Acrylic purification and coatings

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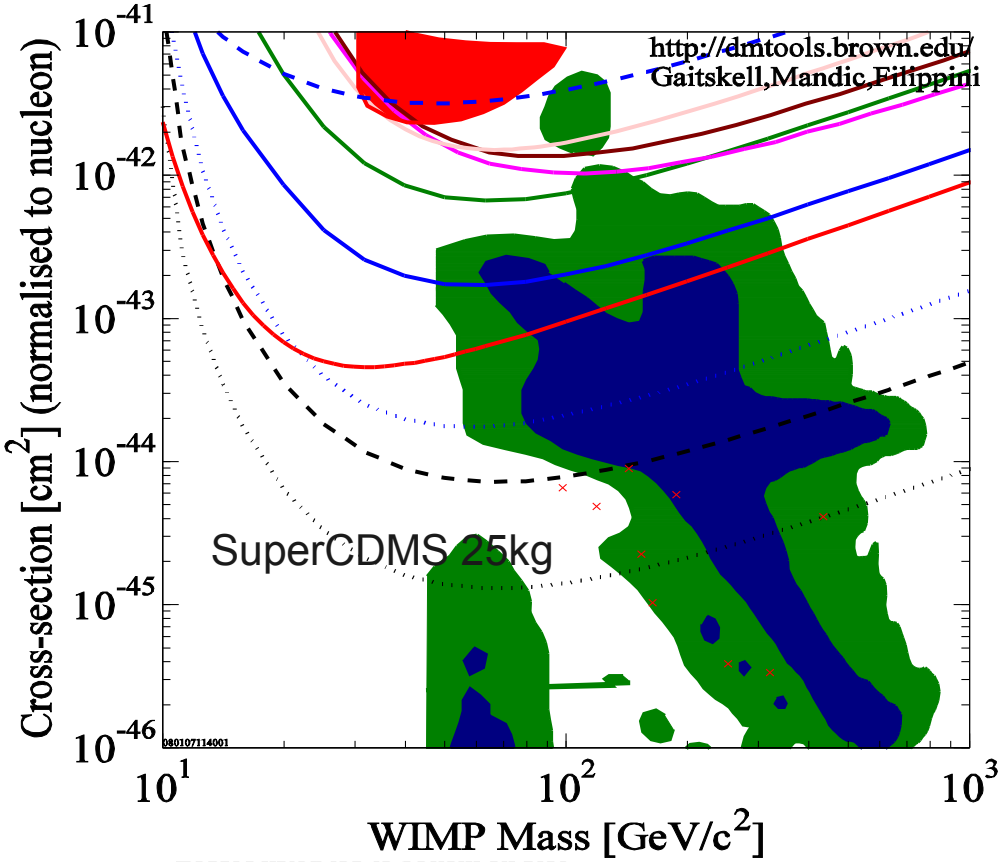
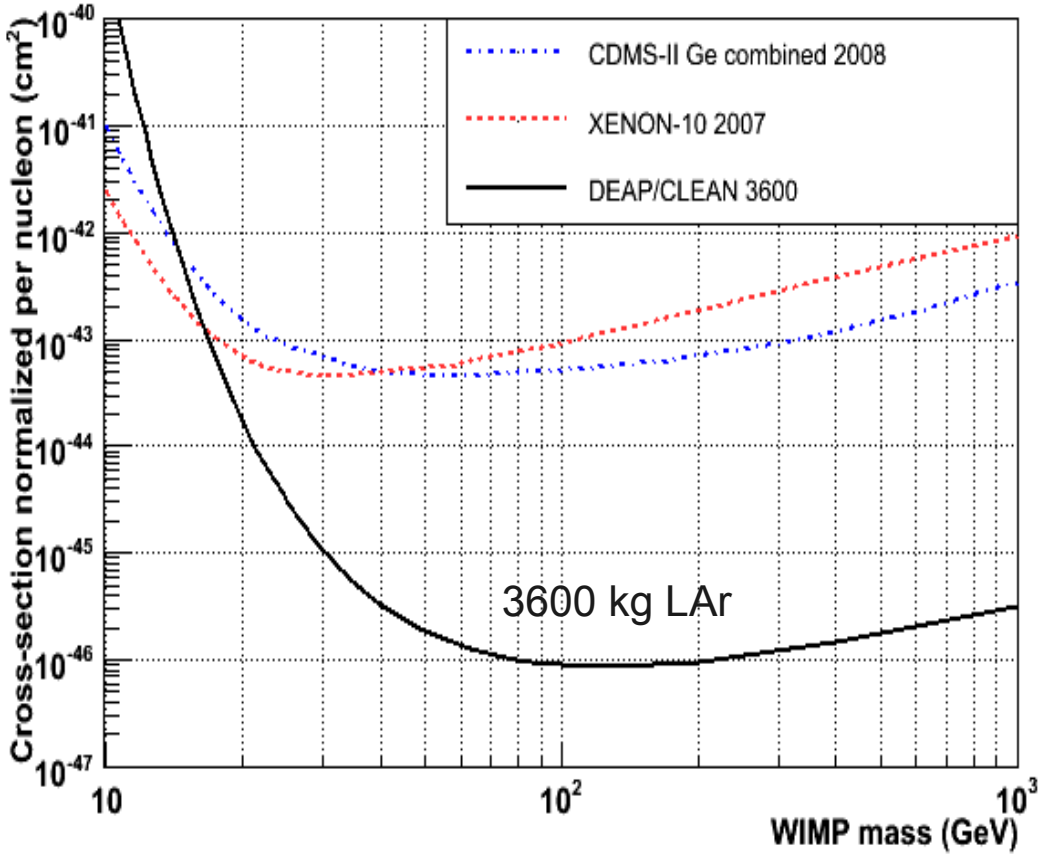
Outline

- DEAP-3600 experiment
- Surface backgrounds
- Backgrounds in DEAP-1
- Purification
- Production of coatings:
  - Solvent-borne (for DEAP-1)
  - Chemical vapour deposition (CVD)
  - In-situ polymerization
- Outlook

Motivation

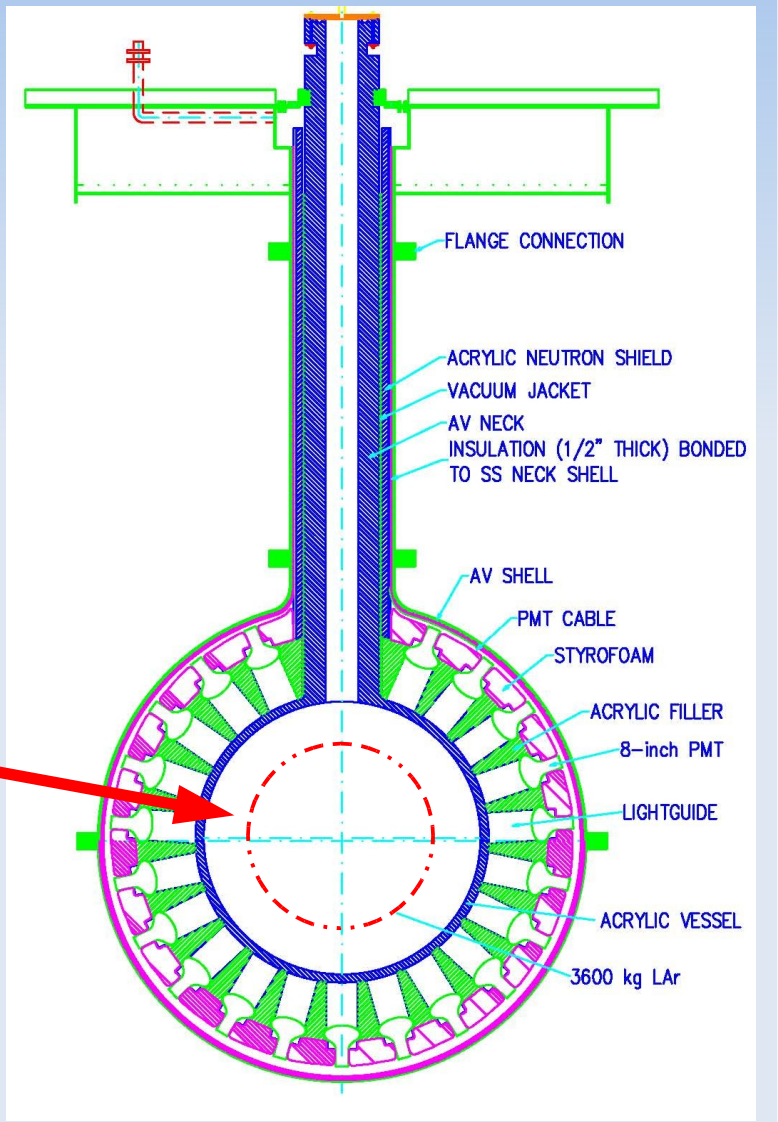




CDMS-II: ~50 kg-days (Ge)
XENON-10: ~300 kg-days (Xe)
DEAP 3600: 1,000,000 kg-days (Ar)

DEAP-3600

- Search for Weakly Interacting Massive Particles (WIMPs)
- Liquid Argon (3600 kg) detector, with 1000 kg fiducial volume
- Main backgrounds and countermeasures:
  - γ/β: *Pulse Shape Discrimination*
  - Neutrons: *Shielding, Radiopurity*
  - Surface α events:
    - Fiducialization
    - Radiopurity
- Fiducialization reduces rate of nuclear recoils induced by radon daughters decaying near the surface
- Requirement: 0.2 events in 3 years in fiducial vol.
- For more, see Bei Cai's talk tomorrow



^{222}Rn progeny

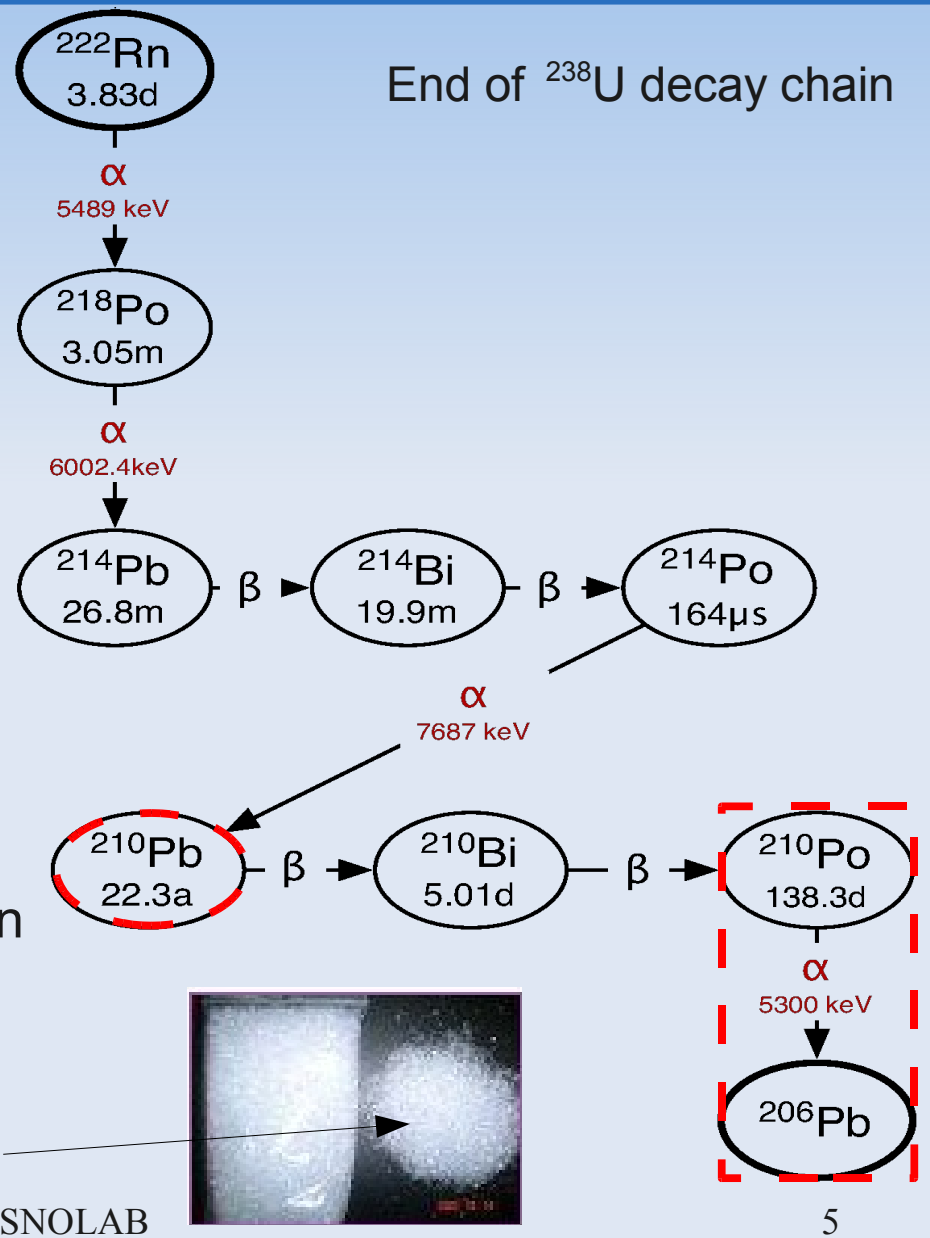
In acrylic, typical U/Th content is low, but...

- ^{222}Rn is always present in air (>10 Bq/m^3)
- Rn diffusion length in acrylic is 0.11 mm
- ^{210}Pb builds up on (and under) surfaces exposed to Rn and feeds ^{210}Po, which is an α-emitter (WIMP-like events!)
- Avoiding exposure to air and surface layer removal allow to reduce the background

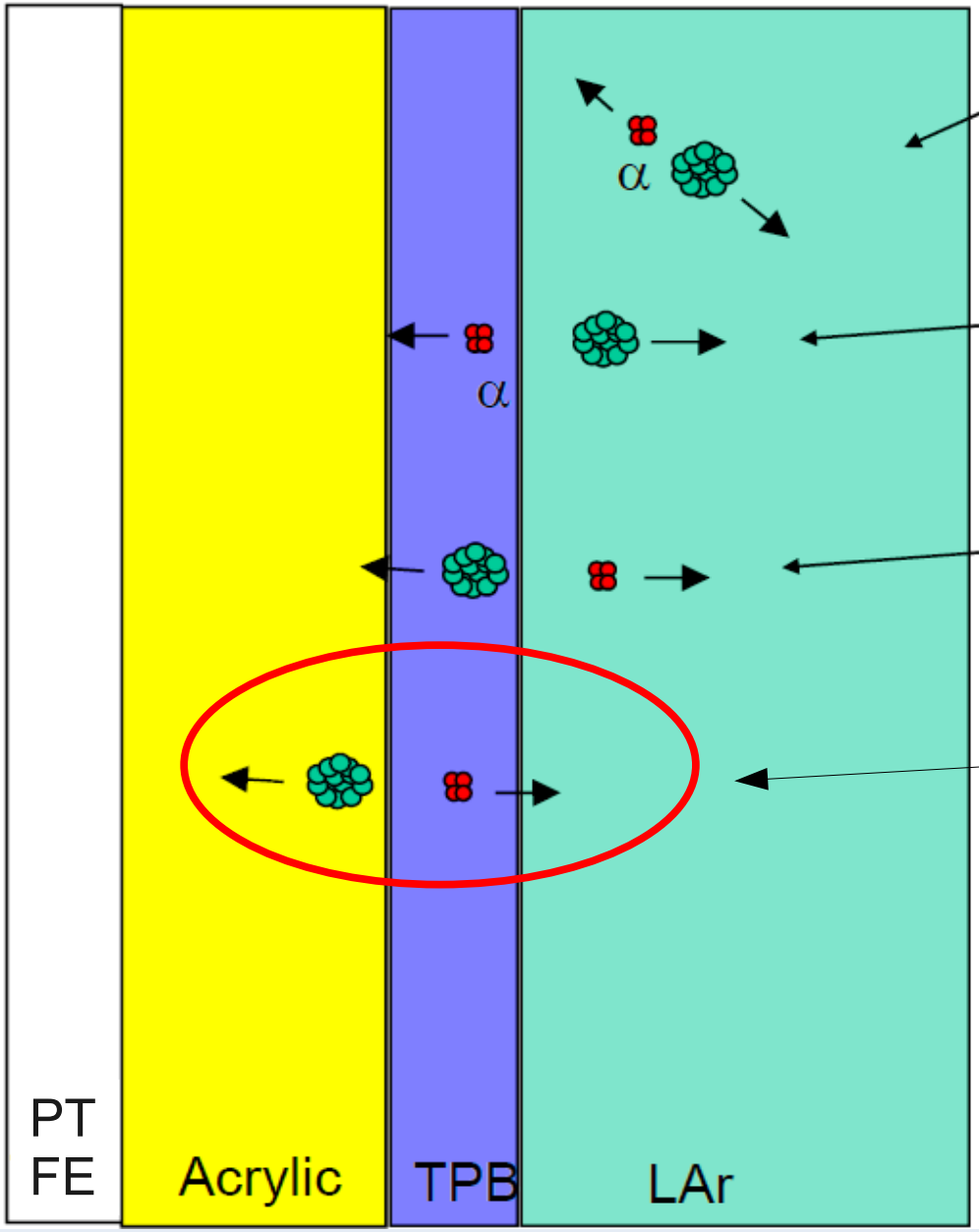
The reduction is limited by Po/Pb concentration in the bulk acrylic, which can be permeated by Rn:

- As a liquid monomer (before polymerization)
- During slush cast or storage (as small beads)

End of ^{238}U decay chain



Surface events



Decay in bulk detector tagged by α-particle energy

Decay from surface releases untagged recoiling nucleus and α in TPB (see both, low energy)

Decay from surface releases untagged recoiling nucleus and α in LAr (see mostly α-particle, high energy)

LE:HE Ratio 1:1 for events on TPB surface

Decay from inside TPB or acrylic releases α which may also enter LAr. Could see
(a) Light from TPB only (prompt) or
(b) Light from LAr (range of energies)

The 5.3 MeV α range in acrylic is ~34 μm.
~10^{-20} g/g ^{210}Pb required,
(which for acrylic beads is equivalent to several weeks of exposure to air)

Direct assay

- To assay for ^{210}Pb (or ^{210}Po) out of equilibrium, we are mounting a program to vaporize large masses of acrylic and counting the residue
- ~10 kg samples will be vaporized, residues counted (46 keV γ from ^{210}Pb)
- Tests of small samples have been vaporized in a test furnace at SNOLAB
- New system of furnaces, sample feeders and suprasil tubes ordered to allow multiple 2 kg samples

13 g sample of acrylic with N_2 flush gas in

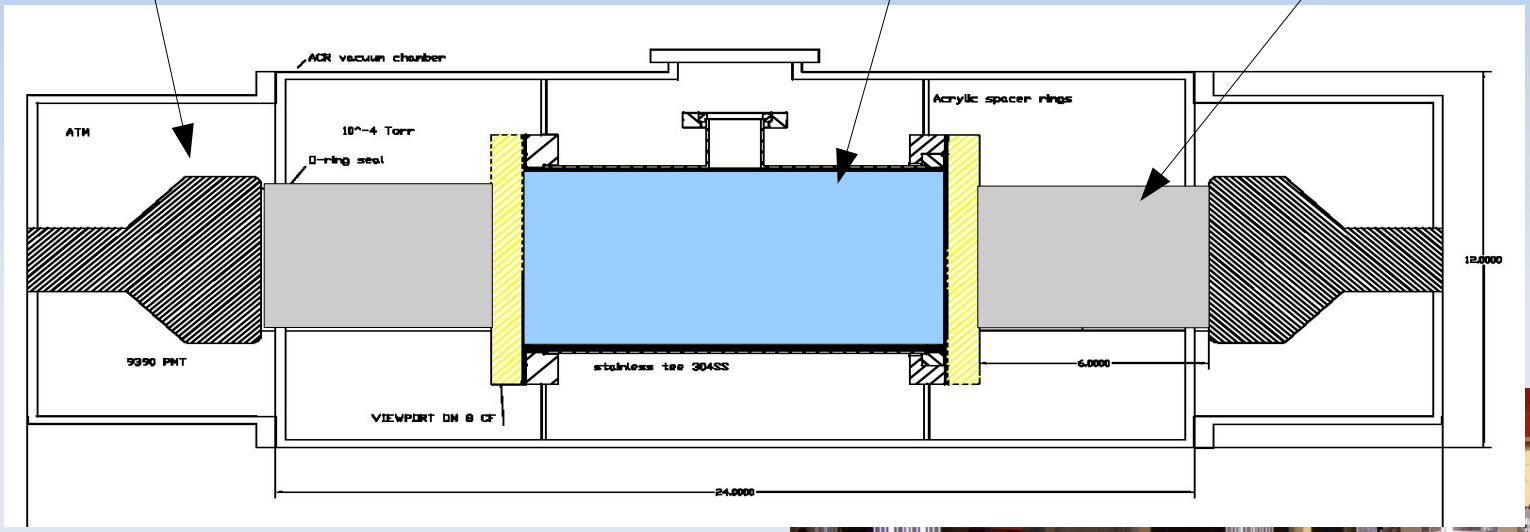
Courtesy: B. Cleveland, M. Batygov

DEAP-1: prototype detector

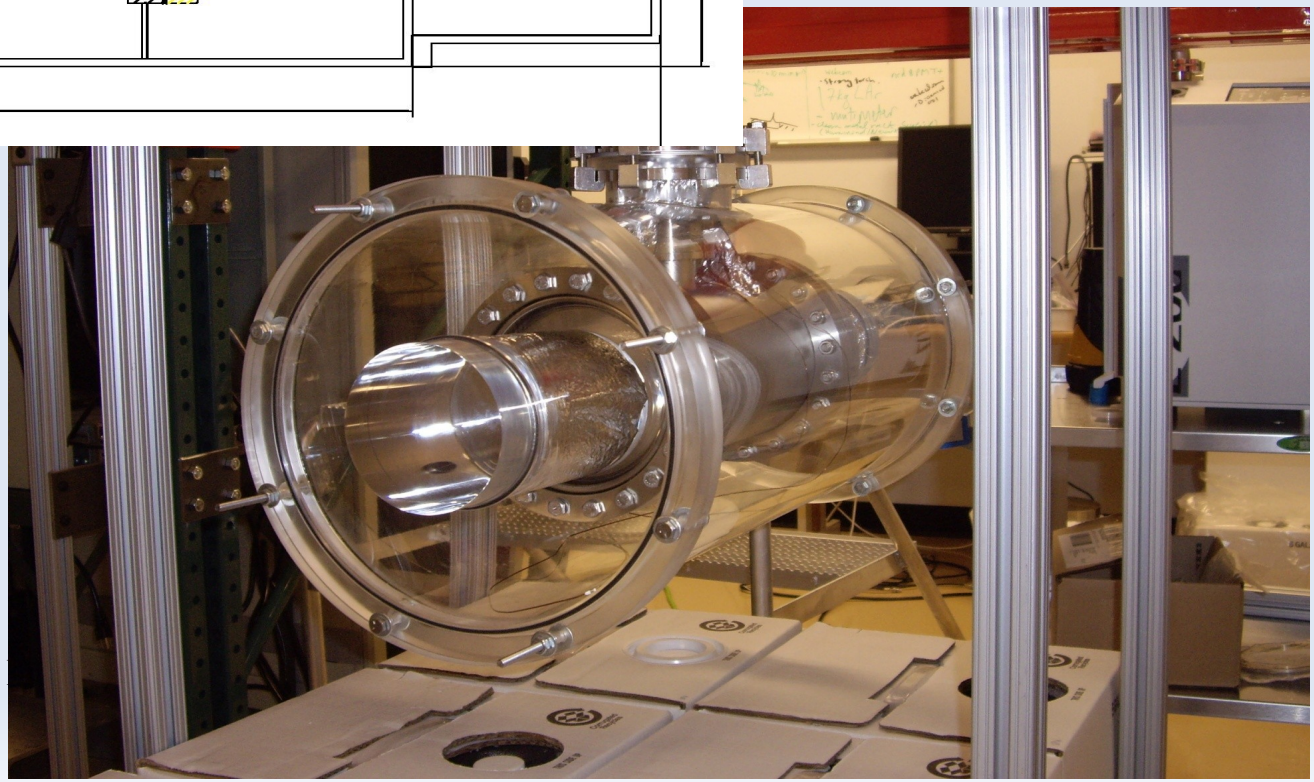
PMT

Acrylic liquid Ar vessel, covered with wavelength shifter

Acrylic light guide



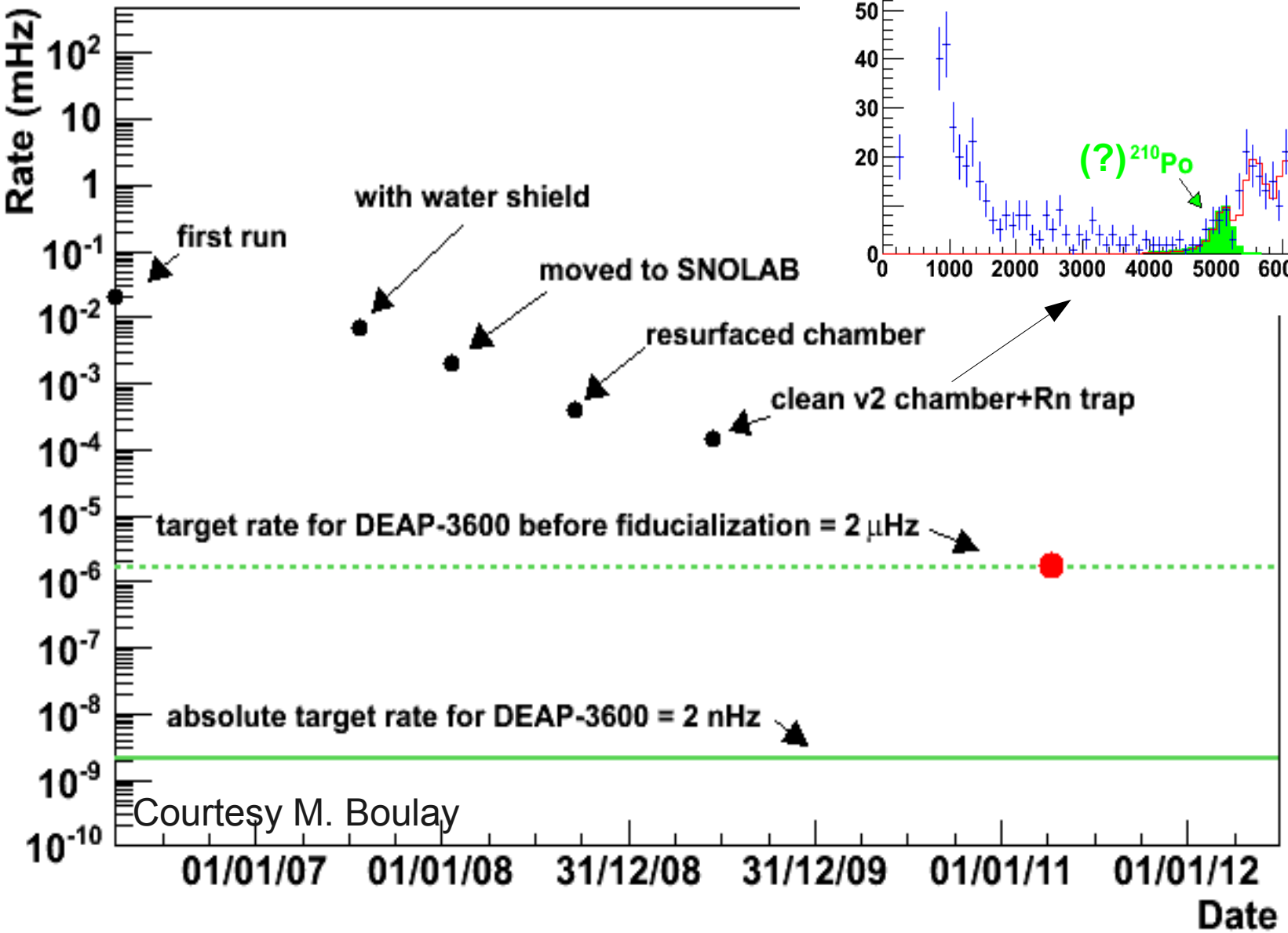
Currently taking data at SNOLAB



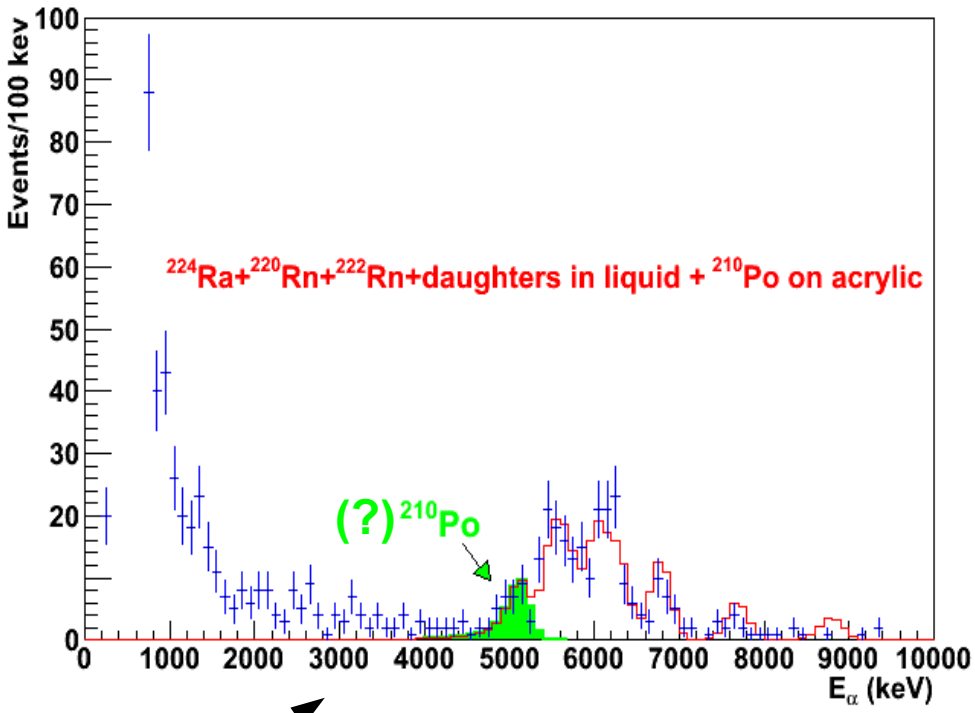
For now, DEAP-1 is the most sensitive tool we have:

measured $<10^{-16}$ g/g ^{210}Pb

Backgrounds in DEAP-1



Courtesy M. Boulay



New approach

- An ultra-clean coating thick enough to stop the alphas (50 - 100 μm)
- Requirements for the coating:
  - Optics: optically transparent, matching refractive index
  - Has to survive cool-down to LAr temperature without delamination: matching CTE, good adhesion to acrylic
  - Possible to purify (through distillation and/or adsorption)
  - Coating process compatible with acrylic
- The best candidate:
  - PMMA (acrylic) and other methacrylates

Purification

1. We start with liquid monomer (MMA) and solvent (ACN)

2. Purification via vacuum distillation and adsorption on porous Al_2O_3 powder

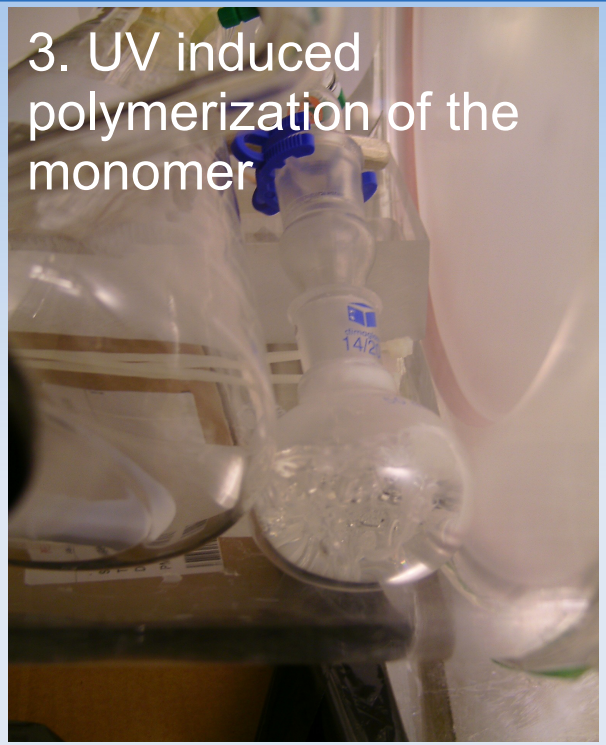
Based on the literature this should yield a reduction factor of:

- ~10000 for Pb [SNO+]
- >500 for Po [Borexino]

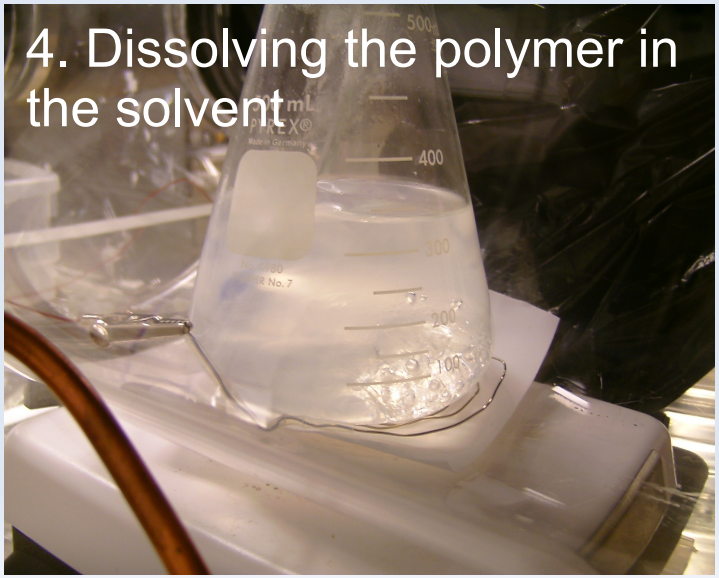
All further steps performed inside a glove box in a Rn reduced atmosphere!

Solvent-borne coating

3. UV induced polymerization of the monomer



4. Dissolving the polymer in the solvent



5. Spin coating

6. Drying
7. Vacuum outgassing

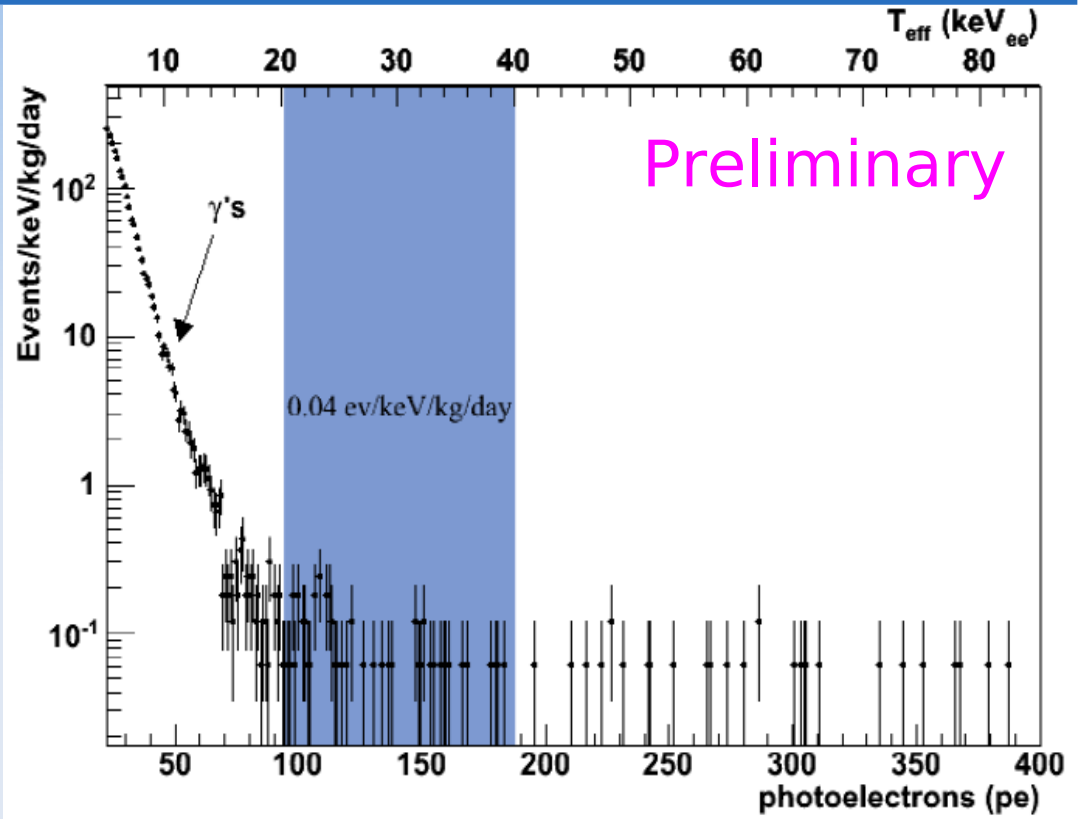
Spin coating

- ~3h at 500-1000 rpm
- Only low Rn emanation materials inside the glove box
- Other possible methods include: casting, spraying, dipping, brush painting ...

final assembly, Feb. 26th 2010

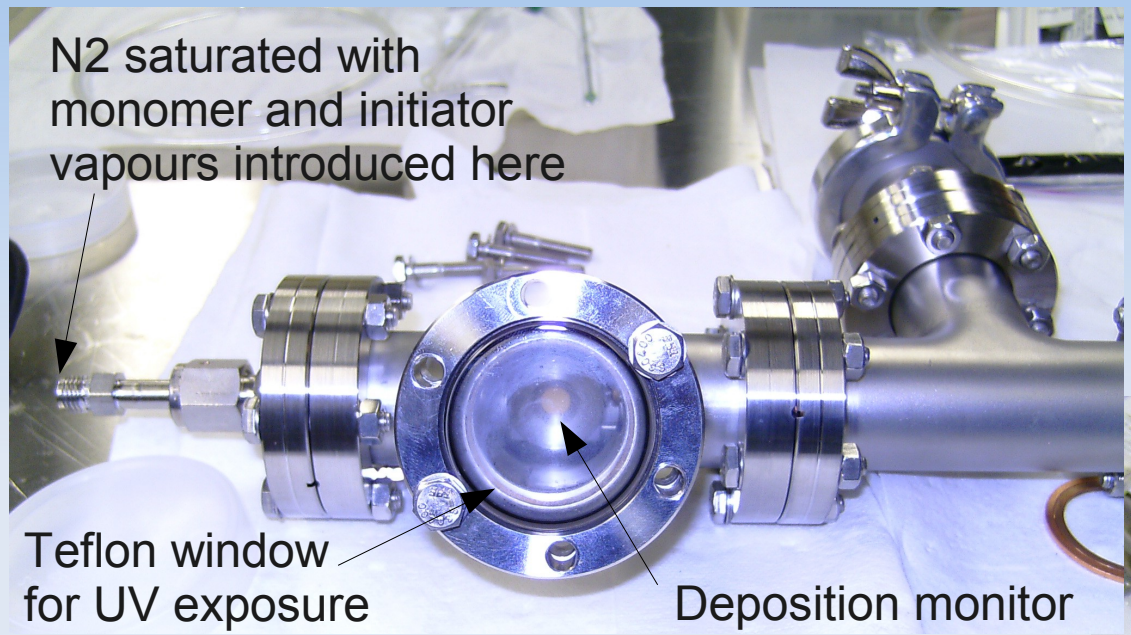
Results?

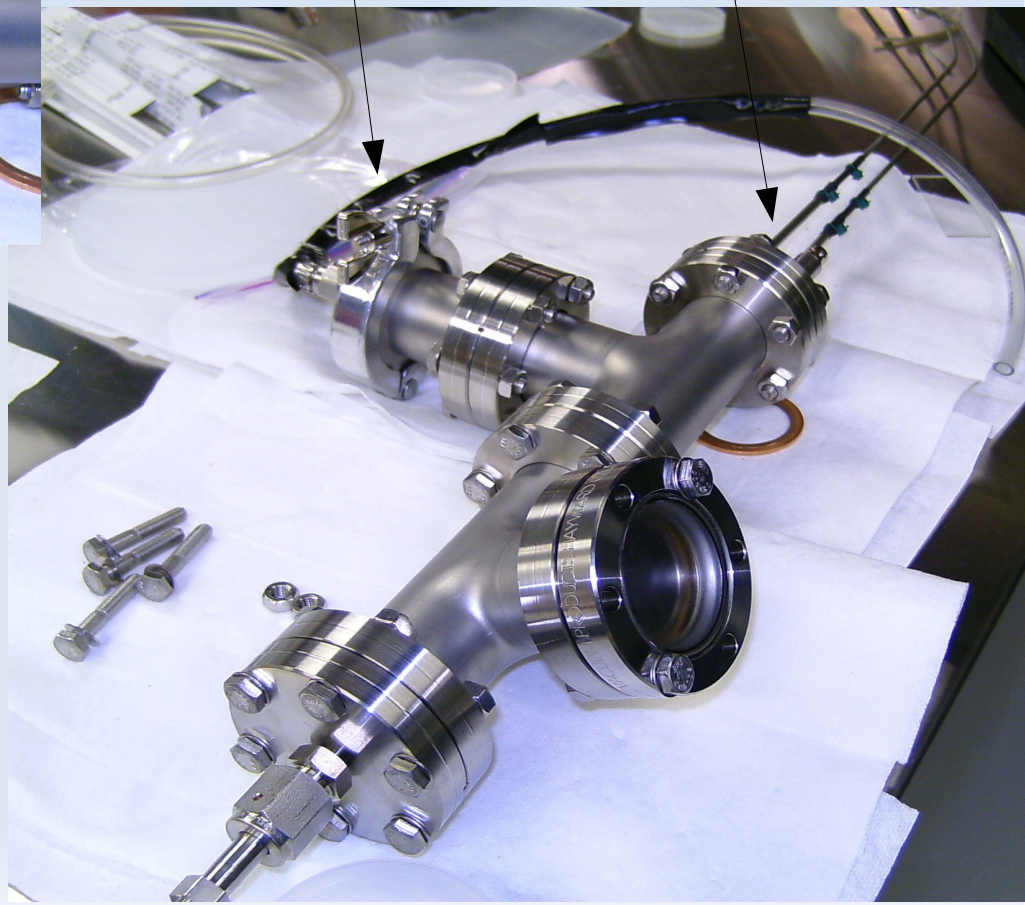
- Deployed in March 2010
- No significant 'WIMP-like' (low energy) background reduction
- Also, no change in ^{222}Rn decay rate (high energy alphas)
- Both high and low energy rates are similar
- Expected if backgrounds are from ^{222}Rn in the chamber



- To be confirmed with a calibrated Rn spike
- => current DEAP-1 backgrounds are not dominated by events from acrylic
- Even with the current surface background rate scaled-up to DEAP-3600, a competetive DM is possible (see Bei Cai's talk)

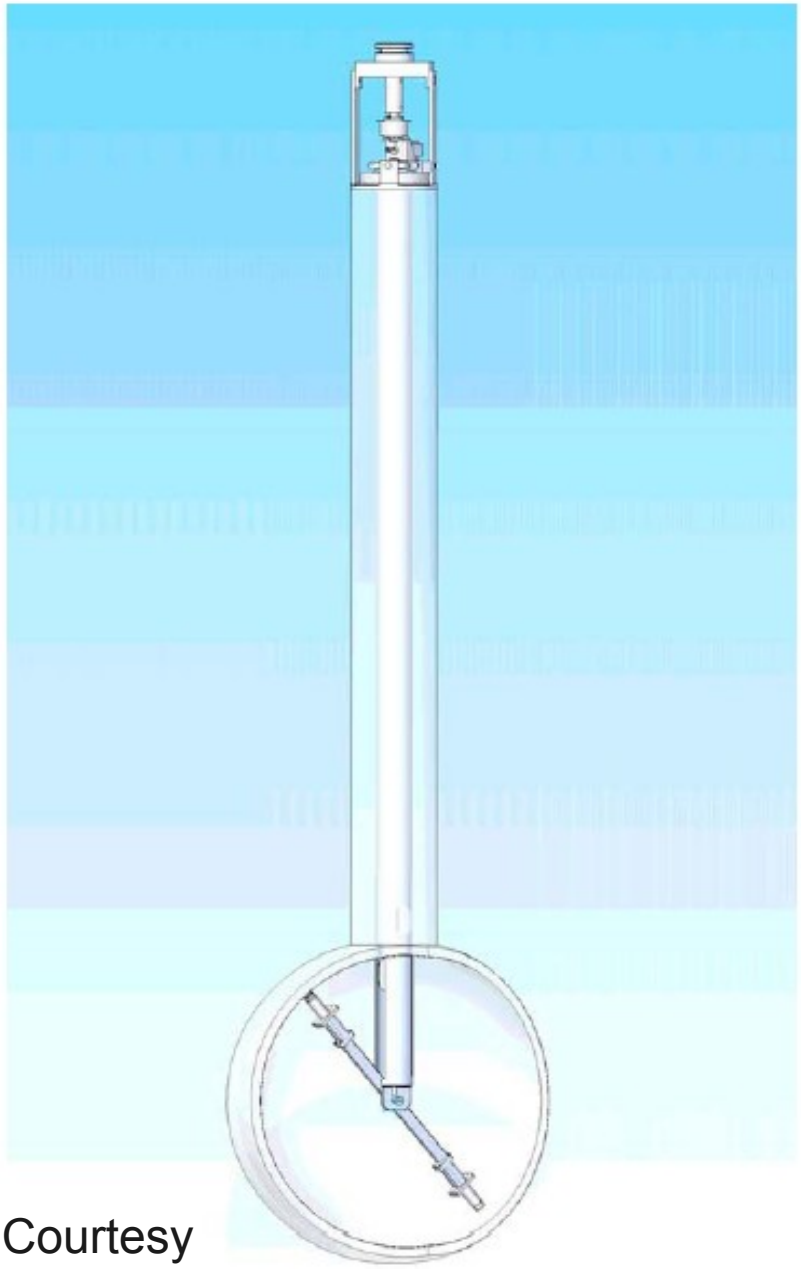
Prototype CVD setup



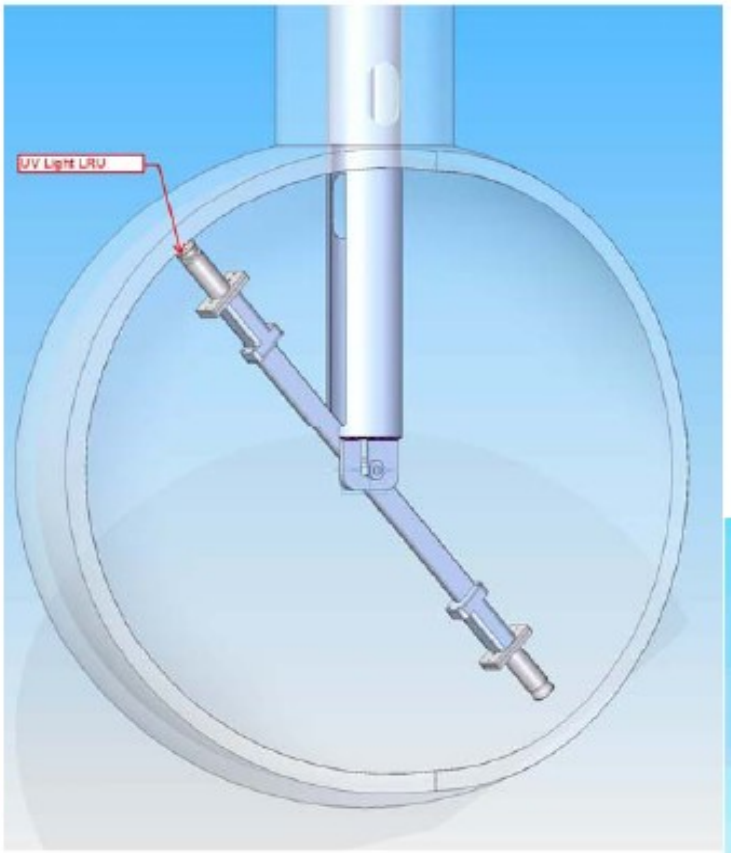


- Photo initiated CVD system:
  - Deposition rate optimization
  - Testing various monomer/initiator combinations
  - Optimizing geometry

Scale-up for DEAP-3600

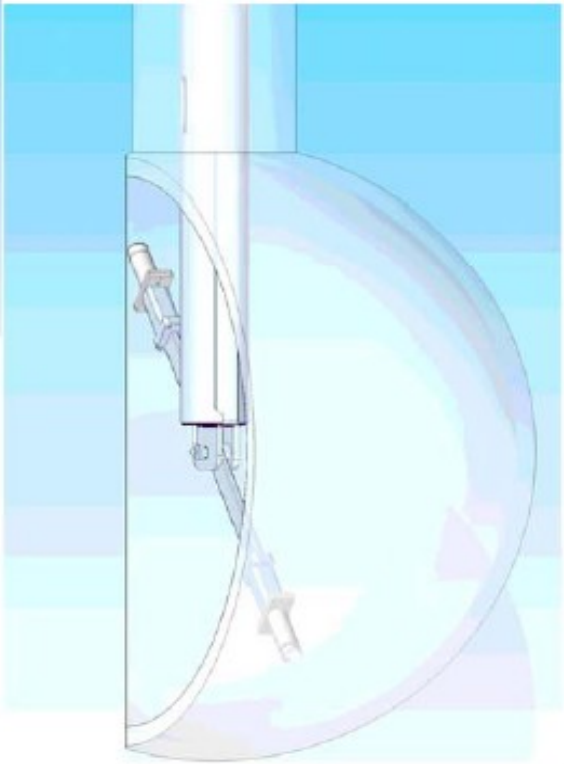


Courtesy
S. Florian

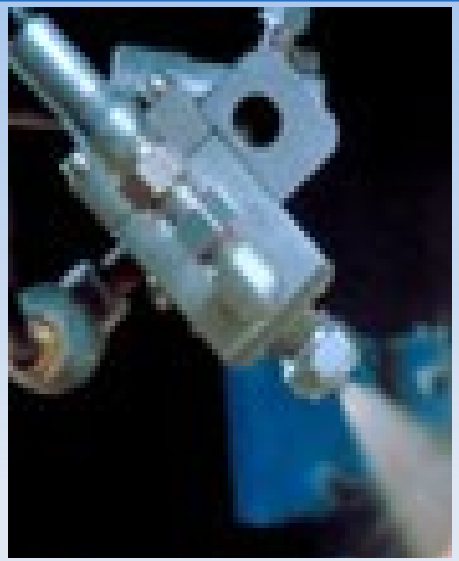


Resurfacing device for DEAP-3600.

Abrasive heads replacable with CVD or UV curing units.



Spraying + UV curing



- Planned tests on one more possibility:
  - Airless spray gun +
  - UV LED light source
- Thin layer of monomer/initiator mixture polymerized directly on the detector surface
- Prototype under construction

Summary & outlook

- Produced first ultra-pure acrylic coatings
- Developed a new method of surface background reduction
- Different coating techniques available, depending on geometry & substrate type
- R&D on scaling it up for DEAP-3600
  - CVD process optimization
  - Tests on spray/in-situ polymerization method

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Backup

Cleaner TPB evaporation

Additional steps in the deposition procedure:

- TPB deposition system (glass crucible and NiCr filament) acid cleaned before use
- initial vacuum bake-out of TPB at ~170°C (to decrease potential contamination with Po)