SABRE
(SODIUM IODIDE WITH ACTIVE BACKGROUND REJECTION)

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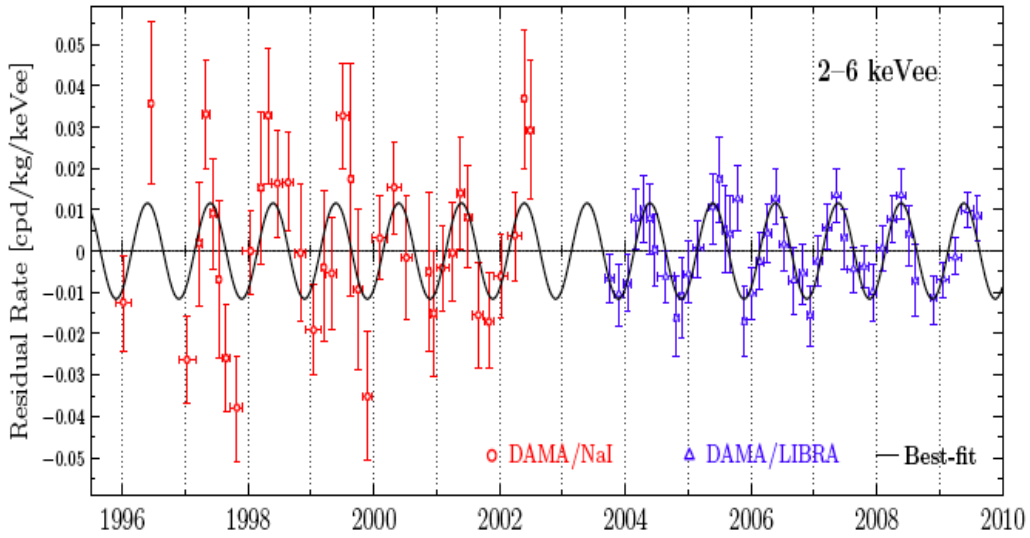
SABRE

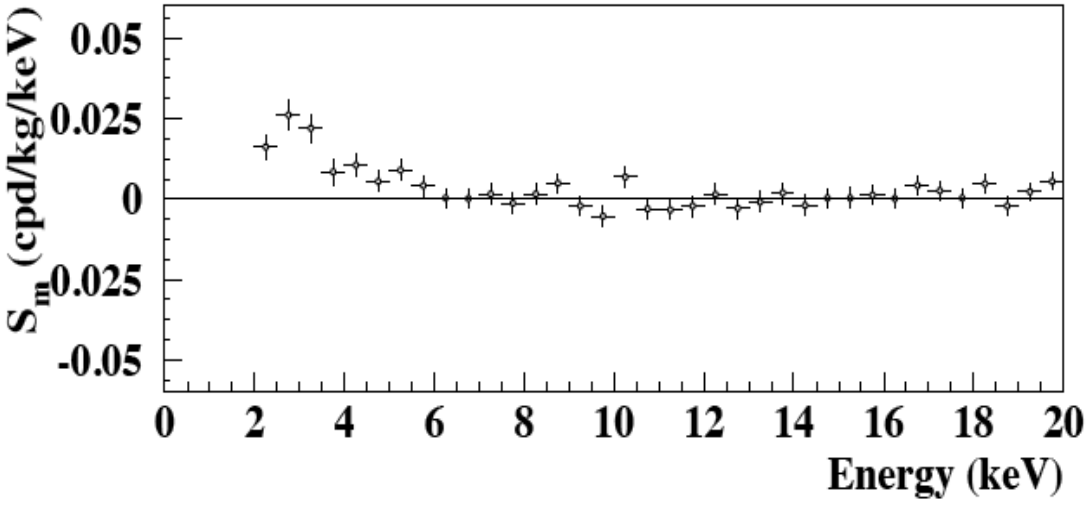
Designed to detect annual modulation in NaI.

1. **Make use of new radio-pure NaI crystals**
    1. Higher purity NaI powder than ever achieved
    2. Further purification during crystallization
    3. Use low background methods (used in Borexino and DarkSide) in handling and processing
2. **Make use of new low-background and high-QE photosensor.**
    1. PMTs R11065/20 (< 10mBq of gamma from U and Th) or upcoming.
    2. SiPM. Should be below 1mBq. To be tested.
3. **Active Background rejection with liquid scintillator.**
4. Make use of low radioactivity copper housing:
    1. U, Th < μBq/kg

THE DAMA/LIBRA MODULATION

- **Modulation**
  - 1 year period
  - Peaked end of May
  - WIMP signal peaked Beginning of June
  - 9σ significance
- **Amplitude**
  - Peaked at ~3 keV_e
  - Prominent in 2-6 keV_e
- **Remarks**
  - Detector makes use of an array of 250 kg high purity NaI (unique)
  - Observation can be explained in the WIMPs framework
  - Tension with other results (XENON, LUX, CDMS)
  - Confirmation of DAMA results still missings





RADIO-PURE POWDER

4-year work (F. Calaprice, J. Benziger and A. Wright at Princeton Univ)

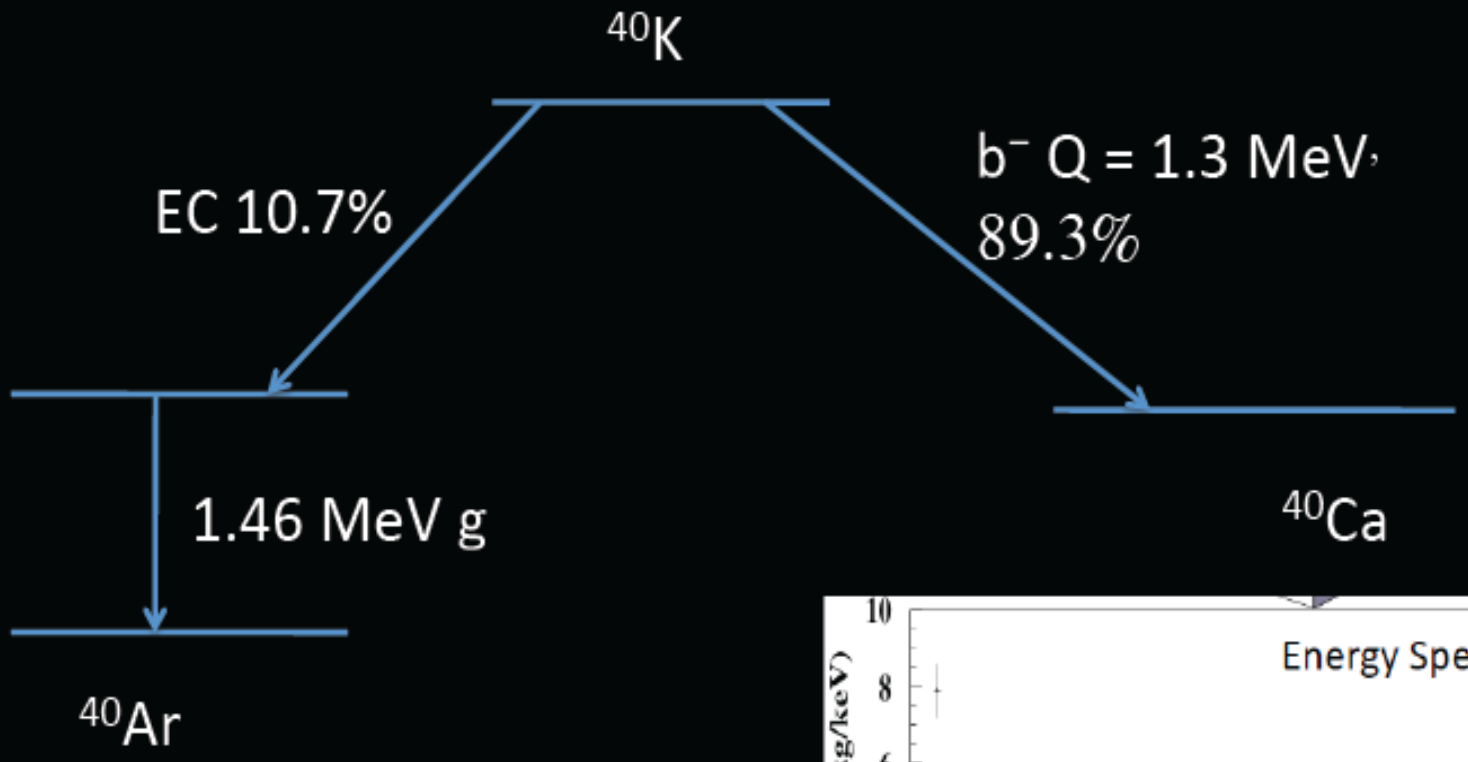
Purify precursors of NaI: Na_2CO_3

Present results:

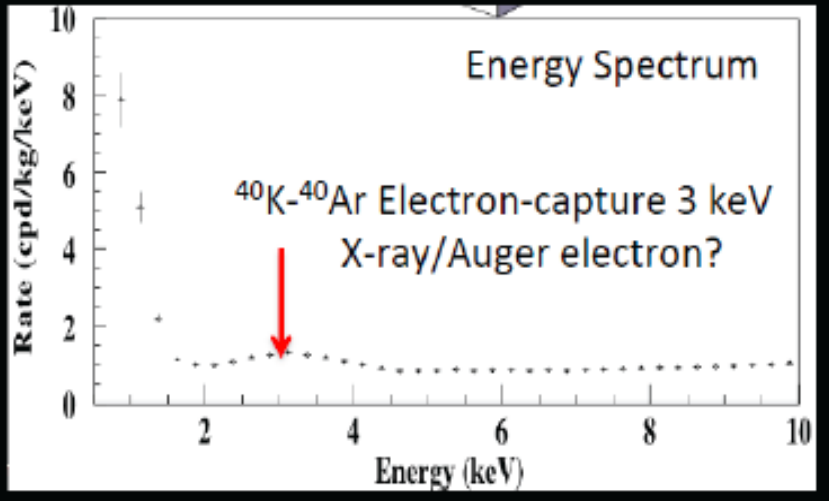
Element	MV laboratories	Siga Aldrich "Astro-Grade"	DAMA powder
K	12ppb	3.5 ppb	<100ppb (13 ppb in crystal)
Rb	14ppb	0.2 ppb	not reported
Th	<200ppt ~ 3.5ppt*	<1700ppt <1ppt*	20ppt
U	<100ppt <1ppt*	<500ppt <1ppt*	20ppt

* Preliminary by means of ICP-MS dilution method at PNNL

Decay Scheme of ^{40}K



EC decay produces 1.46 MeV **g** and hole in ^{40}Ar K-shell, which then fills giving 3 keV X-ray/Auger electron.

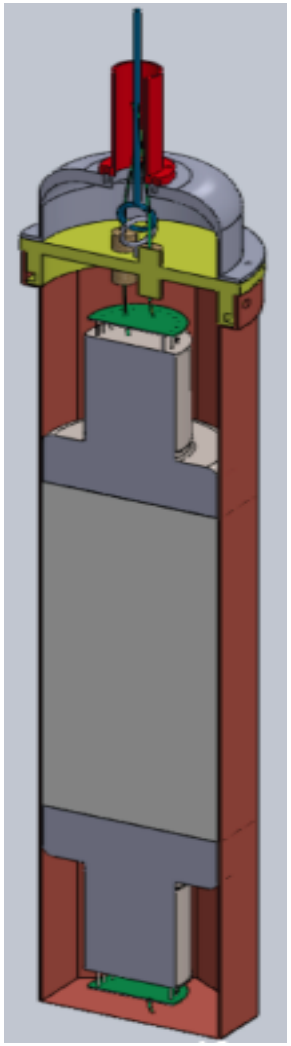


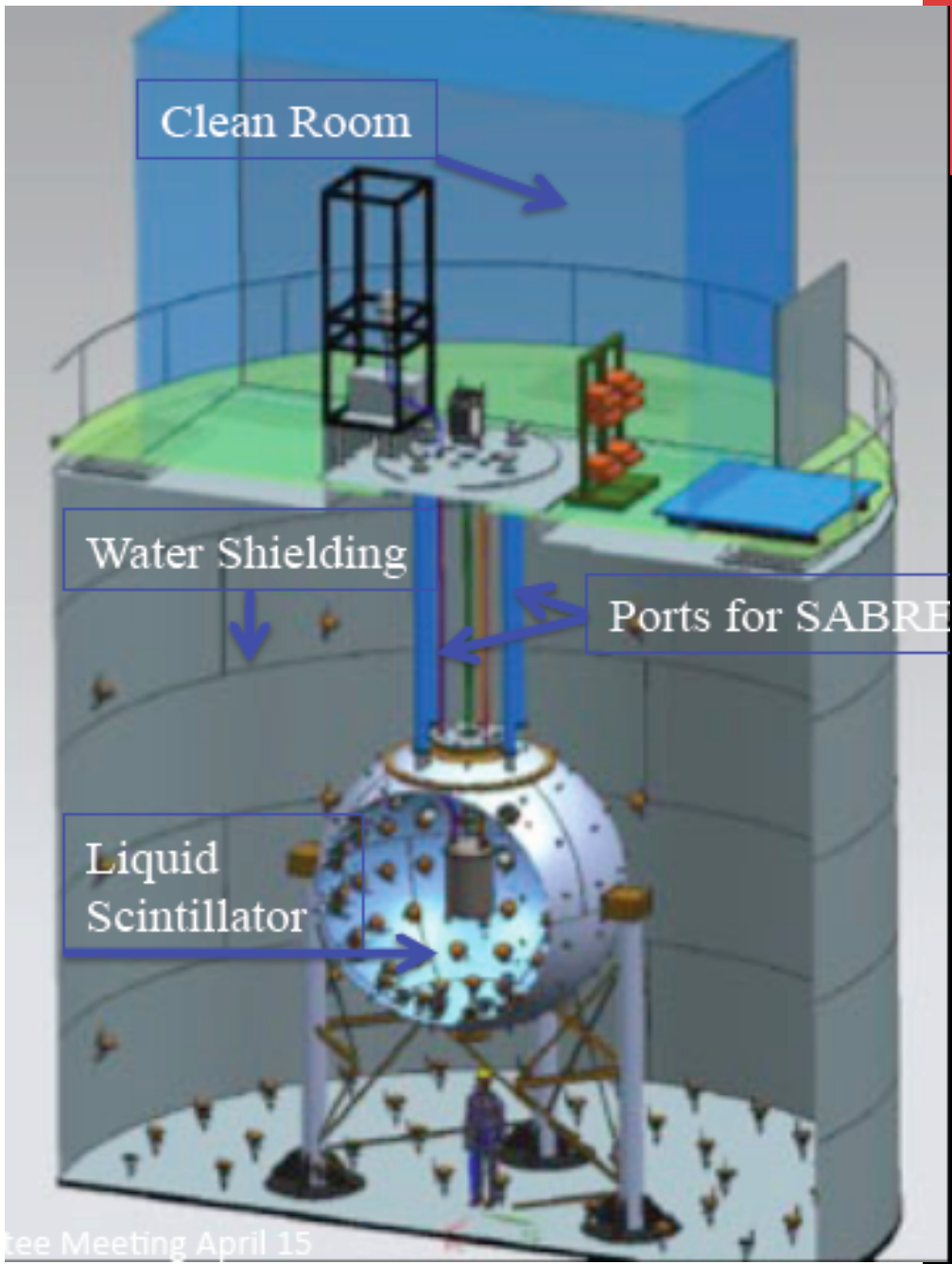
SABRE WORK PLAN

- **Test background rejection in liquid scintillator using DarkSide neutron-veto:**
  - 1° deployment with standard NaI crystal scheduled end of summer
  - 2° deployment with high purity NaI by Seastar (Boston, USA) scheduled in Autumn.
  - 3° deployment with high purity NaI by SICCAS (Shanghai, China) to be scheduled.
- **Make a demostrator to test final design**
- **Make SABRE detector**

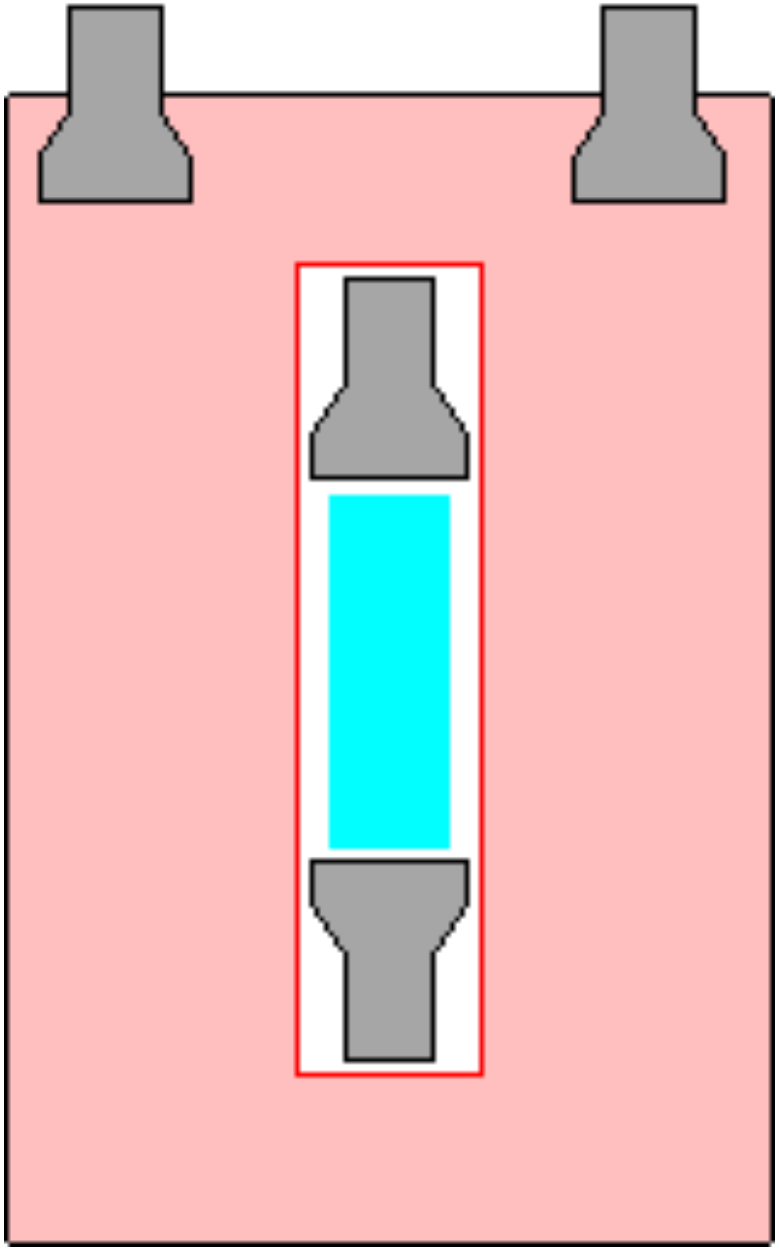
SABRE TEST IN DARKSIDE

- For 1st test TPC trigger turned over SABRE trigger.
- Coincidence with neutron-veto detector
- NaI crystal inside water Cherenkov and active scintillator shielding
- 3” diameter x 4” length cyclindrical NaI crystal





SABRE DEMONSTRATOR

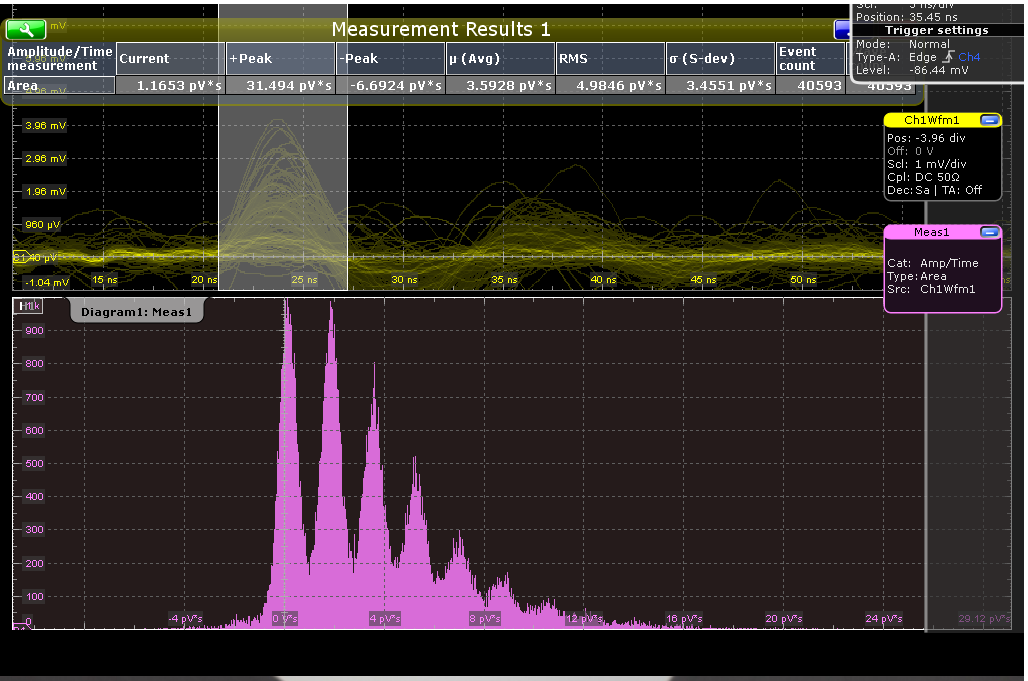


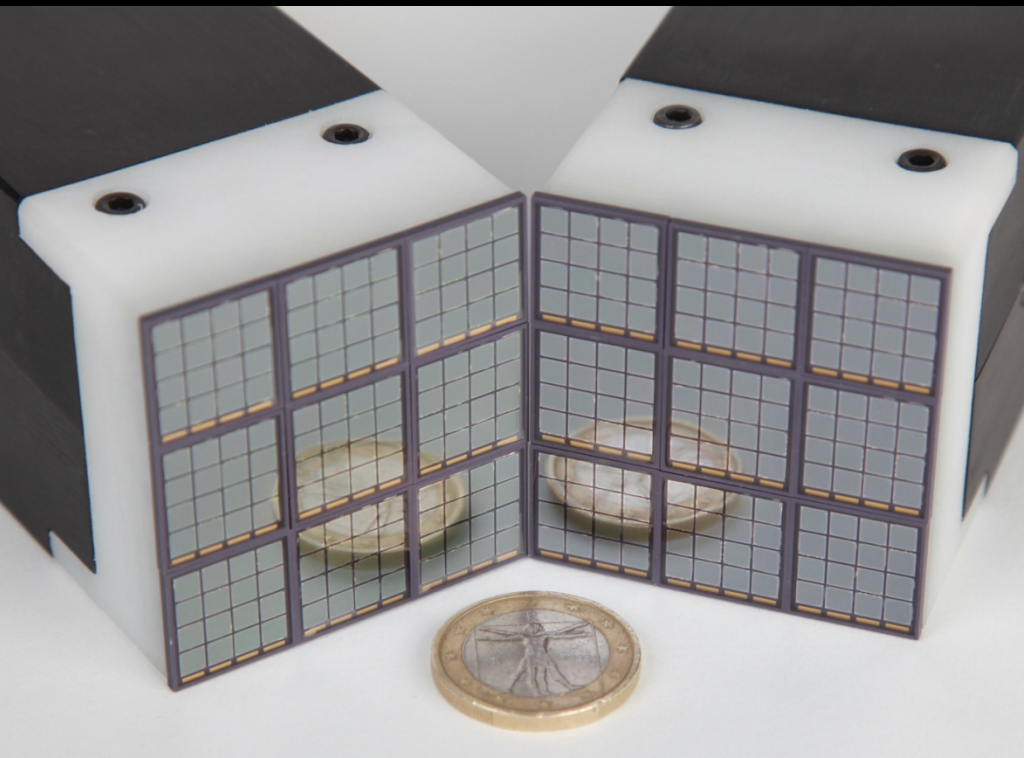
One SABRE detector in an active veto

- Installed in DarkSide-10 water shield
- VETO based on LAB scintillator
- 4 high radiopurity PMTs (or SiPM).

The device will allow to

- Study the purity of different crystals
- Study the optical read-out
  - PMTs vs SiPMs.
- Minimize the threshold
  - Study PMT afterglow
  - Increase LY of NaI with low temperature.





USING SIPM

SiPMs exibts high QE

> 40-50 % (limited only by fill factor)

SiPMs exibit HIGH pe resolution

Up to 5 % (compared to 30 % from PMT)

Low dark rate at T < -50 ^{0}C

Better than 10 cps/mm^2

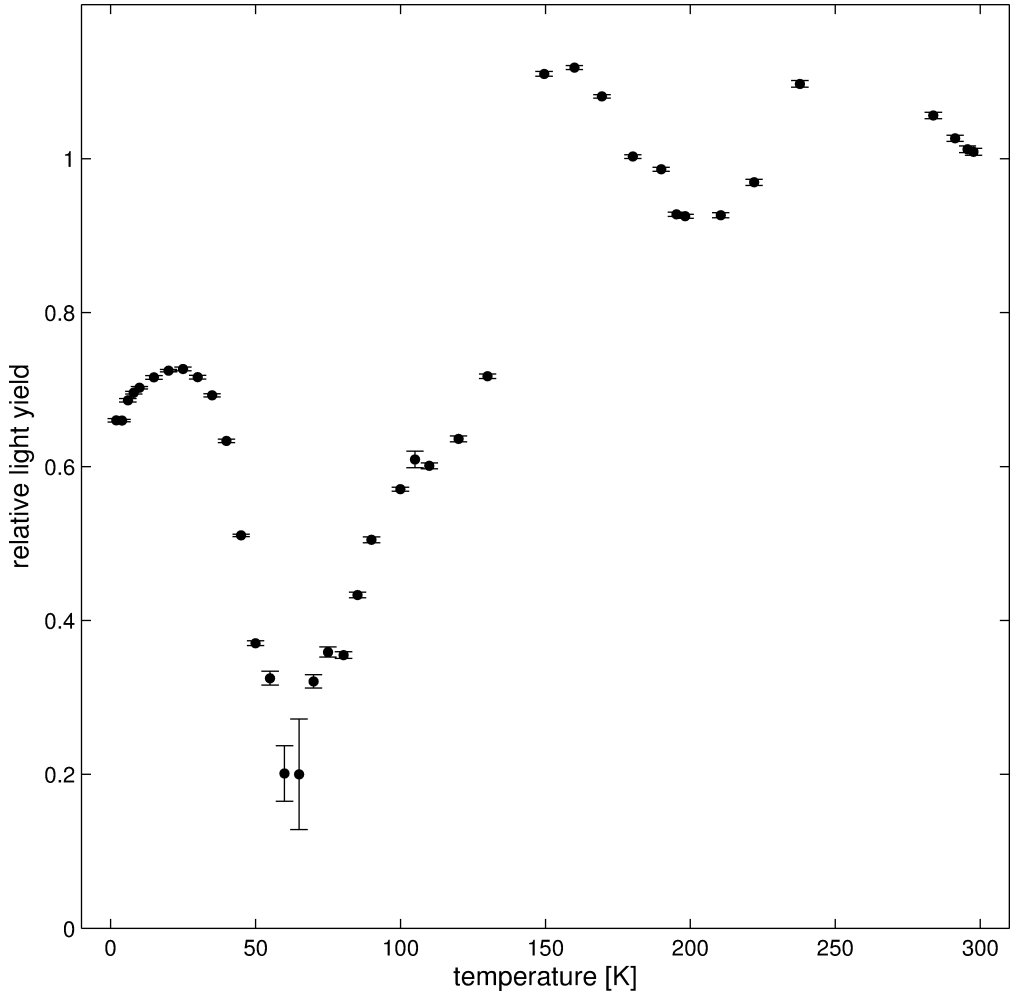
Radiopurity to be tested

In principle can be very good: it is only high purity Si

Cryogenic amplifiers can be used to sum up all the cells

- Radioclean electronics already available

LOW TEMPERATURE READ-OUT



We can use SiPMs

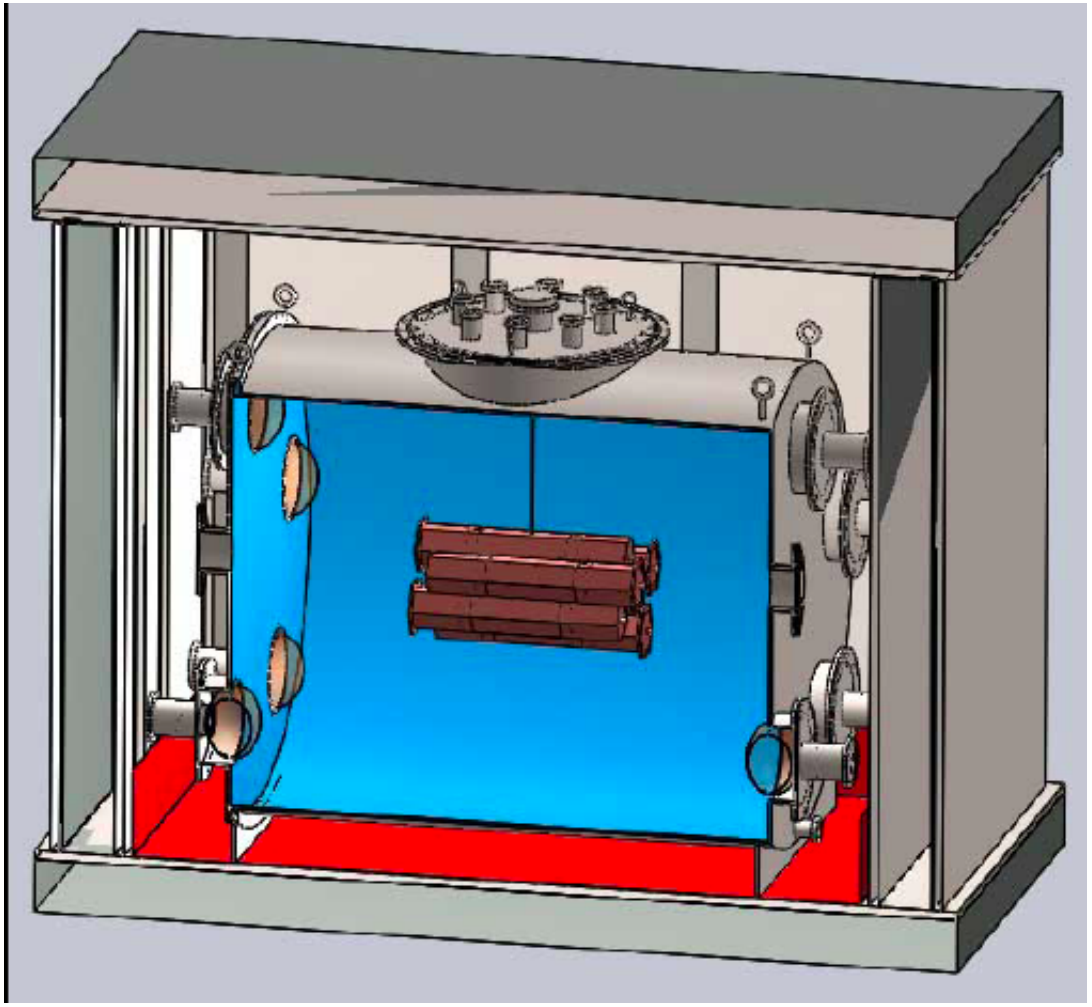
The Light Yield of NaI(Tl) increases slightly ~10%

We can significantly lower the threshold

- SiPM has no afterglow

SABRE DETECTOR

- Cylinder : 1.5 m x 1.5 m
- 2 tons LAB scintillator
- 10 8-inch PMTs
- Reflector in inner surface (>95%).
- Expected: 0.22 p.e./ keV
- Shielding: 25cm Pb
- Portable
- Minimum crystal array: ~50kg (7x8kg)



SABRE BACKGROUND SIMULATION

Based on radio-purity of NaI powder (after crystal gorwth one could reach lower background rate)