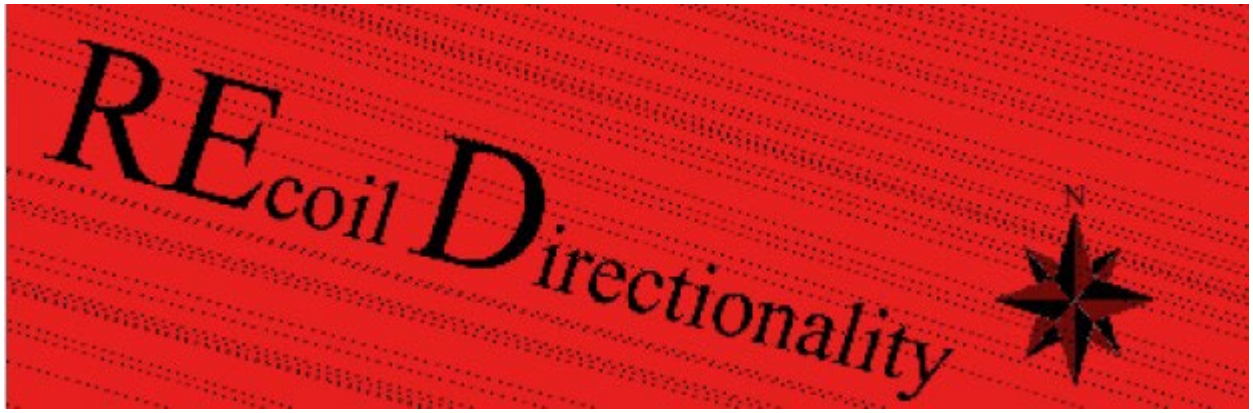


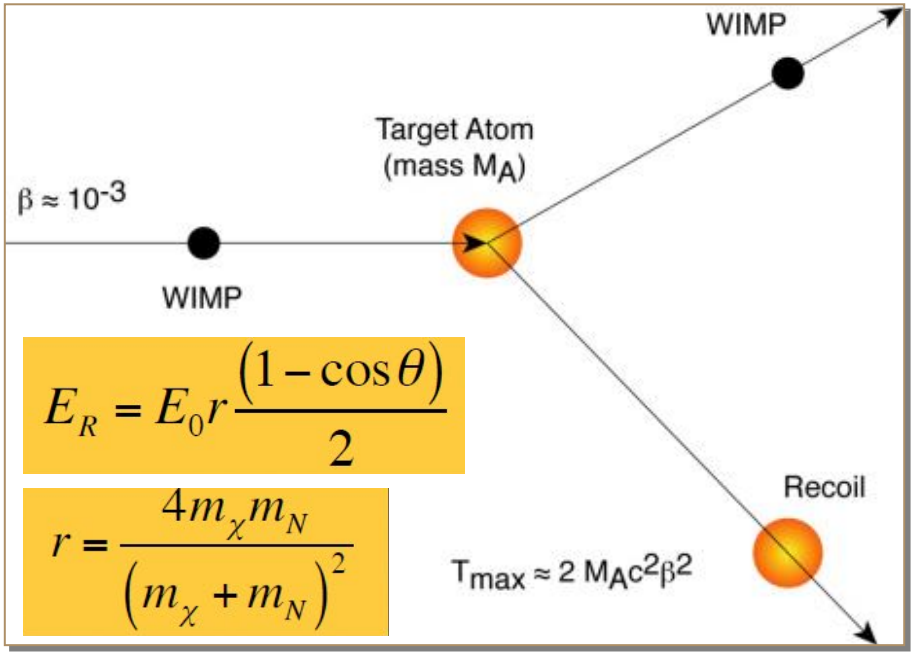
L. Pandola

DarkSide @ LNS

darkside

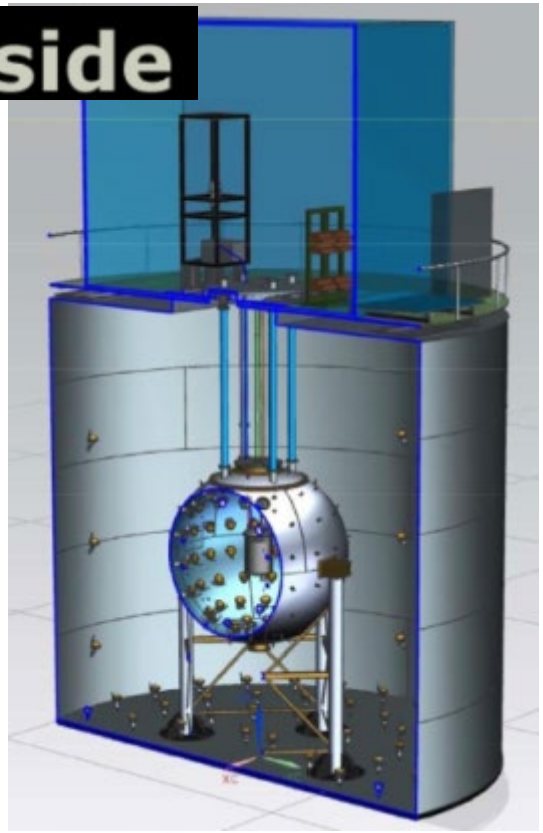
Physics background

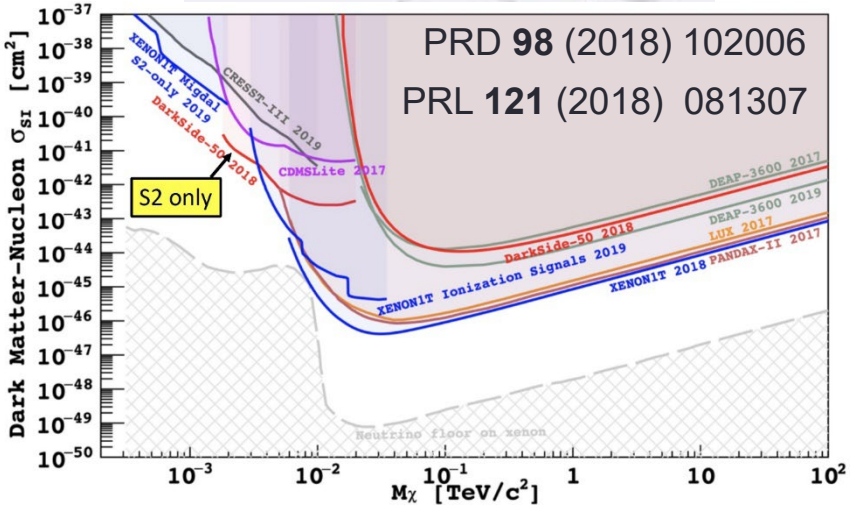
- Search for **dark matter** in the form of Weakly Interacting Massive Particles (WIMPs)
  - WIMP is a favourite candidate, but there are many others
- Signature: low energy (< 100 keV) nuclear recoil produced by WIMP elastic scattering
  - Backgrounds: e^- recoils, neutron-induced recoils
- Global effort worldwide:
  - Rates in the range from 10^{-1} to 10^{-6} events / (kg·day)
  - next generation experiments should eventually reach **exposures** in the range of **kton·day**
  - Need very low background level (and underground site)



Physics background

- **DarkSide** at Gran Sasso Laboratory, WIMPs using search using a dual-phase TPC with low-radioactivity LAr
  - Operated a **50 kg TPC** (DarkSide-50)
  - Next step: 30 ton LAr **TPC** (DarkSide-20k)
    - Novel light readout with SiPM
    - Getting ready for 2022, exposure O(100) ton yr
    - Expected sensitivity 10^{-47} cm^2 @ M_W =1 TeV/c^2
  - Next-next step: global worldwide effort (ARGO, 300 ton LAr)
- More sensitive to low-mass WIMP than Xe, due to the lighter target



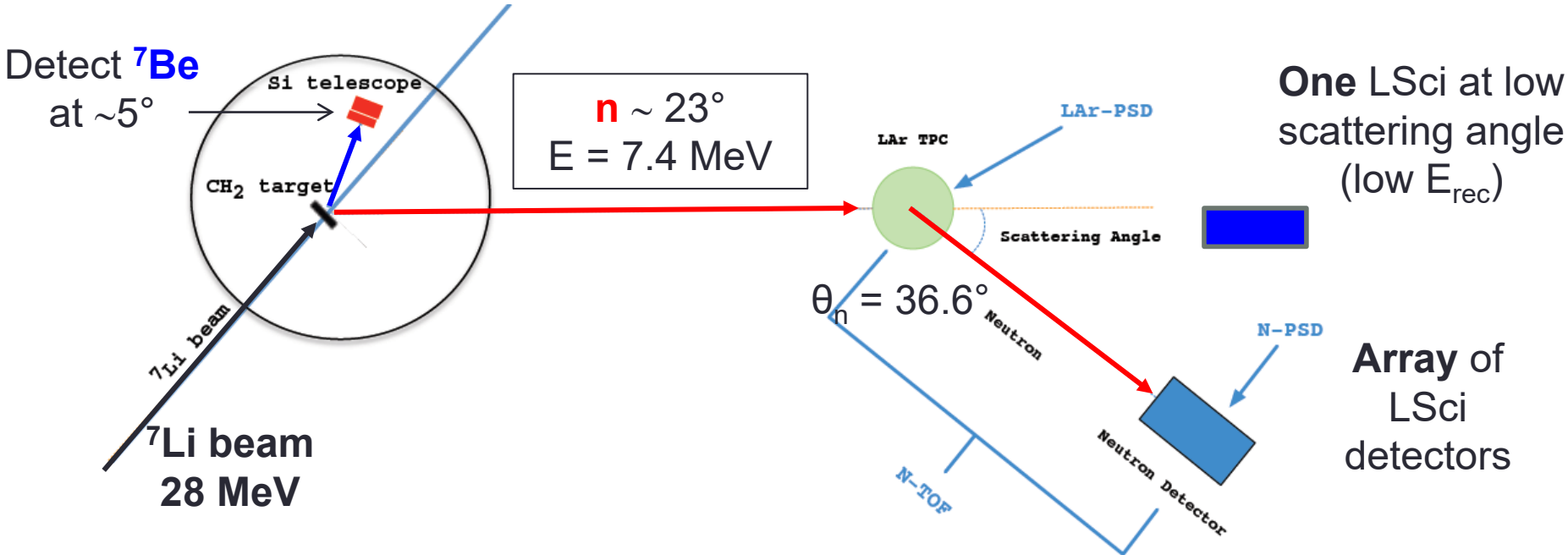


DS activities@ LNS

- Main involvement is in the **ReD project**, whose goals are:
  - demonstrate that a dual phase LAr TPC has a potential sensitivity to the direction of Ar recoil; additional goal:
  - characterize the response of the LAr TPC to very low-energy recoils (< few keV) → recently became a **hot topic (S2-only)**
  - act as a test bench of the technical solutions for DarkSide-20k TPC
- Nuclear recoils of known directions can be produced by neutron elastic scattering
- **Beam at LNS**: host the measurement by delivering a neutron beam via ^{7}Li+p reaction and by taking care of the logistics; provide the ΔE/E Si Telescope
  - Beam run (tailored to *directionality*): **done in February 2020** (^{7}Li beam)
- During the **beam stop**:
  - run a dedicated calibration with a **fission neutron source (^{252}Cf)** → focus on low-energy recoils
  - Strong cooperation with the DarkSide group @Sezione

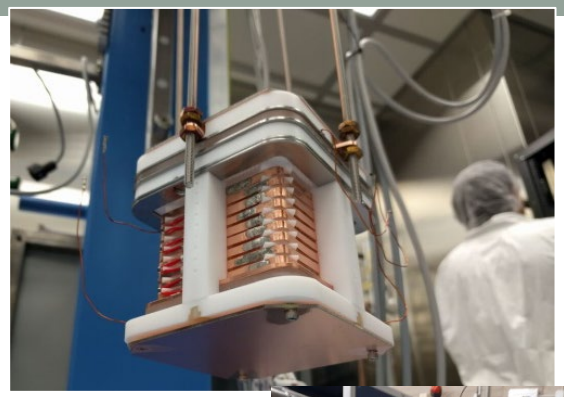
ReD conceptual design

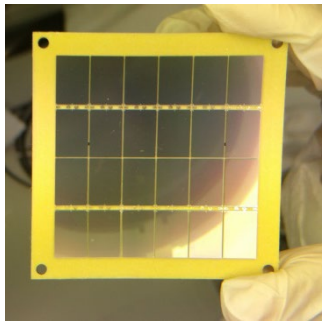
- Use a neutron beam produced via **p(^{7}Li,n)**
- Detect the associate particle (^{7}Be) and ToF to **tag neutron energy** event by event (fixed by kinematics)
- Pay attention to arrange the setup such to tag nuclear recoils ~parallel and ~perpendicular to the E
  - Displace the TPC **vertically**, such that the (n,n') interaction plane is not "horizontal"
  - Deploy LSci to tag recoils of the **same energy**, but different angle with respect to the E **(including 90° and 180°)**

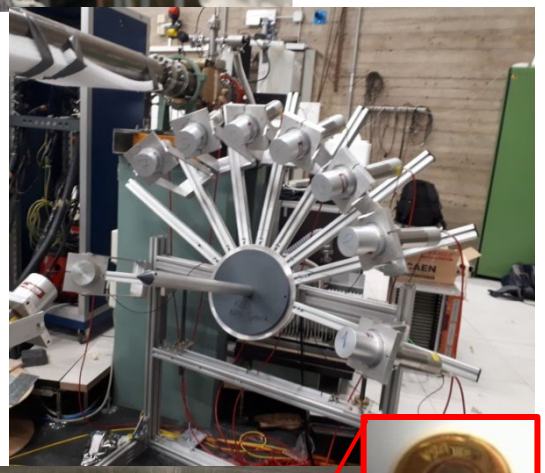


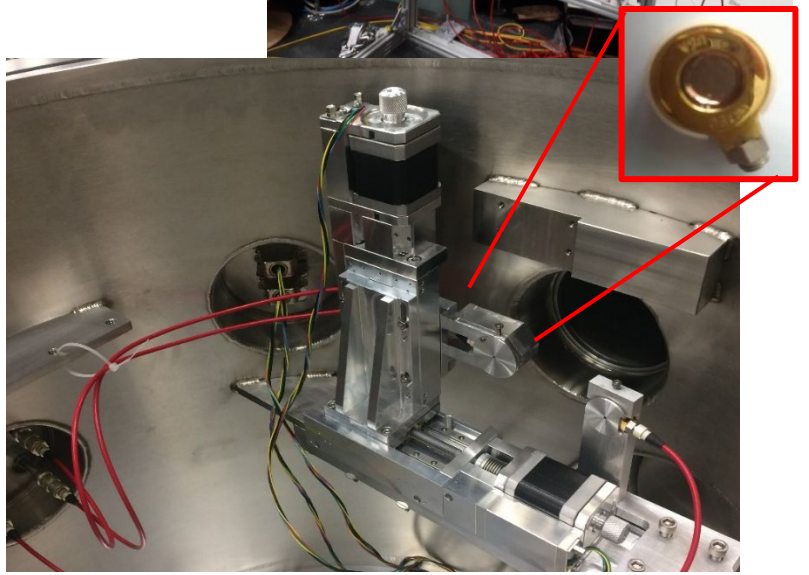
The ingredients

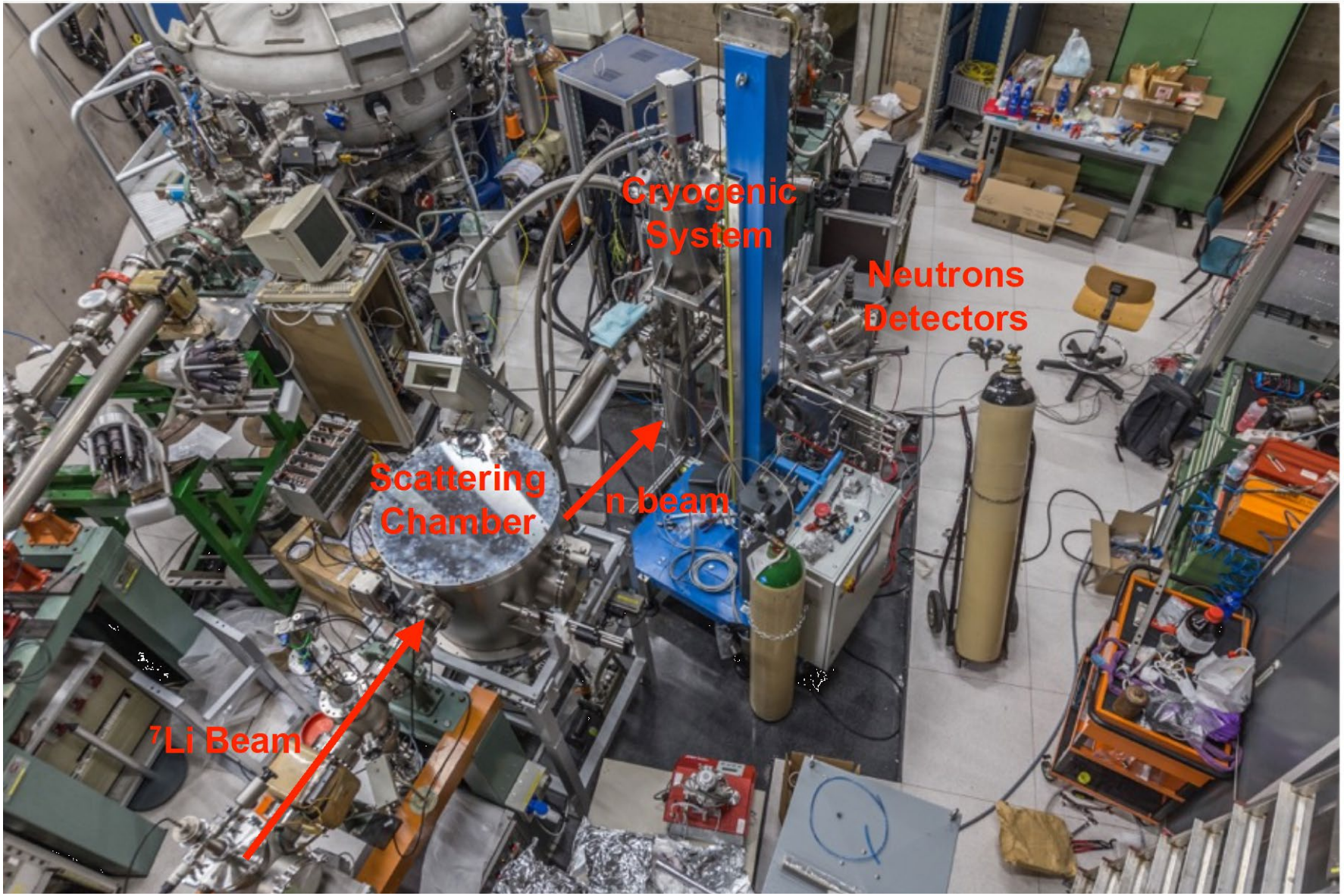
- TPC
  - Light readout: 5x5 cm^2 SiPM (DS-20k)
    - 24x1cm^2 SiPM, 24 channel readout
    - 24x1cm^2 SiPM, 4 channel readout
  - Light yield up to 9 phe/keV
- Liquid Scintillators
  - Readout by PMTs
  - Featuring n/γ discrimination
  - Absolute calibration with ^{252}Cf (@LNS)
- Si telescope (LNS responsibility)
  - **ΔE Si** detector (20 μm), **E Si** detector (500 μm)
  - Placed at **5 deg, movable**
- Targets
  - CH_2, 250-400 μg/cm^2





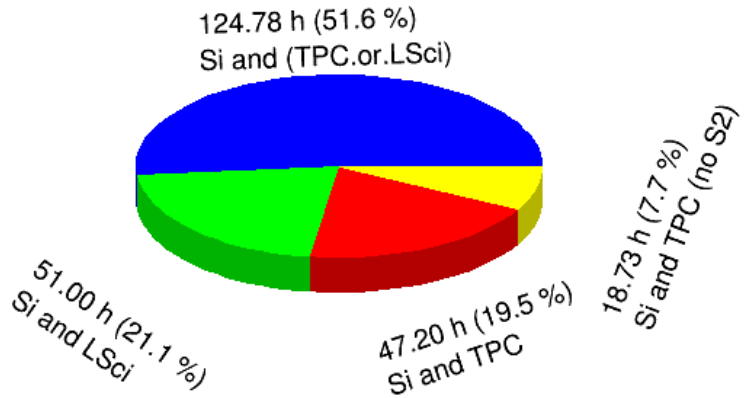





Cryogenic System
Neutrons Detectors
Scattering Chamber
n beam
^{7}Li Beam

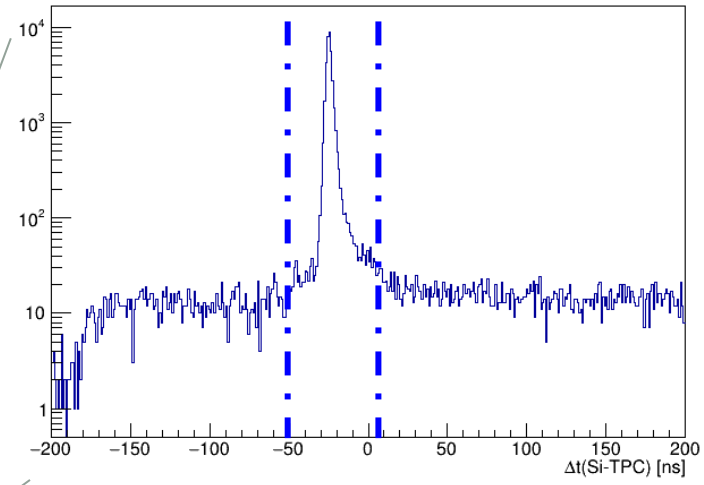
Beam measurement

- Beam slot from Jan 27th to Feb 14th
  - 4 days of preparation + 2 weeks beamtime
  - Actual **beam start on Feb 1st**
- Daily calibrations with laser and ^{241}Am
- In total, 124 runs are selected for the final analysis
  - Different trigger, field and cabling conditions
- Total time: 241.7 h (= 10.07 days)
  - Remarkable duty cycle
- Huge **support** from all Divisions and Services of the LNS
  - Very much **appreciated**!

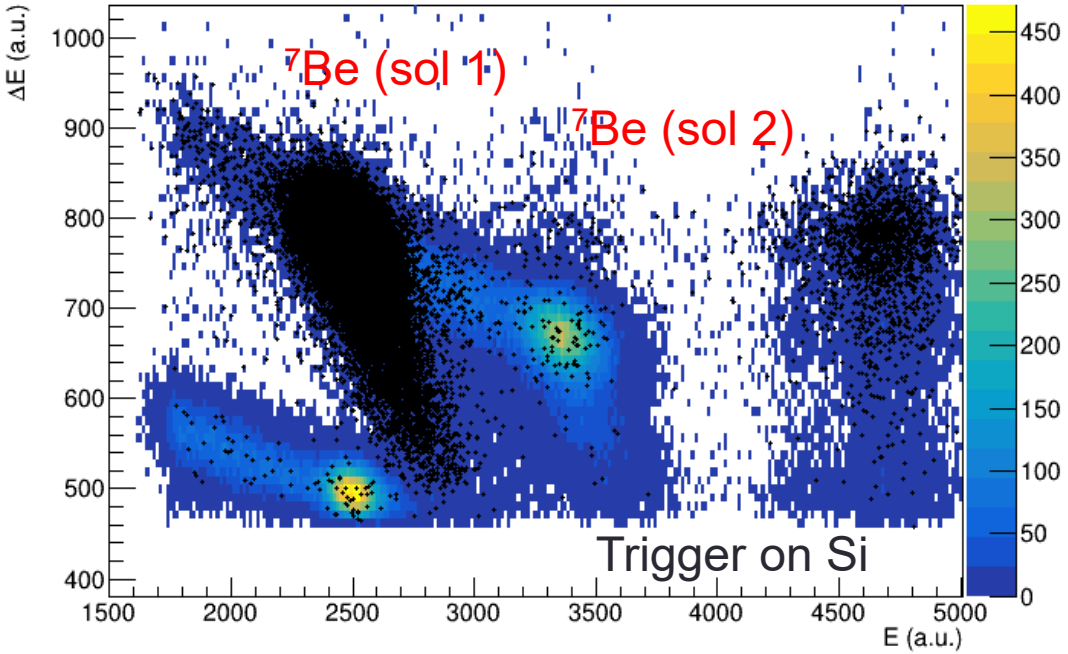


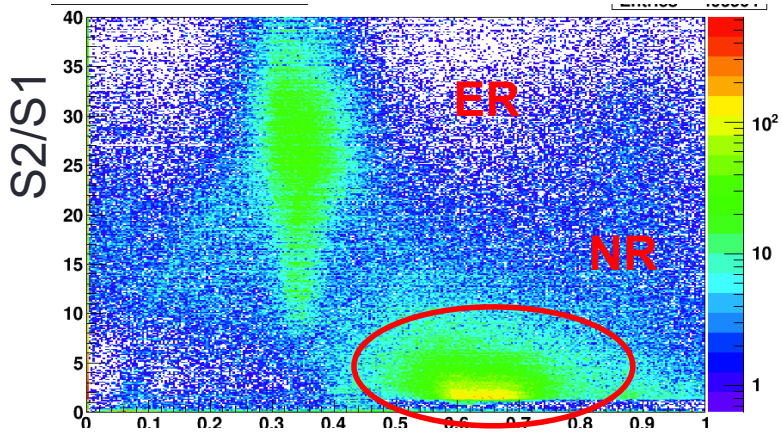
TPC-Si coincident events

- Successful tagging of neutron events in the TPC by using ^{7}Be in the Si telescope
  - Events with a signal in the TPC
  - Correlated events + flat accidentals
  - Clear ER/NR discrimination
- **Large sample of NR events**



Δt TPC-Si

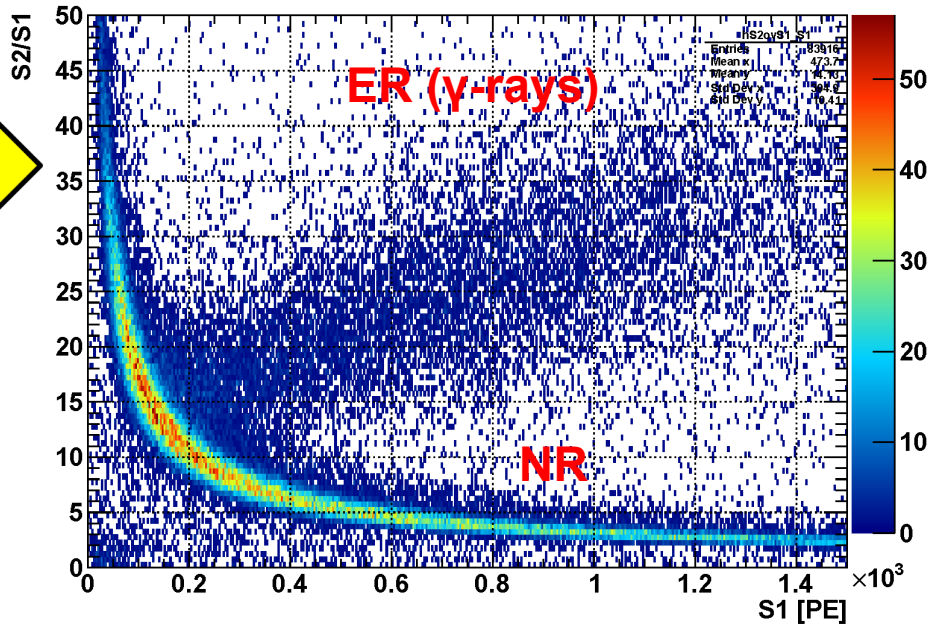




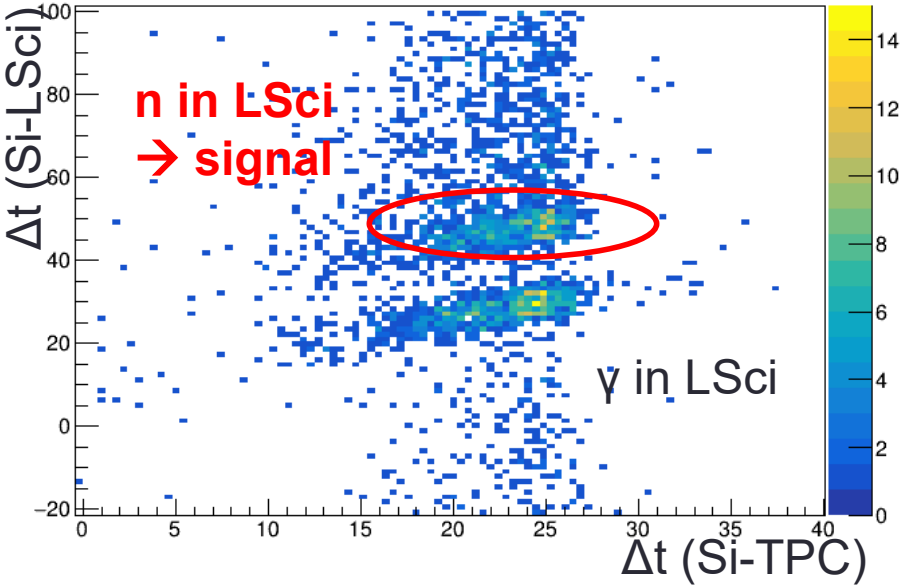
PSD parameter

ReD run @ LNS

- Full three-fold coincidences **(Si ∧ TPC ∧ n-Spectrometer)**
- Very clean identification of events based on: ^{7}Be tagging, timing and PSD (TPC and LSci)
  - ToF resolution **~1-2 ns rms**
- **Data analysis in progress**, planning for a publication within the year
- An other technical publication in preparation, based on the TPC commissioning in Naples



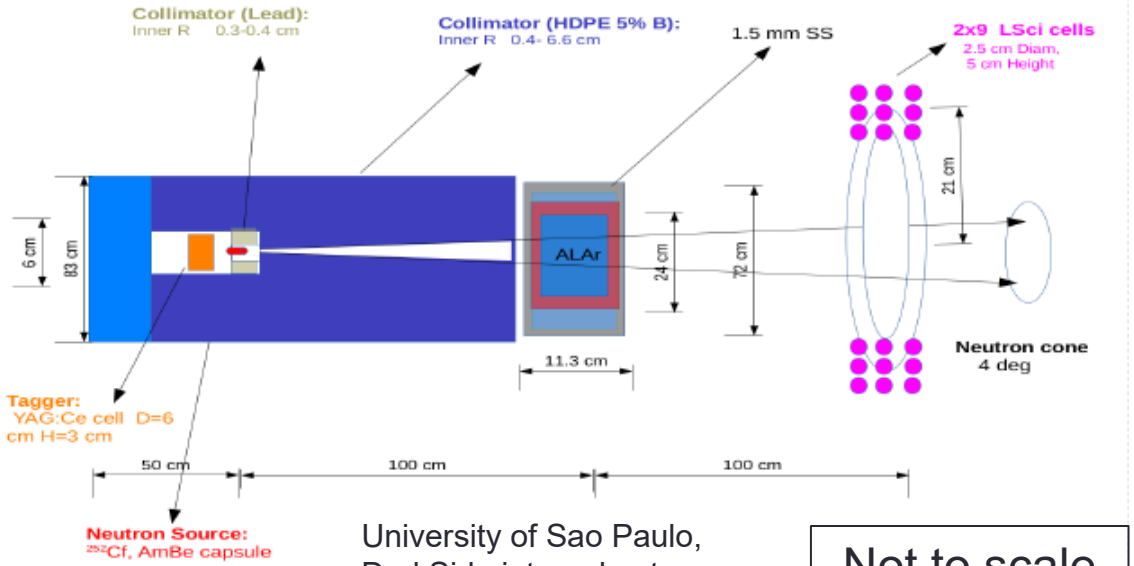
Ar recoil events in the TPC



Planning for 2020-2021 (after beam stop)

- After the beam stop, perform low-energy recoil measurements using a ^{252}Cf source
  - Neutrons **O(2 MeV)**, more appropriate for **E_{rec} ~ 1 keV**
  - Directionality not possible
  - **Conceptual layout** available: ToF measurements
- Deploy the system at the **Physics Department UniCt**
  - TPC still cold and working in the 80deg Hall
  - Commissioning and calibration in Summer-Fall 2020

- Measurements with ^{252}Cf (+ background and calibrations) **throughout 2021**
- Financial requests for 2021 limited to running costs and travels
  - Almost all pieces of hardware already funded

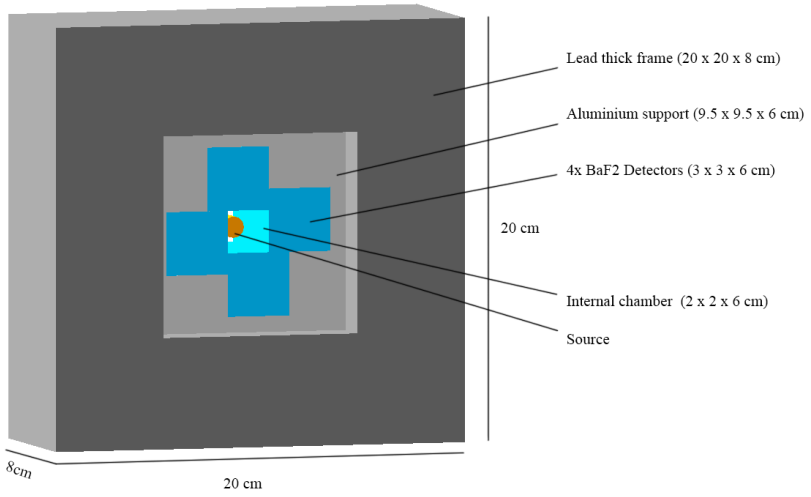


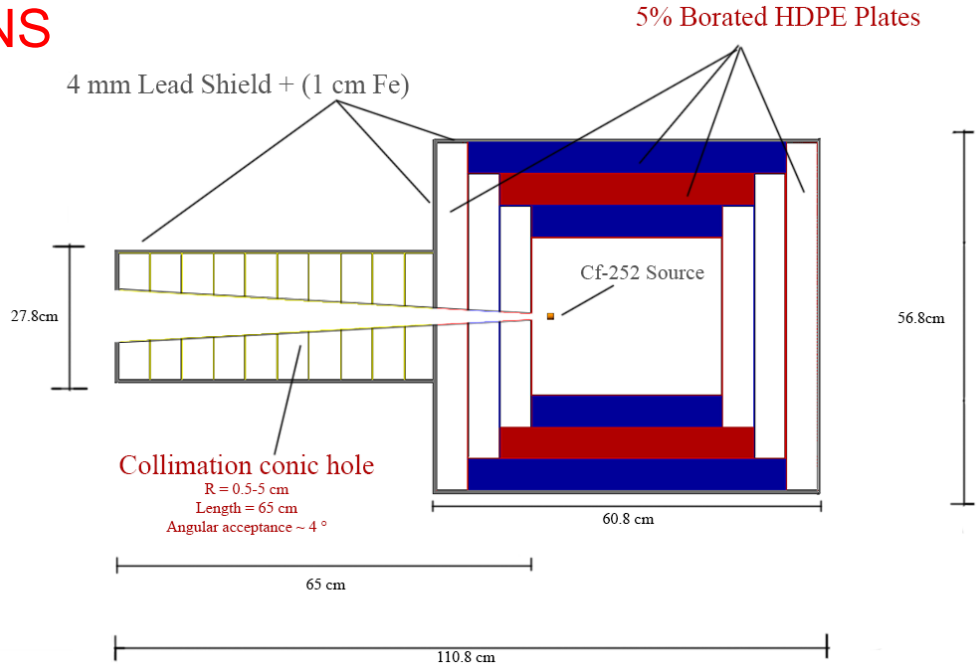
University of Sao Paulo, DarkSide internal note

Not to scale

Preparation for the ^{252}Cf measurement

- Hardware:
  - 400 kg of B-loaded HDPE purchased by SezCt (Pb still missing) ☑
  - ^{252}Cf (~750 kBq) source to be purchased by **LNS** (funded 2020)
  - Fission taggers: BaF detectors (available) ☑
- MC simulations (Sez. Catania) in progress to optimize the shielding arrangement
  - Technical design supported by LNS





Attività e richieste 2021 – gruppo LNS

- Prosecuzione e supporto della **presa dati con l'apparato ReD** con **sorgente di ^{252}Cf**, per la misura della risposta della TPC a bassissime energie:
  - Acquisto e gestione della sorgente di ^{252}Cf
  - Spostamento e riaccensione del sistema presso il DFA, in collaborazione con il gruppo CT e gli altri gruppi della Collaborazione
  - Presa dati e coordinamento delle attività on-site
  - Sviluppo software e algoritmi per analisi dati
  - Coordinamento globale del progetto (L. Pandola, L1 manager)
- Realizzazione dell'impianto **URANIA** per l'estrazione di Ar depleto in ^{39}Ar in Doe-Canyon (Colorado)

Richieste 2021 – gruppo LNS

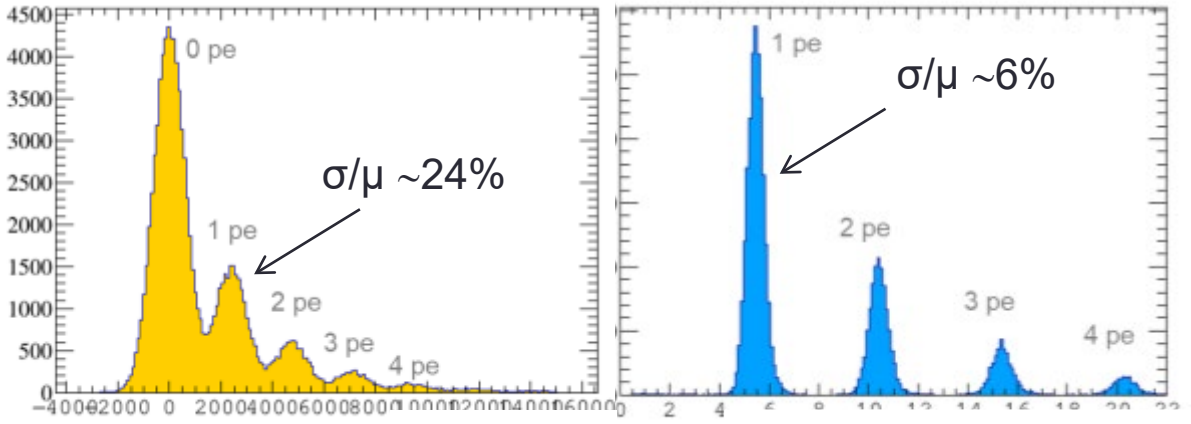
M. Gulino	Associato (UniKore)	40%
L. Pandola	Ricercatore III	60% (RespLoc)
G. Schillaci	Tecnologo II	50%
TOTALE		**1.5 FTE** (1.7 nel 2019)

Consumo	- Metabolismo (liquidi criogenici, materiale di pulizia, …) - Materiali e lavorazioni meccaniche per le strutture di supporto	5 k€
Missioni	- Contatti con altri gruppi e meeting di Collaborazione	8 k€
TOTALE		**13 k€**

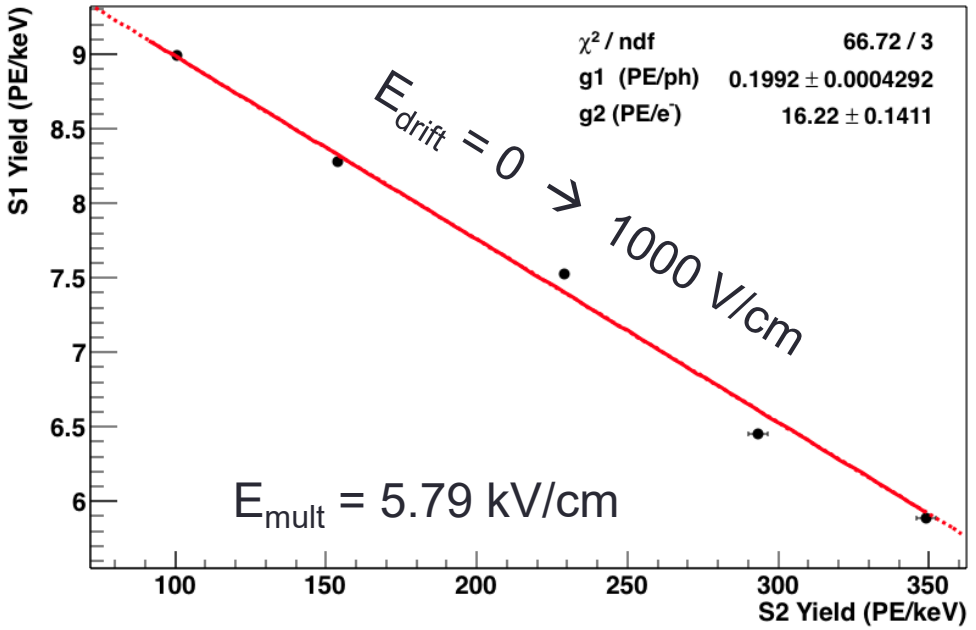
BACKUP

TPC Performance - 1

- Single-phe spectrum from laser
  - Single photons nicely separated
  - Effect of after-pulses and x-talk, K_{dup} = 30%
  - Digital filtering
- Light yield at null field about 9 phe/keV
  - Scintillation (S1) anti-correlated with charge (S2)
  - Relative balance changes with electric field, due to recombination
- Electron lifetime > 1 ms
  - Purity OK



charge filtered amplitude



Data selection and analysis

- Events scanned to search for triple coincidences with a NR signal in the TPC and with **loose** time gate
  - at least one S1 TPC signal found, with fprompt > 0.4 (→ NR)
  - TPC event in sync with the Si telescope (± 400 ns)
  - at least one event in the LSci, with E > 40 keV_{ee} and in-sync with Si telescope (± 140 ns)

- **Data analysis in progress**, planning for a publication within the year
- An other technical publication in preparation, based on the TPC commissioning in Naples