWO_4$ melt
- Drawing in z direction under rotation
  $\Rightarrow$ Formation of a cylindrically shaped crystal with crystallographic orientation of seed crystal



Radon decay chain



Multi-Element Target $CaWO_4$



TUM40: Cut Efficiency