Quenching Factor Measurements of $CaWO_4$ at mK Temperatures

Direct Dark Matter Search with CRESST

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on behalf of the CRESST collaboration

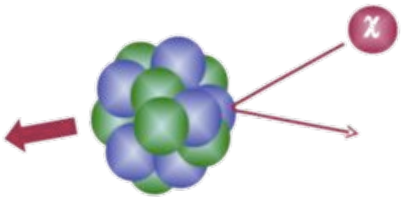
LTD-15, Caltech
Pasadena, 28.06.2013

Outline

- Cryogenic CRESST Detectors
- Final Results of Quenching Factor Measurements of $CaWO_4$ at mK Temperatures
- New Dark Matter Run of CRESST

CRESST in a Nutshell

Elastic WIMP-nucleus scattering



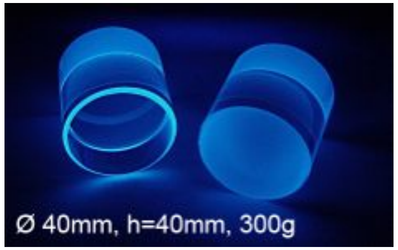
Challenge:

- Low rates (<0.1/kg/day)
- Tiny recoil energies *O*(10keV)

$CaWO_4$ as Target Material

^{16}O

^{40}Ca

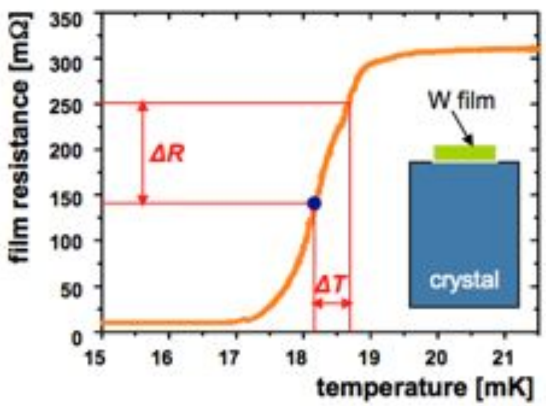


^{184}W

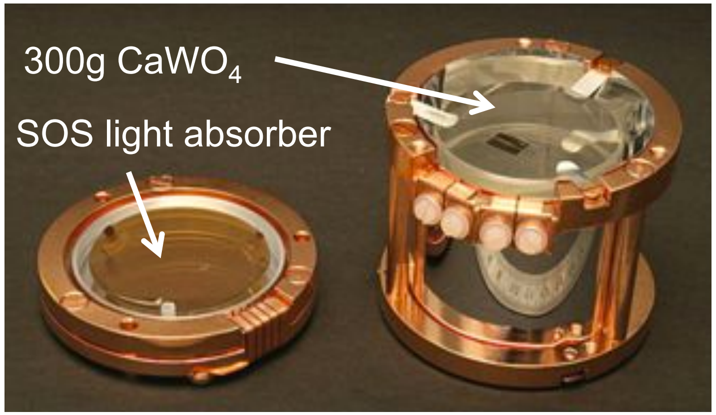
Scintillating crystals → LIGHT

Cryogenic detector → PHONON

Cryogenic Detectors with TES

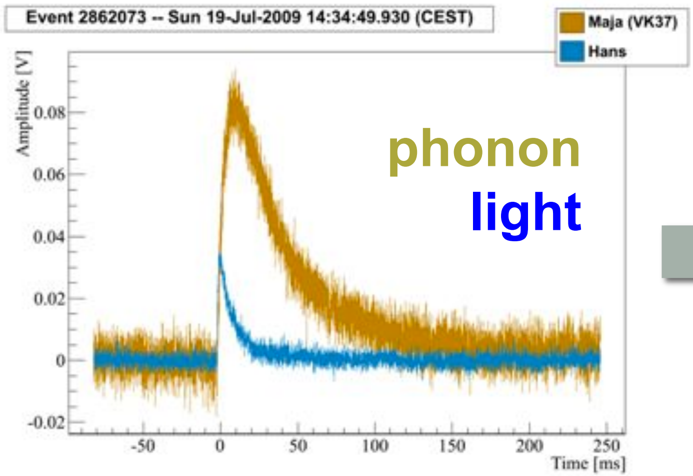


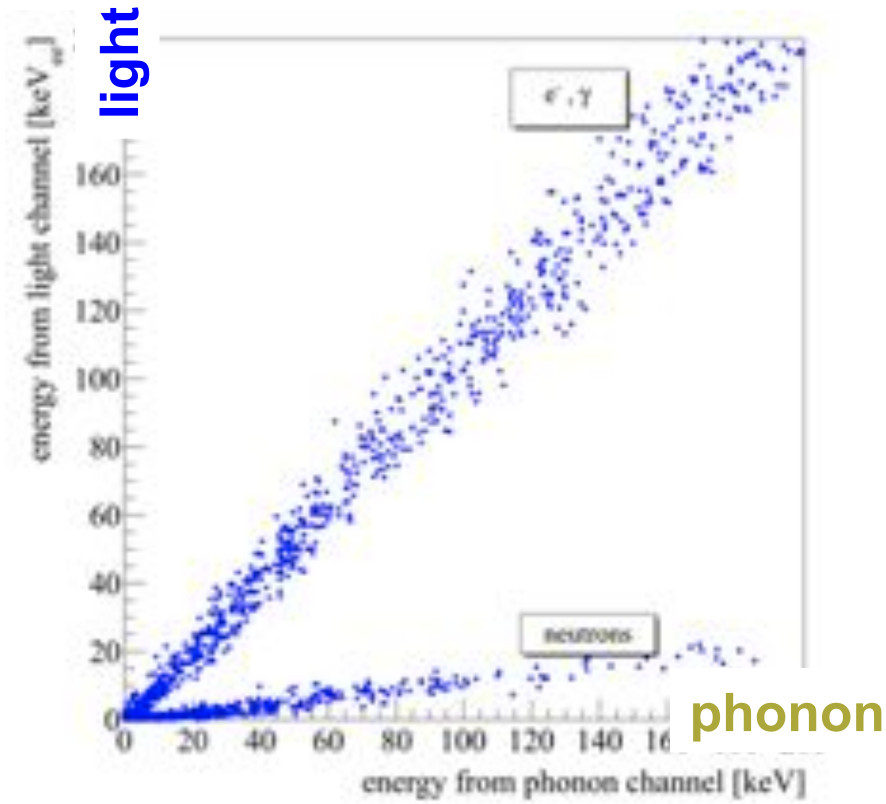
Realization – Detector Module



Phonon-Light Technique

Simultaneous Measurement
of phonon and light signal

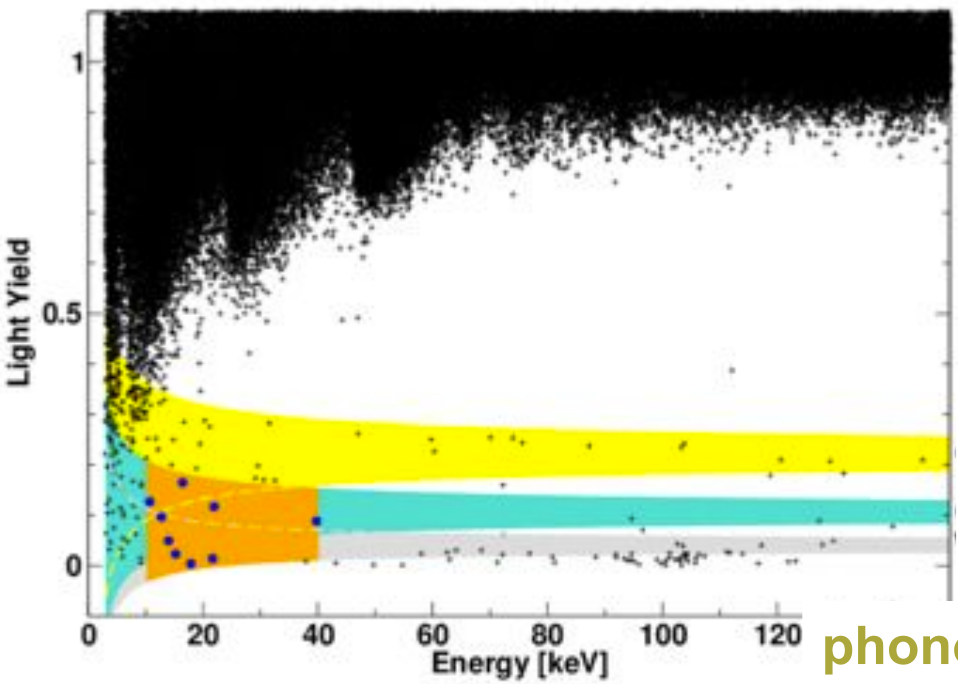




Reduced light output for highly ionizing particles → Quenching

Typical CRESST Detector Module (Run32)

light yield = $\frac{\text{light}}{\text{phonon}}$



phonon

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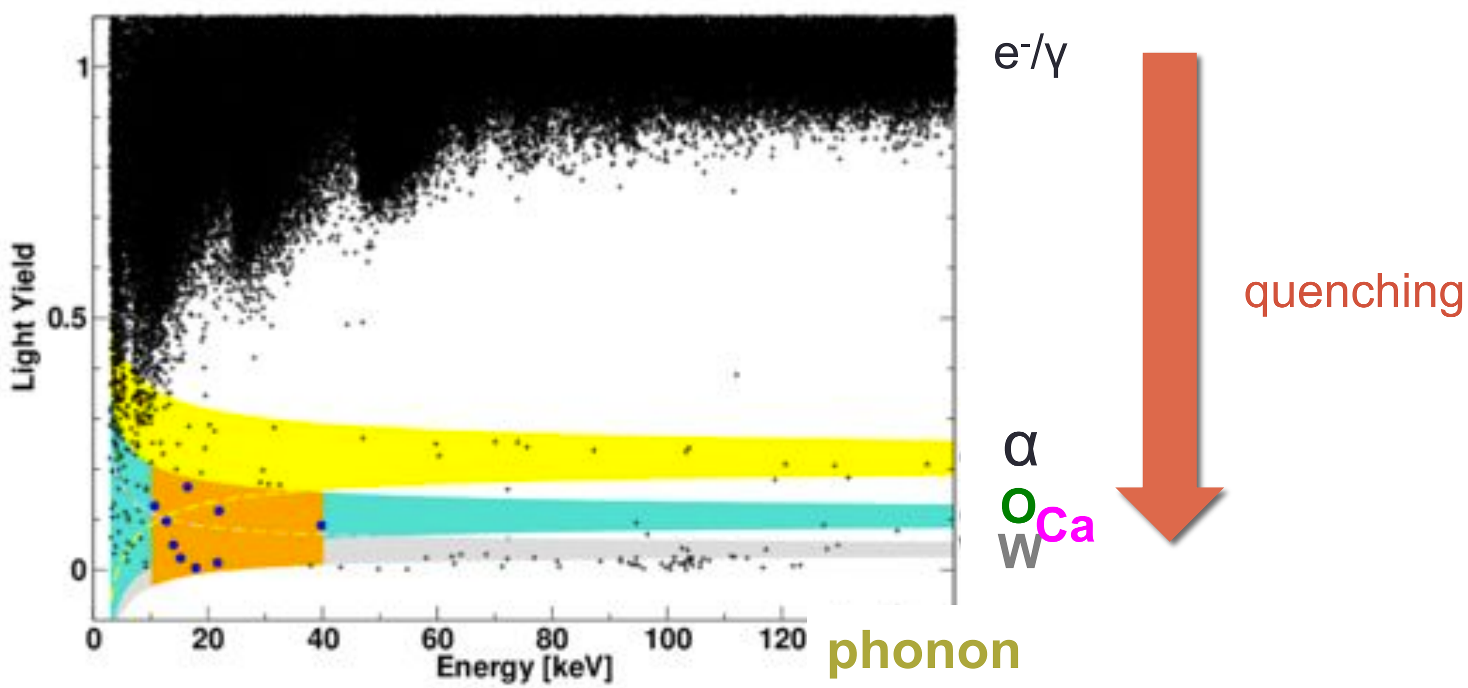

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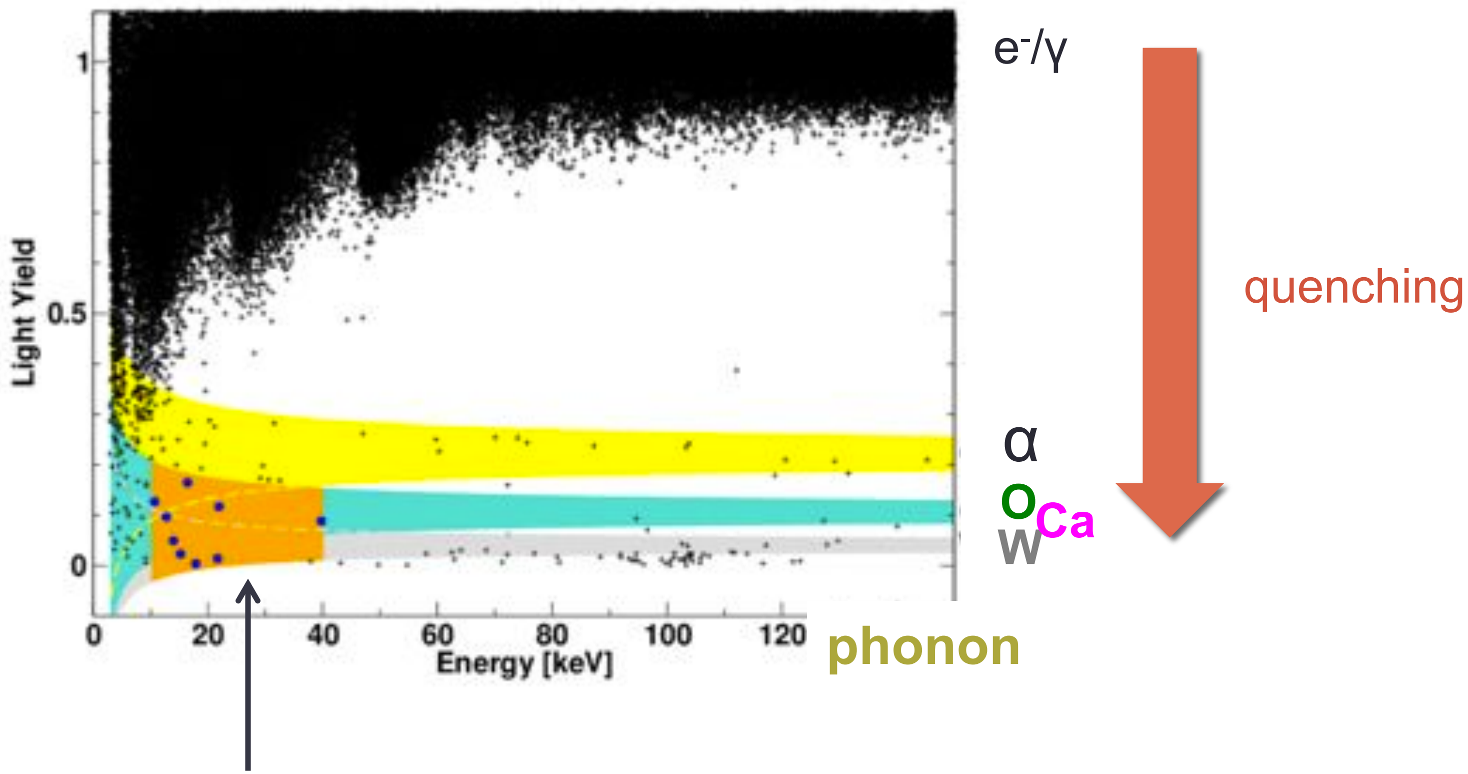

Acceptance region for WIMP scattering
typ. 12-40 keV (O + Ca +W)

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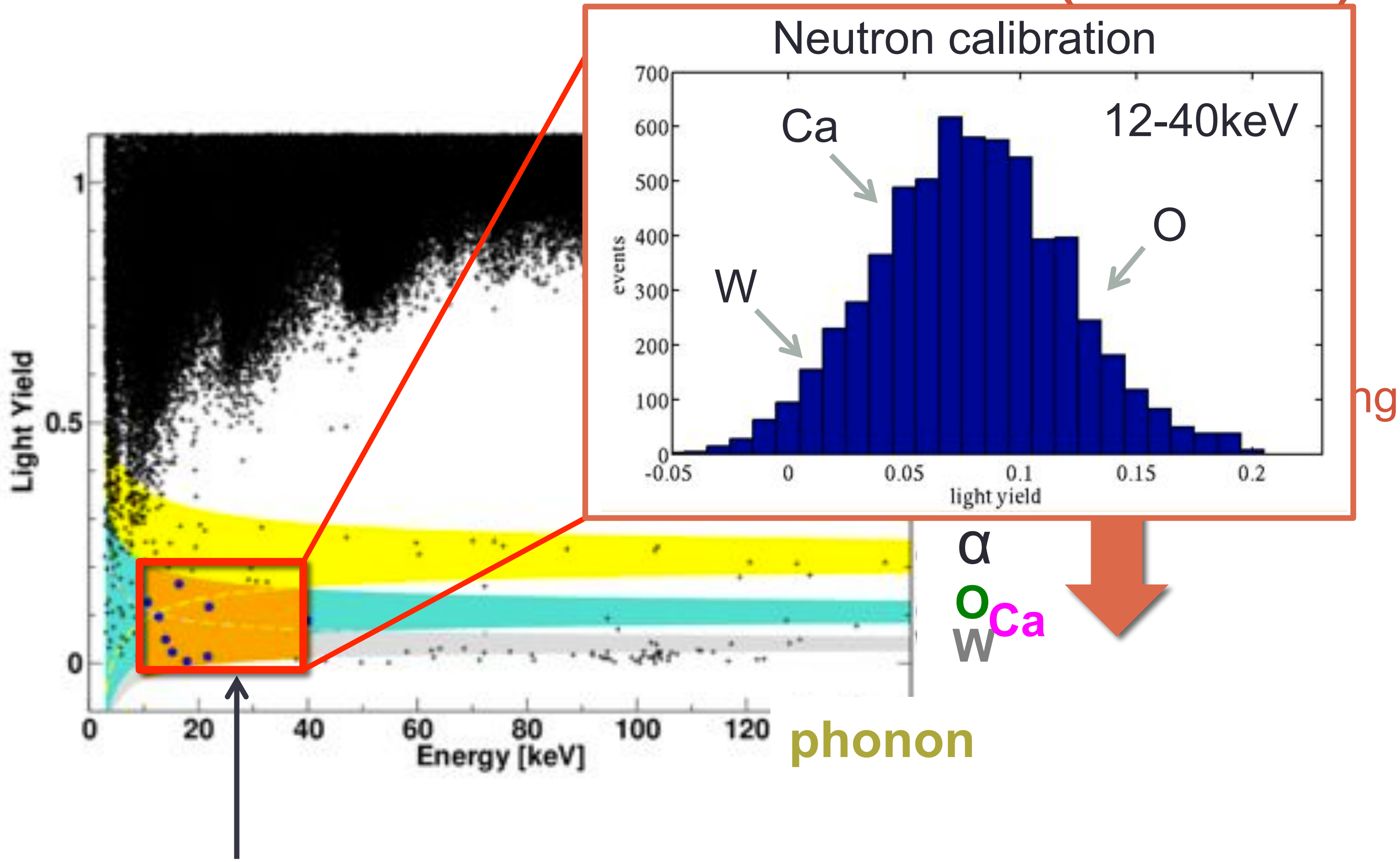

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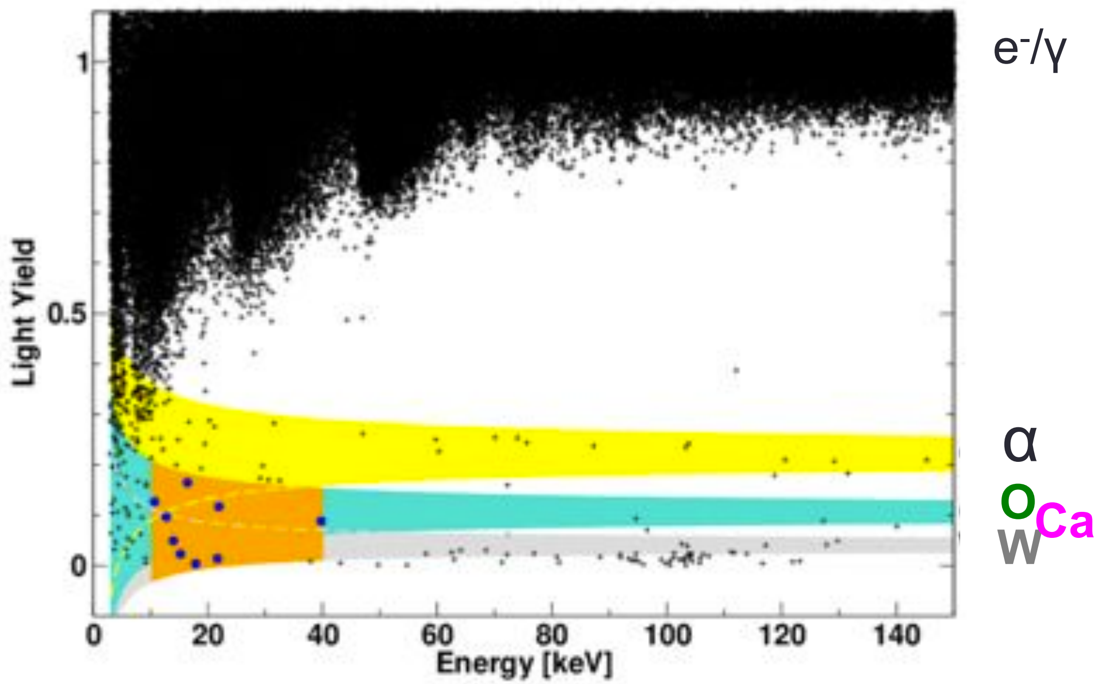
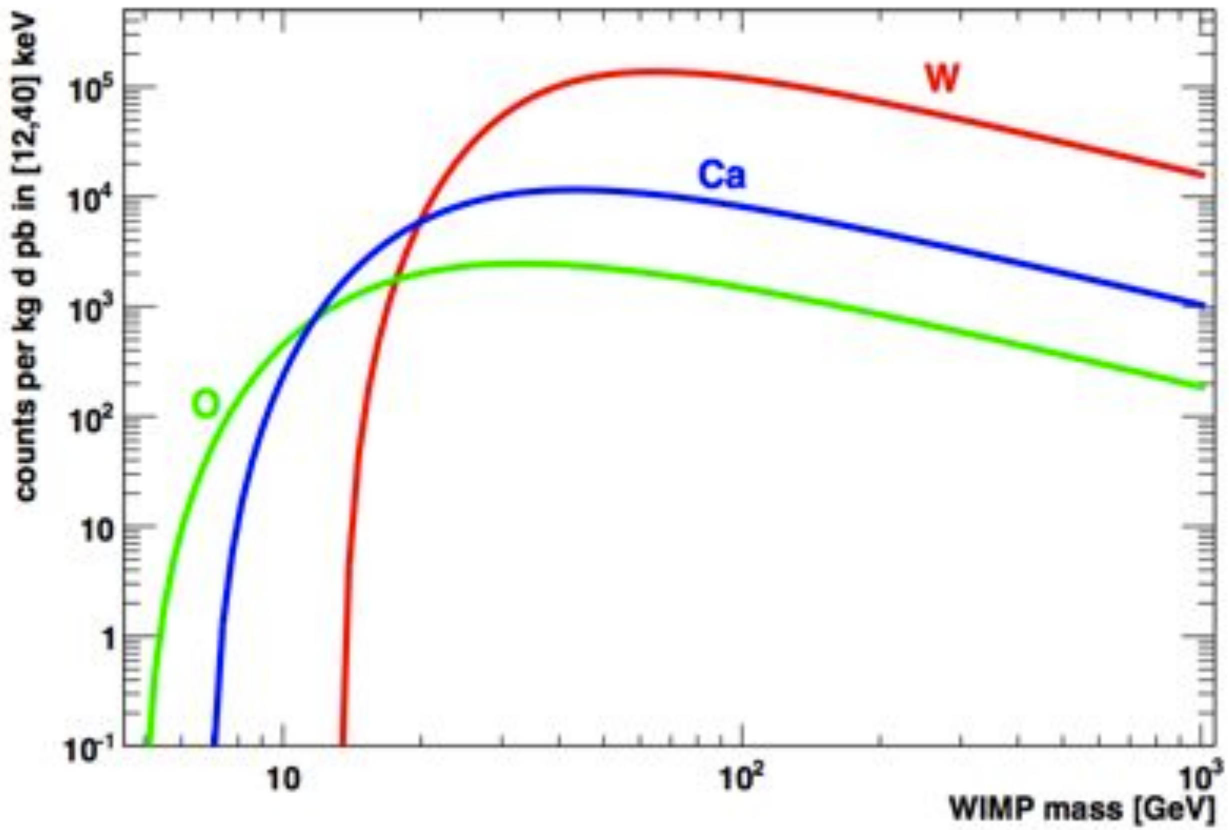


Dedicated measurement required!

Quenching Factors (QF)

Definition: $QF_x(E_r) = \frac{LY_x(E_r)}{LY_{\gamma,np}(E_r)} = \frac{\text{Light yield of nuclear recoil}}{\text{Light yield of } e^-/\gamma \text{ recoil}}$

CRESST: Sensitivity to Different WIMP Masses



low WIMP masses ≤20GeV: only O, Ca recoils above threshold

high WIMP masses ≥30GeV: dominated by W recoils

neutron background mainly O recoils above threshold

$$\frac{\partial R}{\partial E_R} \propto \sigma_{\chi n} A^2 e^{-\frac{E_R}{E_0}}$$

differential recoil rate

mass number

Status of QF Measurements

- In-situ determination of QF_O from neutron calibration
- Room-temperature measurements for O, Ca, W

Our Goal

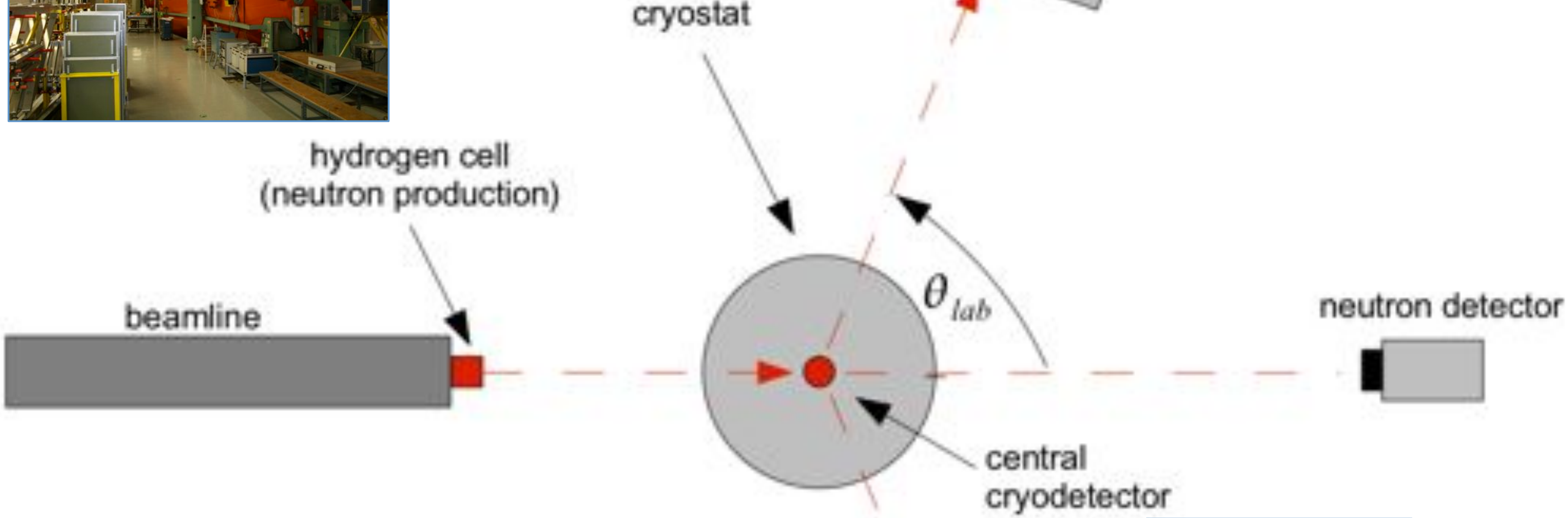
Precision measurements of the QFs of $CaWO_4$

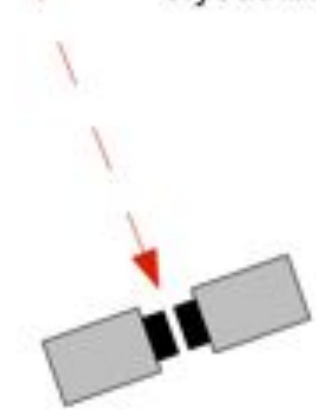
... in a running cryodetector

... at mK temperatures

... by neutron scattering

Neutron Scattering Facility – Experimental Setup





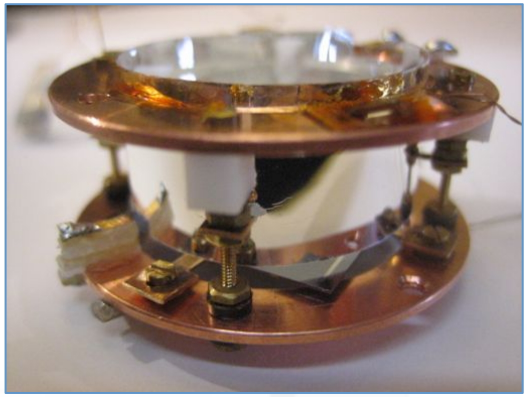
<u>Our Approach:</u>

- Fast neutron scattering
- Running **cryodetectors** (@mK)
- **Time-of-Flight** measurement

Neutron Scattering Facility – Central Detector

Dedicated CRESST-like detector module in dilution refrigerator

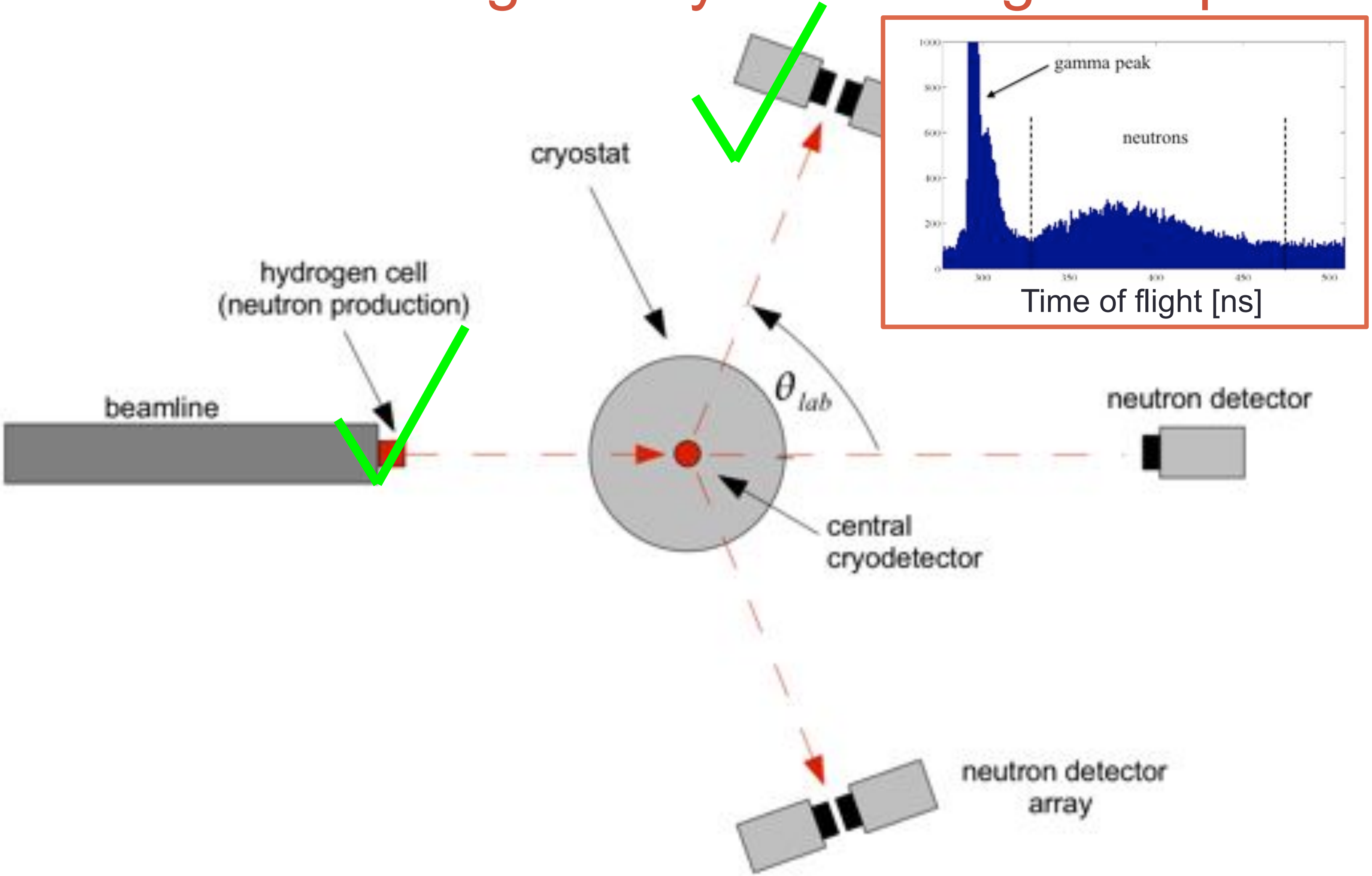
- ~10g $CaWO_4$ target crystal as phonon detector
- Si absorber as light detector
- Suited for higher event rates (up to 100Hz)
- Low-mass holder (~20g)



PHONON channel ⇒ energy deposition in absorber

LIGHT channel ⇒corresponding light output ⇒QF

Neutron Scattering Facility – Working Principle



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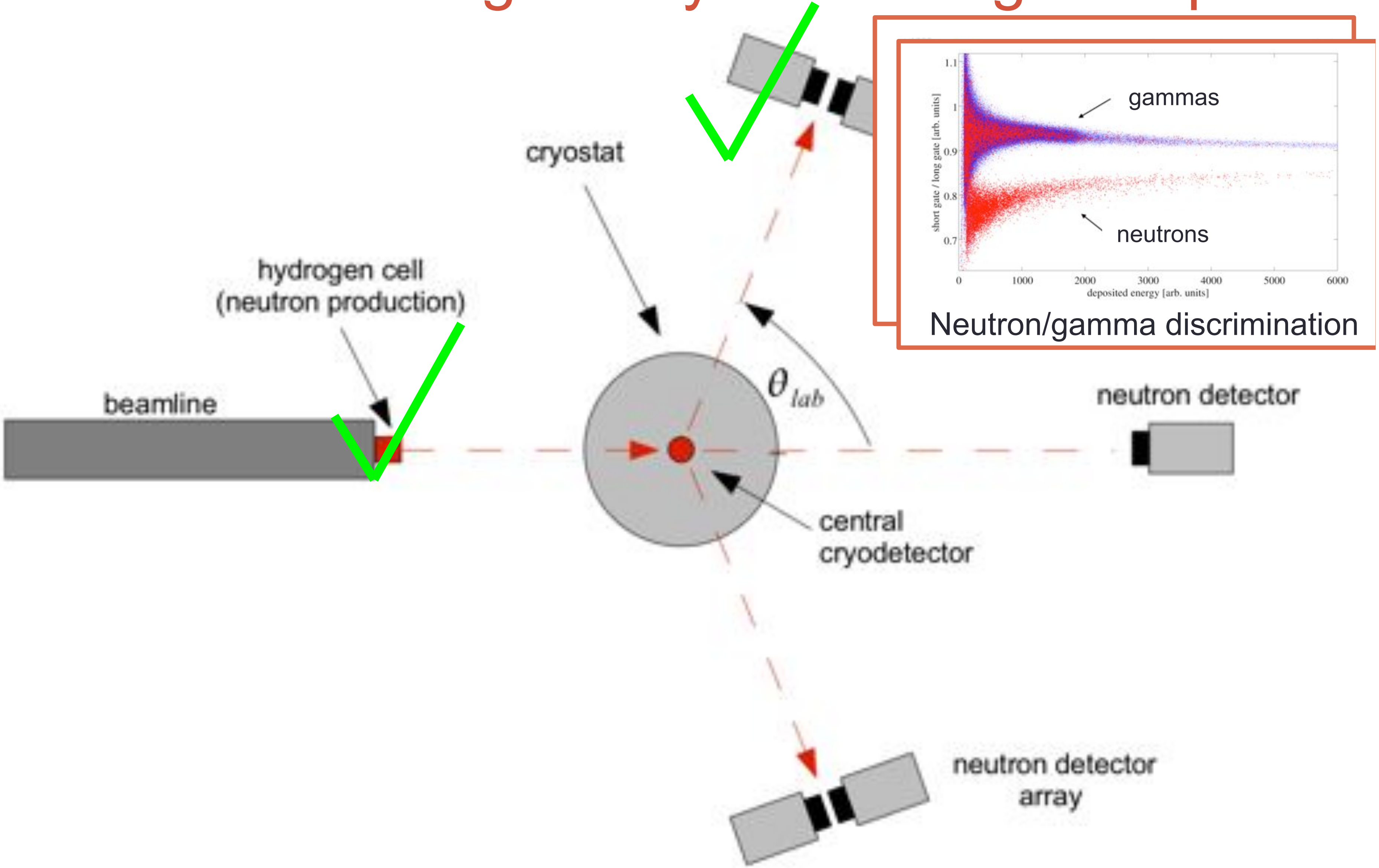

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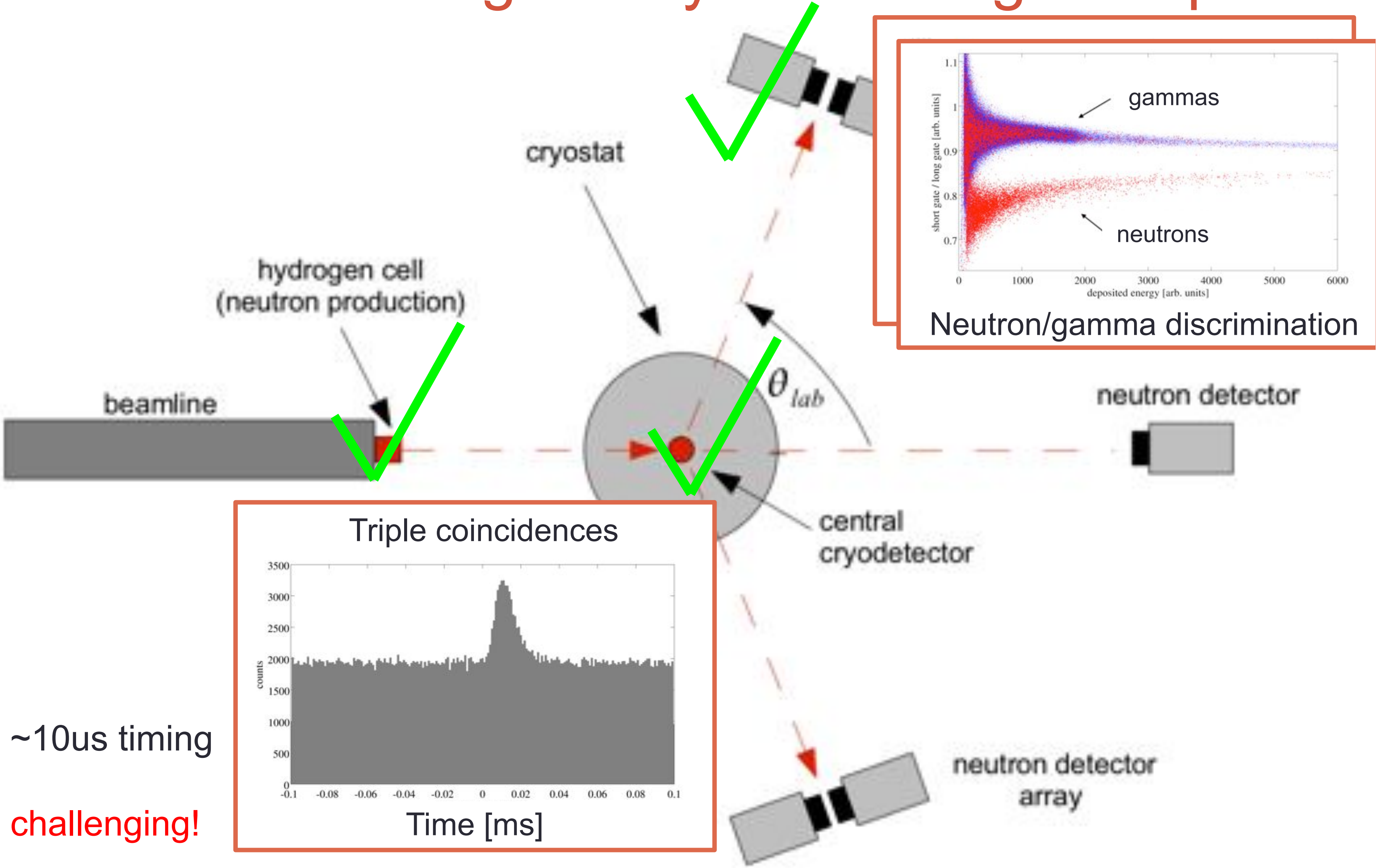


~10us timing

challenging!

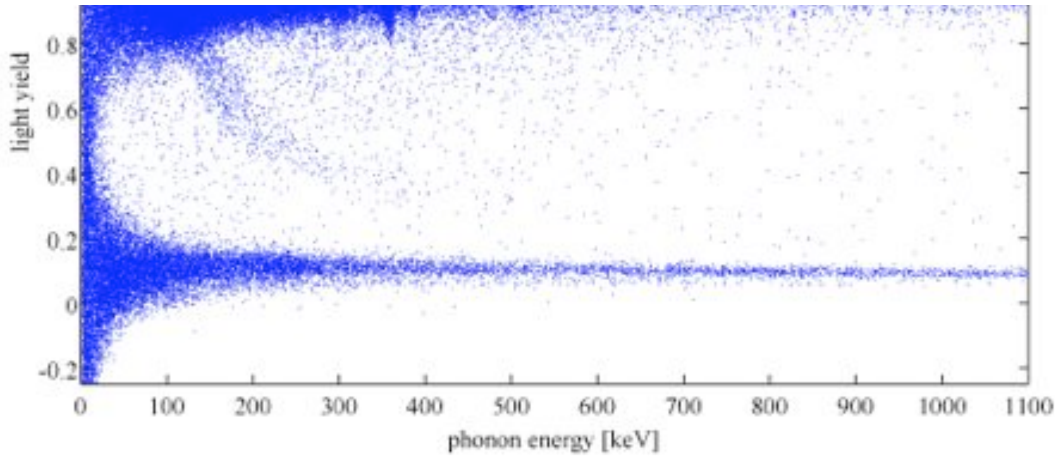
Identification of Recoiling Nucleus

Fixed kinematics due to

- mono-energetic neutrons (~11MeV)
- fixed scattering angle (e.g. 80°)

⇒ for $CaWO_4$: 3 populations of events in phonon detector

$E(^{16}O)$ = 1100keV
$E(^{40}Ca)$ = 450keV
$E(^{nat}W)$ = 100keV



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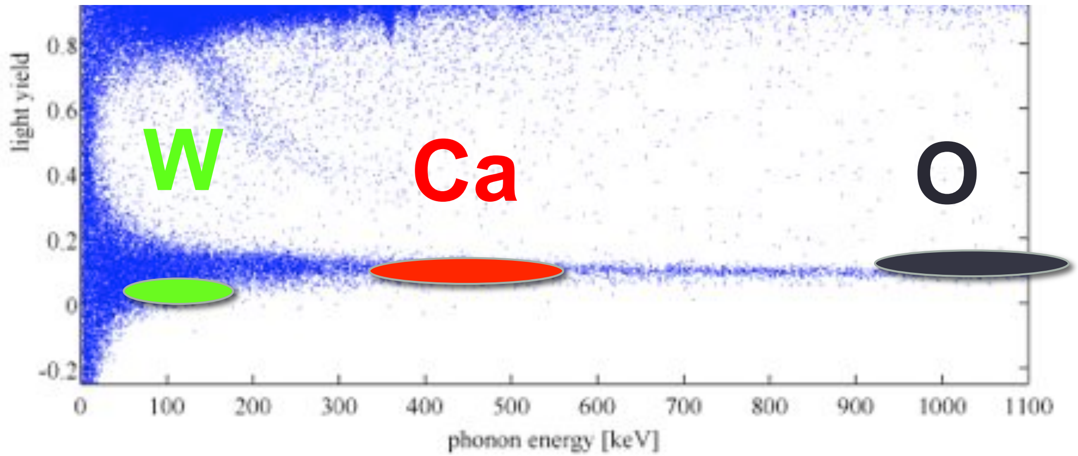

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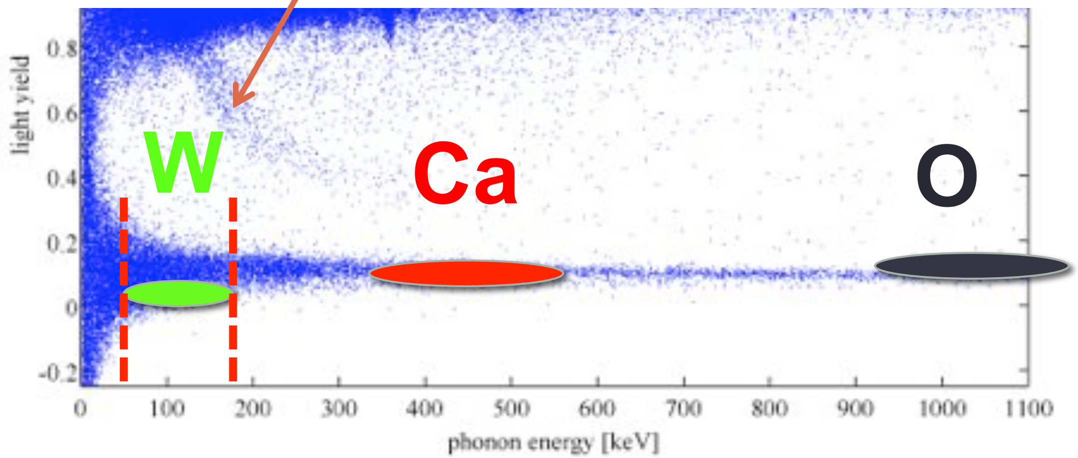
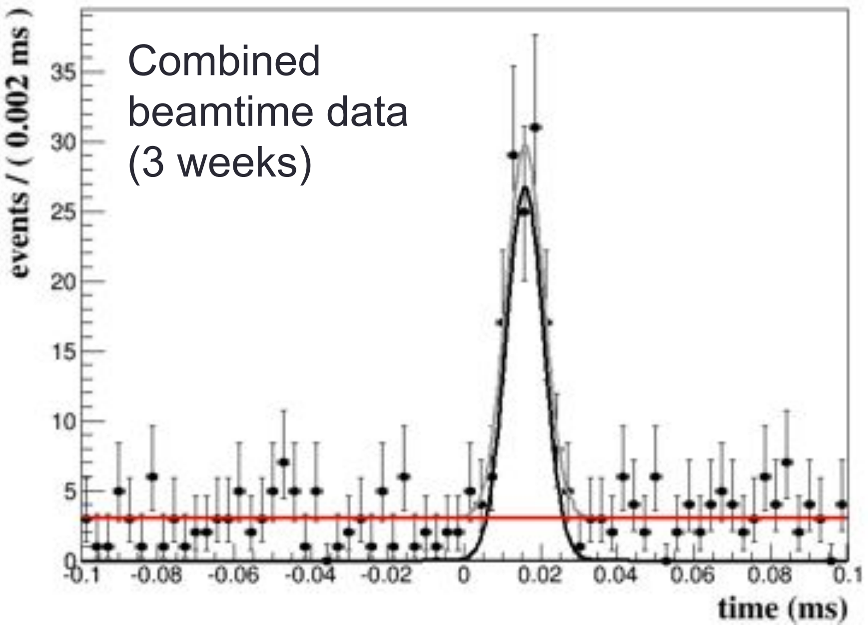
Experiment optimized for the measurement of QF_W

energy cut on W



Final Results for QF_W

Identification of W recoils



Signal-to-background ratio ~ 7:1

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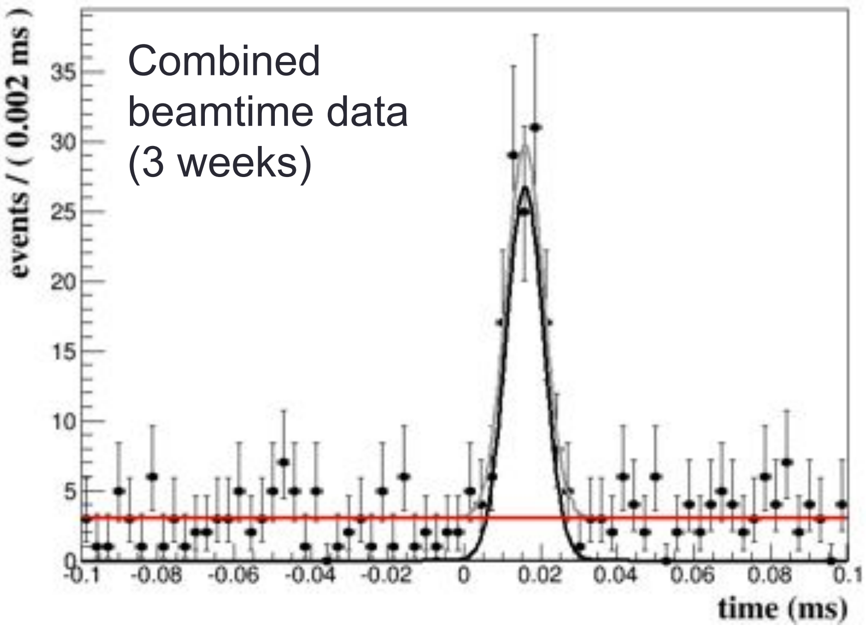
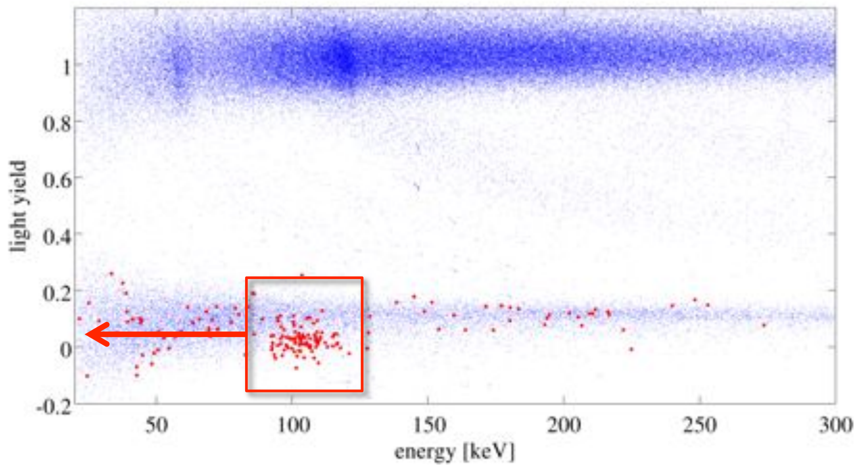


Signal-to-background ratio ~ 7:1

Quenching Factor of W



Final Results for QF_W

preliminary

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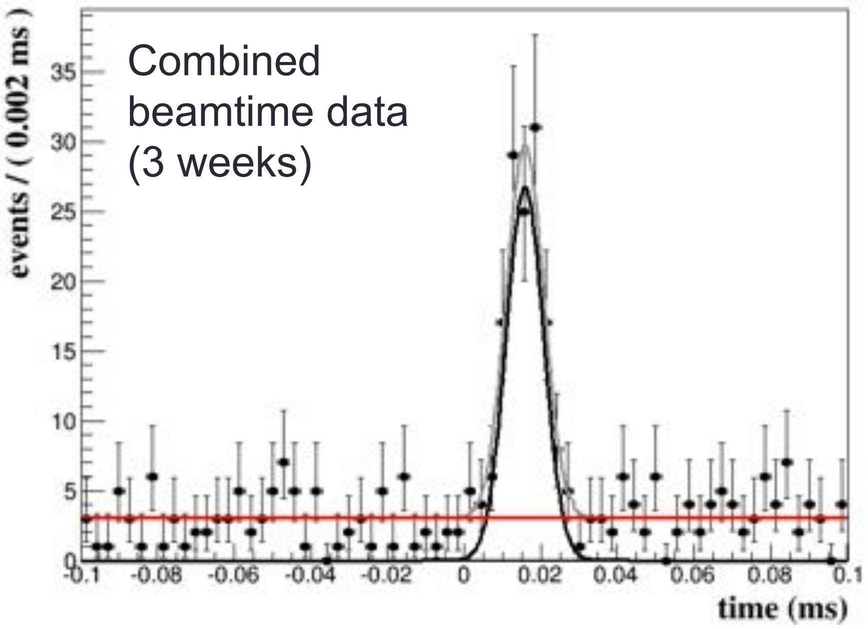
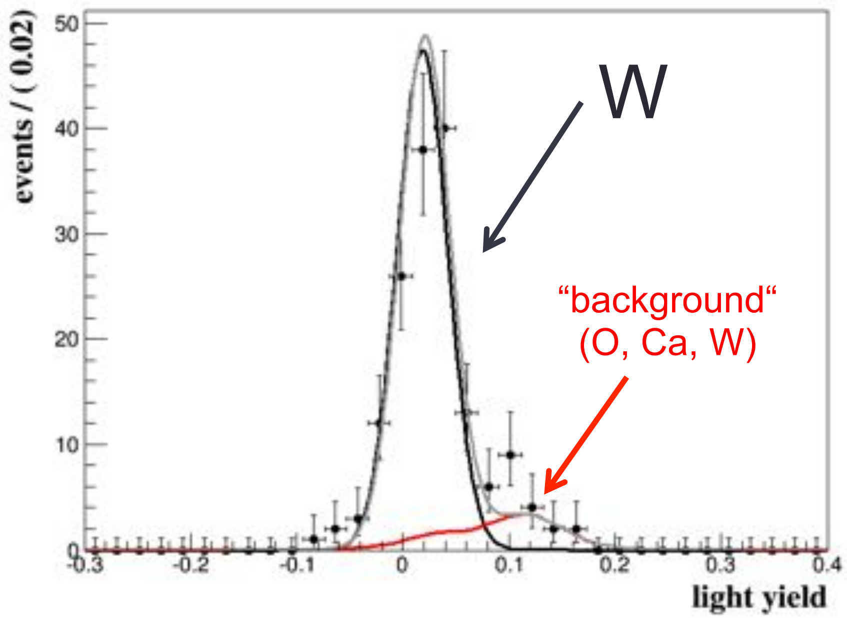


Signal-to-background ratio ~ 7:1

Quenching Factor of W



Final Results for QF_W

preliminary

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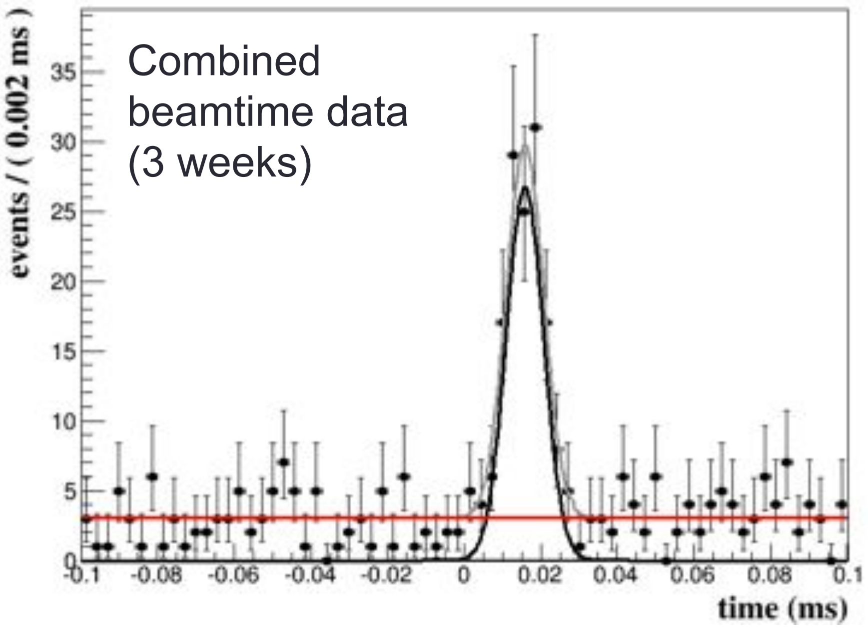

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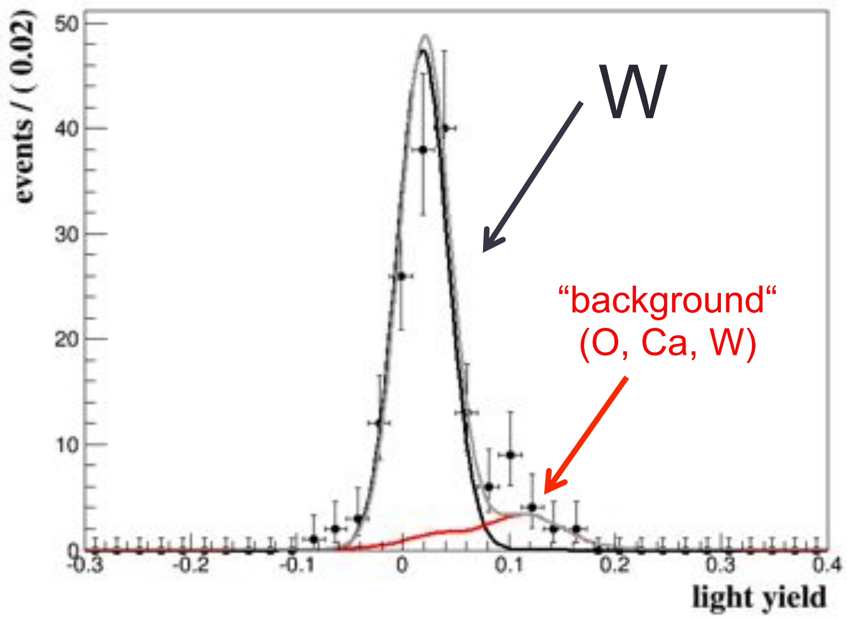
Quenching Factor of W



$QF_W = 0.0196 \pm 0.0022$

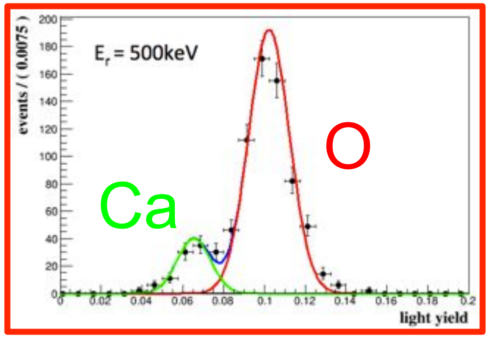
Correlated maximum-likelihood fit

Conclusion and Outlook

- First precise measurement of QF_W by neutron scattering
  - at mK temperatures
  - bulk events
  - 10% precision
  - Realistic measurement condition → low systematics

$QF_W = 0.0196 \pm 0.0022$

- QF_O and QF_{Ca} can be disentangled at higher energies
  - improved light-channel resolution
  - precision QF measurements (≲5% error)
  - $QF_O = 0.1212 \pm 0.0035$
  - $QF_{Ca} = 0.0667 \pm 0.0030$
  - Energy-dependent QF analysis



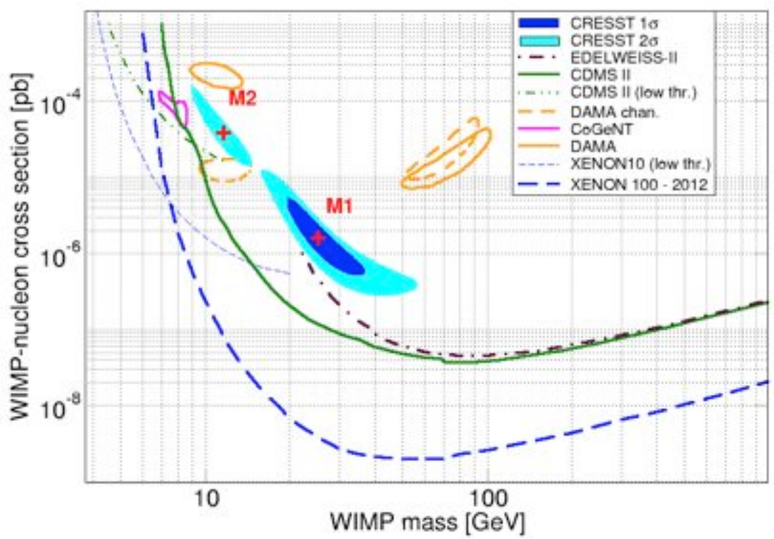
- Precise description of QFs of $CaWO_4$ to be published soon
- Influence on CRESST data under investigation

* QFs are preliminary values measured at E_r=100keV

New Experimental Run of CRESST – Run33

Excess signal in Run32 with
high statistical significance (>4σ)

Low-mass WIMPs ??



Main Goal:

Clarification of the origin of the excess signal

by

- Background reduction
- Increase of the target mass

Mounting of Run33 – Completed!

12 standard CRESST modules
- highly improved background situation
- ultra-pure materials
- radon prevention

6 fully-scintillating CRESST modules
- highly efficient veto against surface backgrounds

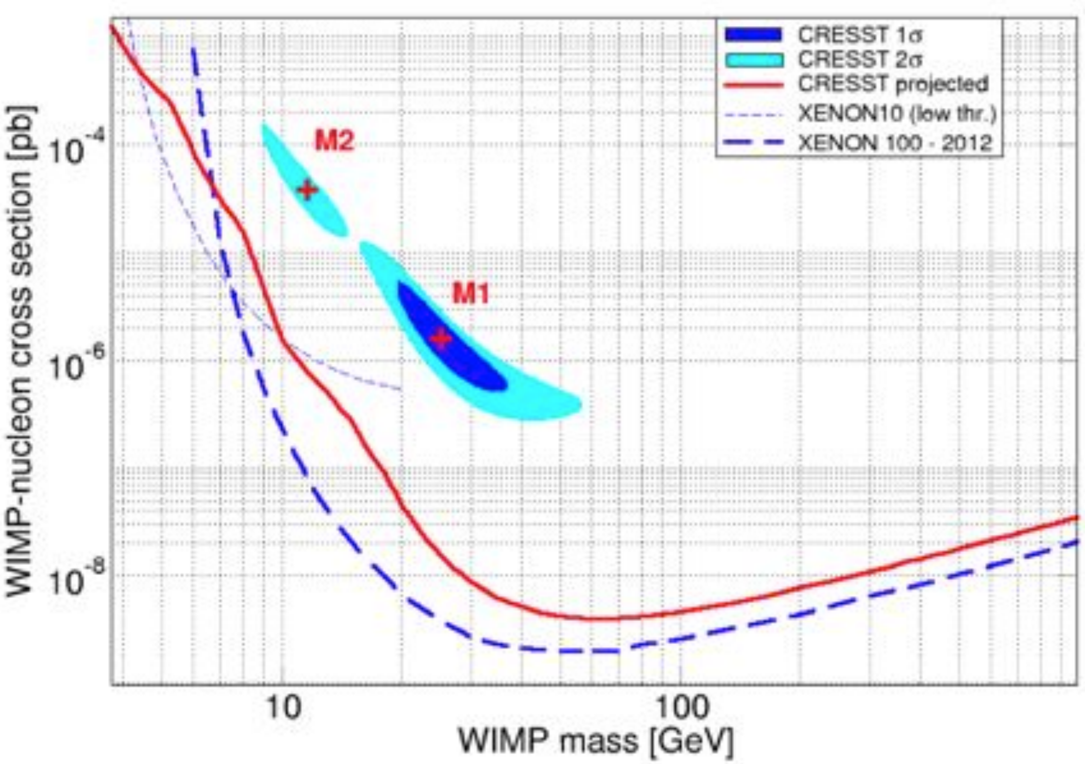
Additional PE shielding against neutrons

The cryostat has reached mK temperatures ...

Perspectives for the Next Run (Run33)

In case of...

- **low-mass WIMPs exist**: Confirmation of Dark Matter scenario with high confidence
- **background induced signals**: Competitive limits over a wide WIMP-mass range



Total target mass: ~5kg

$\gtrsim$ 2 ton-days of exposure (after cuts) with 2 years of data-taking

THANK YOU !!