Dark Matter Search Activities at the University of Montreal

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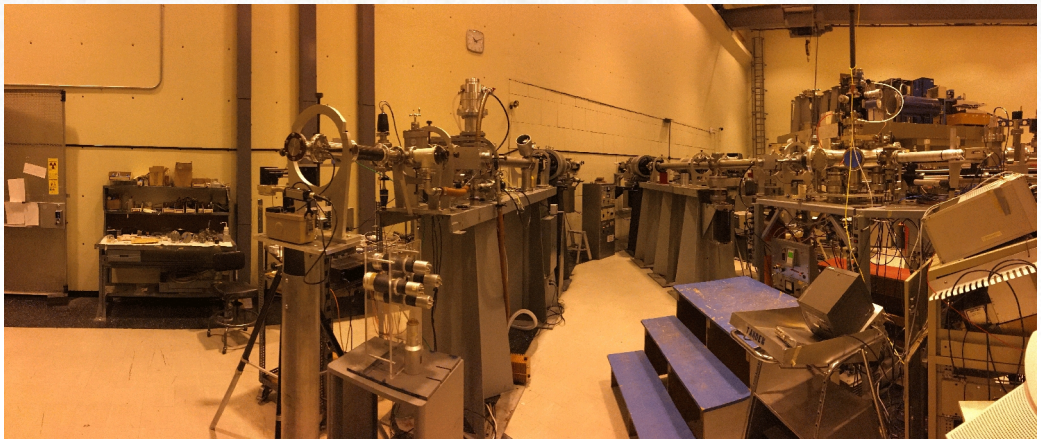


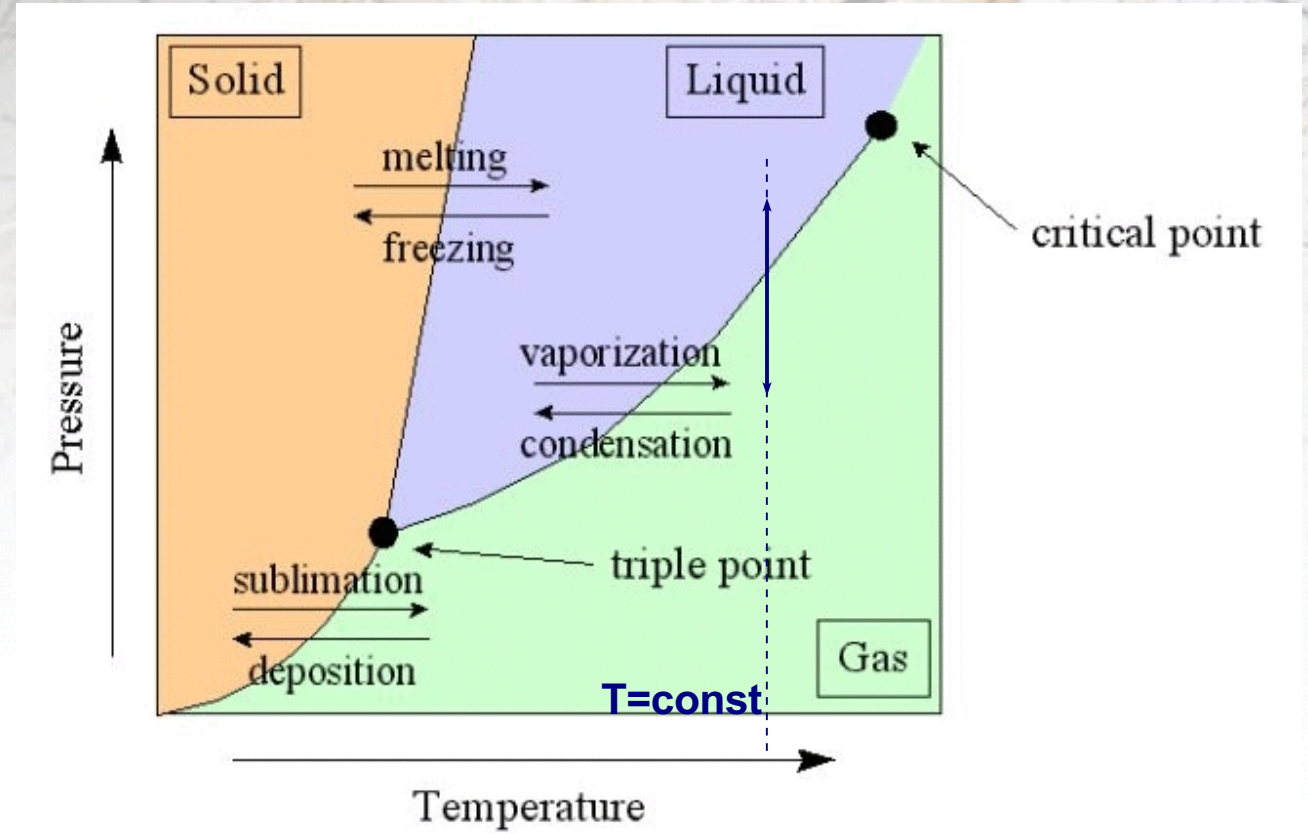
Outline

Technology Group (GT.)

- We are part of PICASSO/PICO collaborations from the beginning.
- We provide full support for R&D, design and manufacturing of Detectors and DAQ.
- Some “new” ideas from the PICASSO era still didn’t make into PICO design.

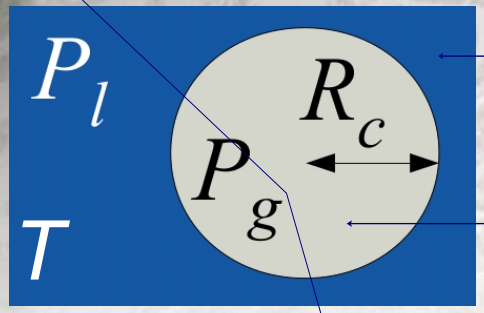
Bubble Chambers

PICASSO and PICO - no tracks, just bubble



Bubble recipes

Thermodynamic bubble formation theory of F.Seitz



Superheated fluid

Gas Bubble

In a superheated fluid, energy deposition grater than Ec in a radius less than Rc will result in a bubble large enough to overcome surface tension σ.

$$E_{loss}(\Delta x) > E_C$$

$$\Delta x < R_C$$

$$R_C = \frac{2\sigma}{P_g - P_l}$$

P_g - gas pressure;

P_l - liquid pressure.

$$\sigma = \sigma_0 \left(1 - \frac{T}{T_C}\right)^n$$

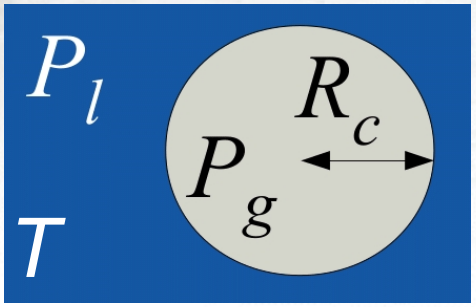
T_C - liquid critical temperature;

$$n \approx \frac{11}{9}$$

Critical Energy

$$E_C = \frac{4\pi}{3} R_C^3 \left(P_l - P_g\right) + \frac{4\pi}{3} R_C^3 \rho_i \left(h_g(T) - h_l(T)\right) + 4\pi R_C^2 \left(\sigma - T\frac{d\sigma}{dT}\right) + W_{etc}$$

Pressure Work: needed to form a proto-bubble; to compensate the ambient pressure.



Latent Heat: energy needed to evaporate the liquid into gas.

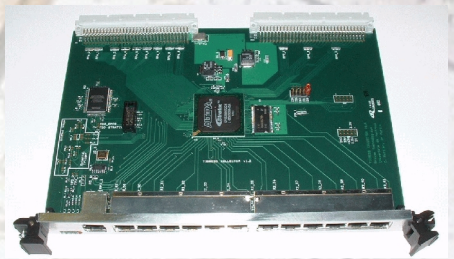
Surface Formation: energy needed to work against the surface tension.

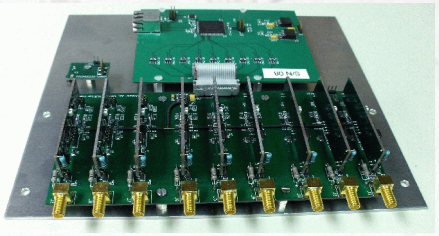
Small balance includes the work needed for acoustic emission, etc.

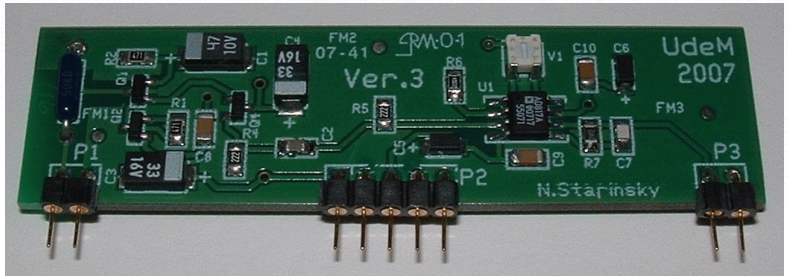
The detector is tuned to be blind to gammas and electrons!

PICASSO Piezo Sensors & DAQ

Still used today as R&D for PICO



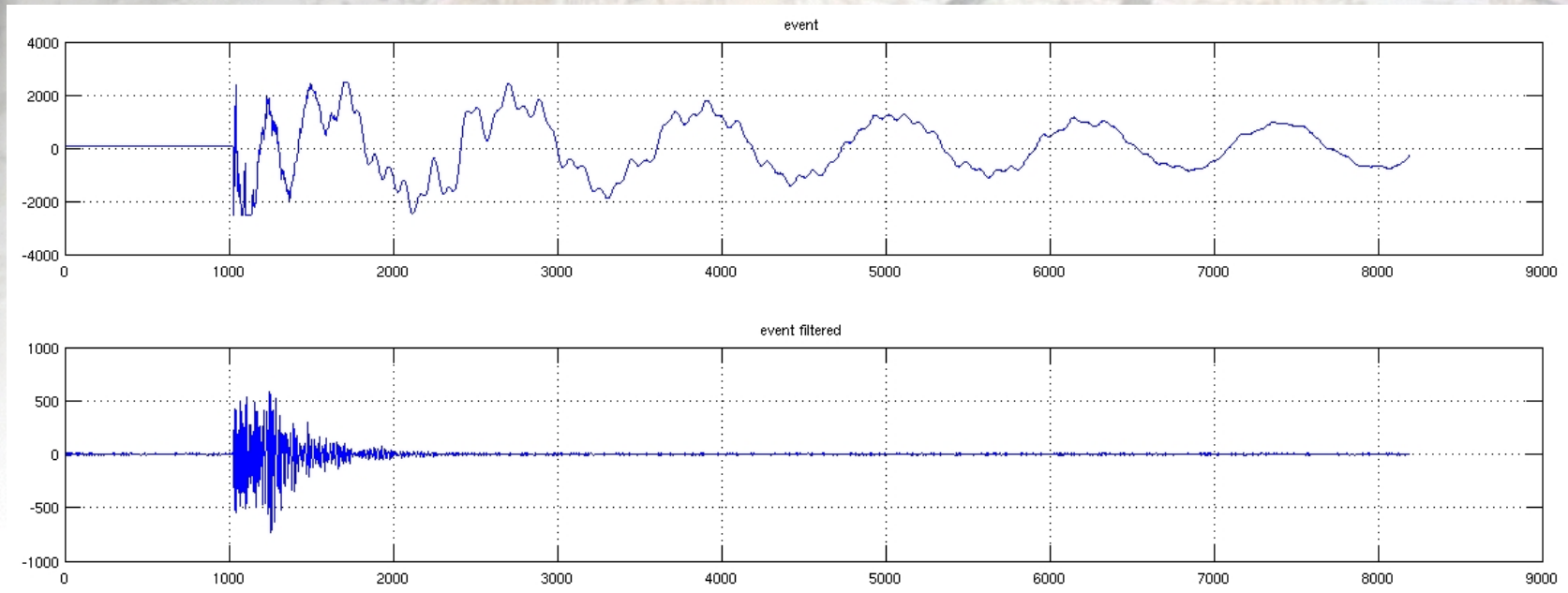




Piezo signal

We see bubbles and hear them!

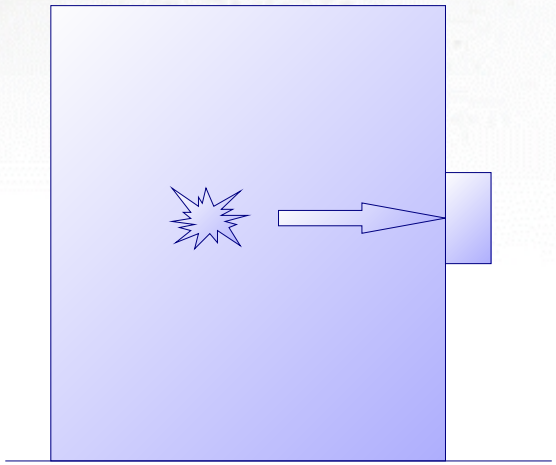
A raw signal



After High-pass Filter

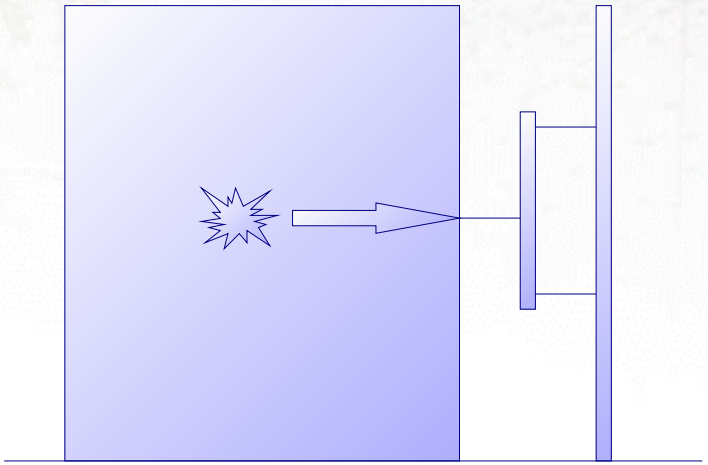
- All piezos in PICASSO/PICO are accelerometers; they do not measure the displacement of the detector's wall directly.
- So far, their partial success is only due to the oscillatory nature of the bubble sound.
- Why it is important?

$V_{out}(t) \sim a(t)$



$V_{out}(t) \sim \Delta r(t)$

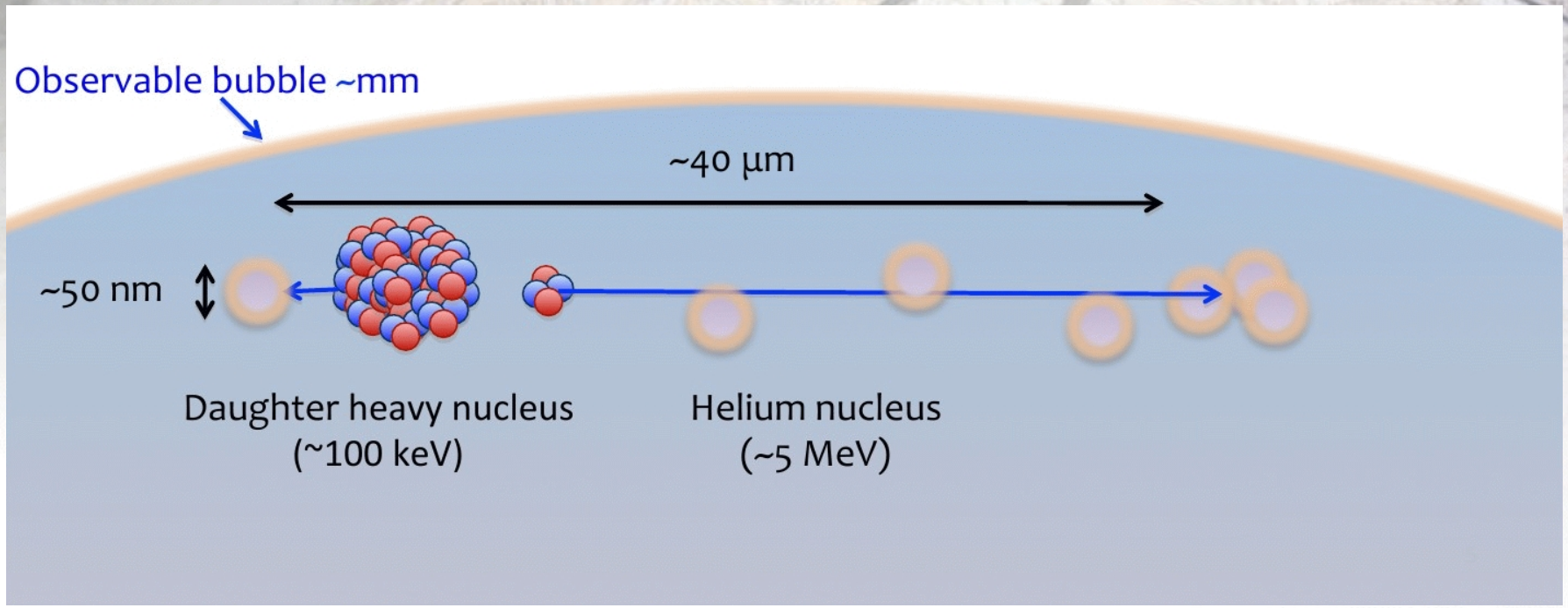
Fixed wall



Bubble Creation Dynamics

Alphas deposit their energy over tens of microns.

Nuclear recoils - over tens of nanometers.

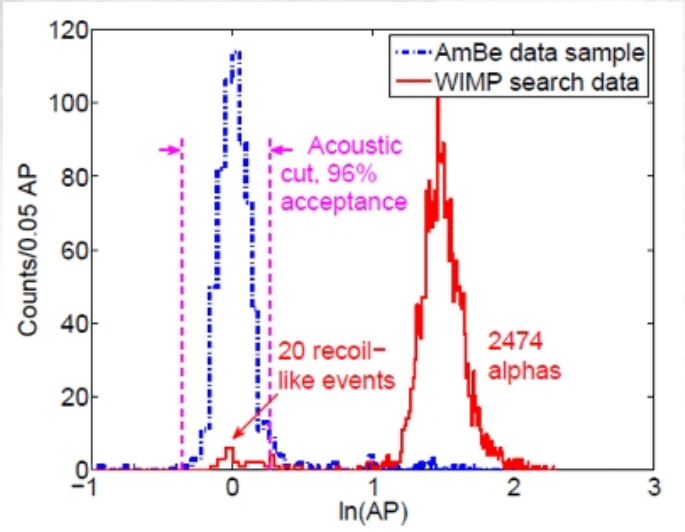


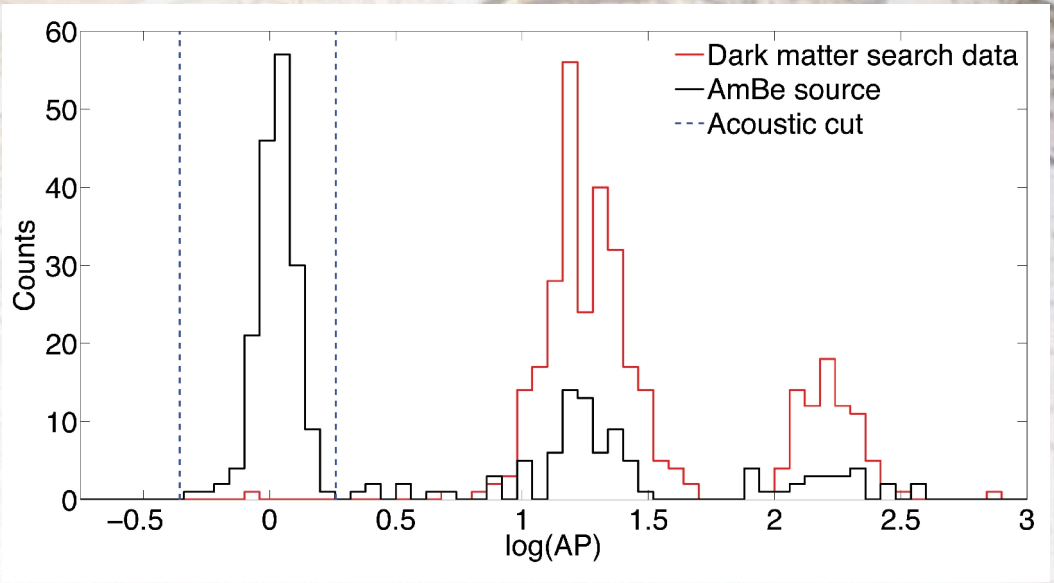
Type of reaction is in the very beginning of the bubble formation!

Alpha/Neutron Separation

AP - Acoustical Power

- Alphas are louder than neutron events;
- Alpha rejection is >99.6%.



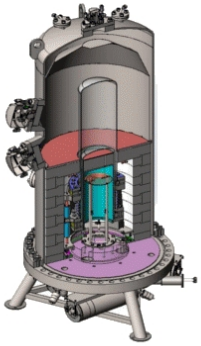


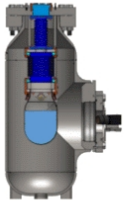
This analysis is done on the time scale close to the beginning of the bubble.
After that all bubbles are the same...

PICO Evolution Line

PICASSO *COUPP*

PICO-2L → PICO-60 → PICO-40L*

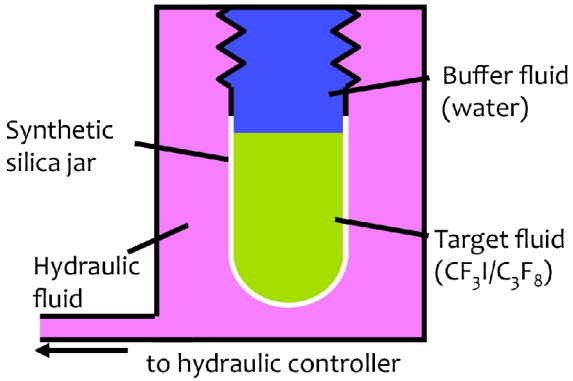




PICO-500*

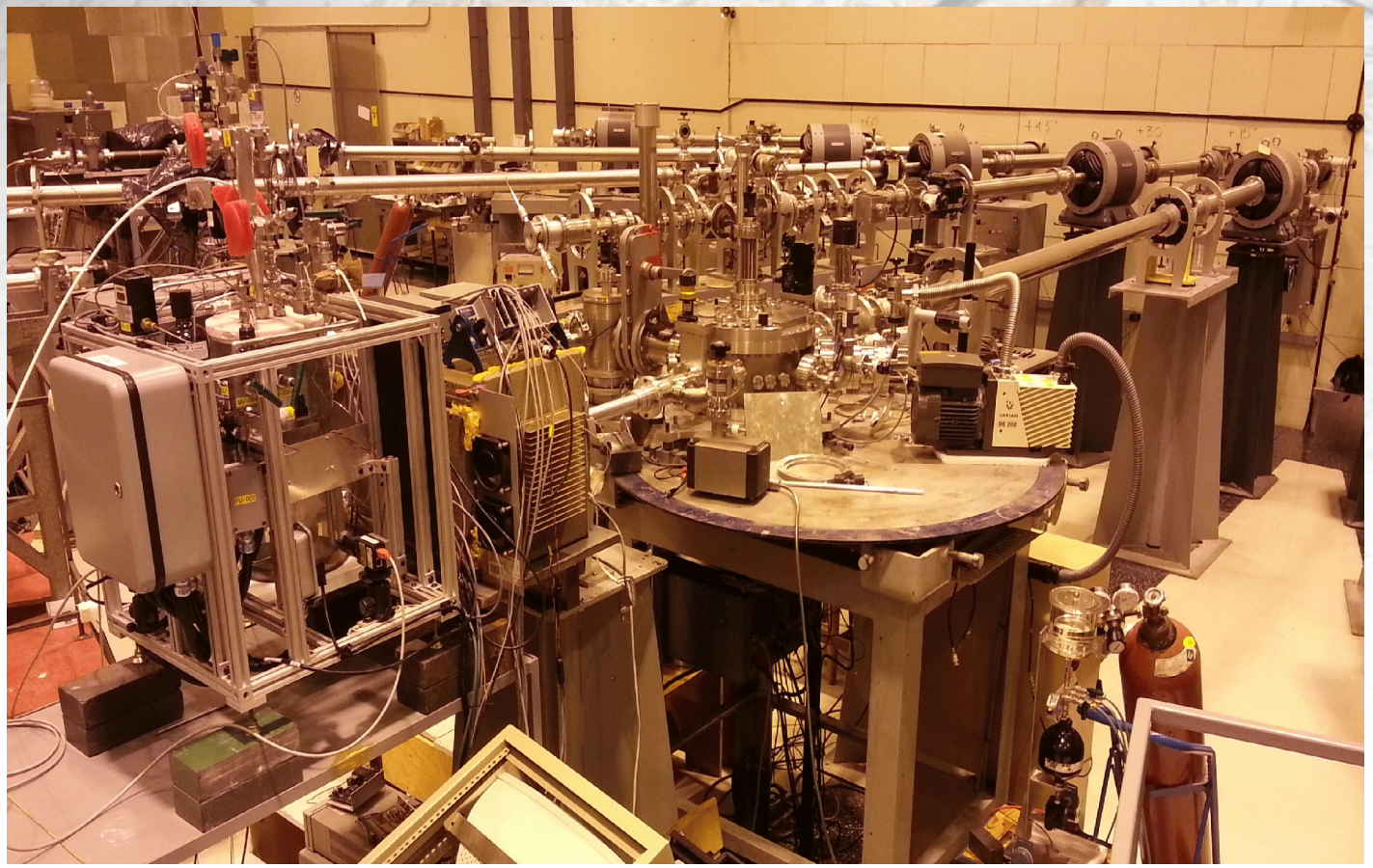
* Improve cleanliness
* No buffer fluid

Preliminary Vessel Design



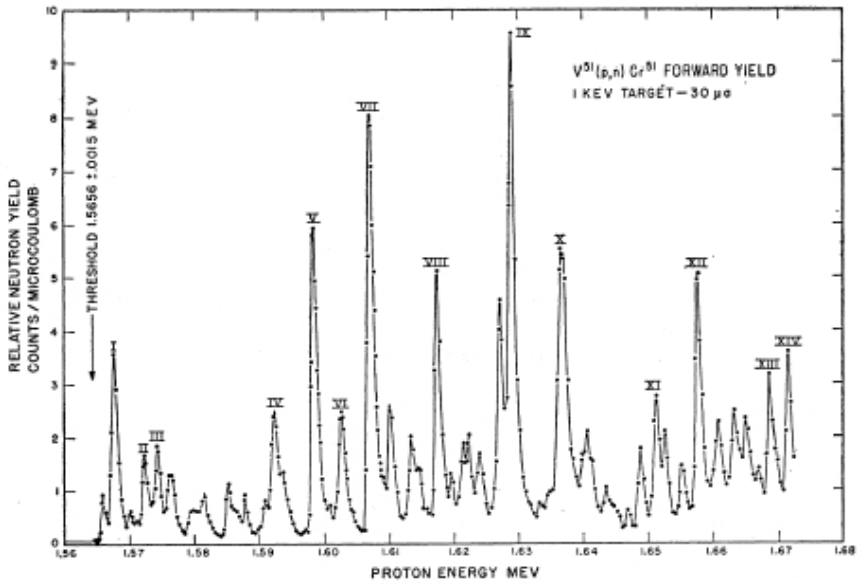
PICO-0.1L

UdeM has unique mono-energetic neutron beam!

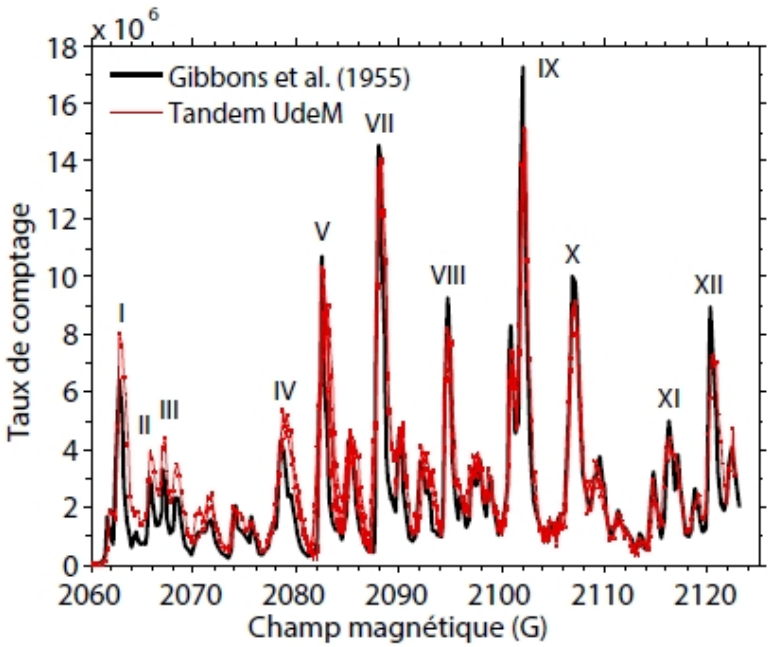


A mono-energetic neutron beam

$$p + {}^{51}V \rightarrow {}^{51}Cr + n$$



(a)

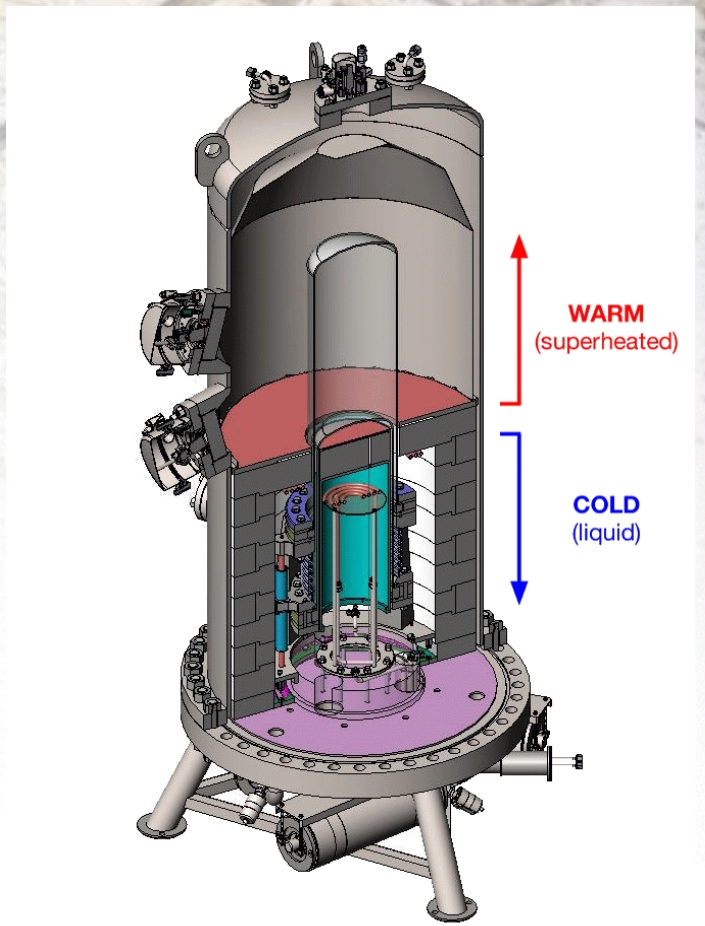


(b)

PICO-40L

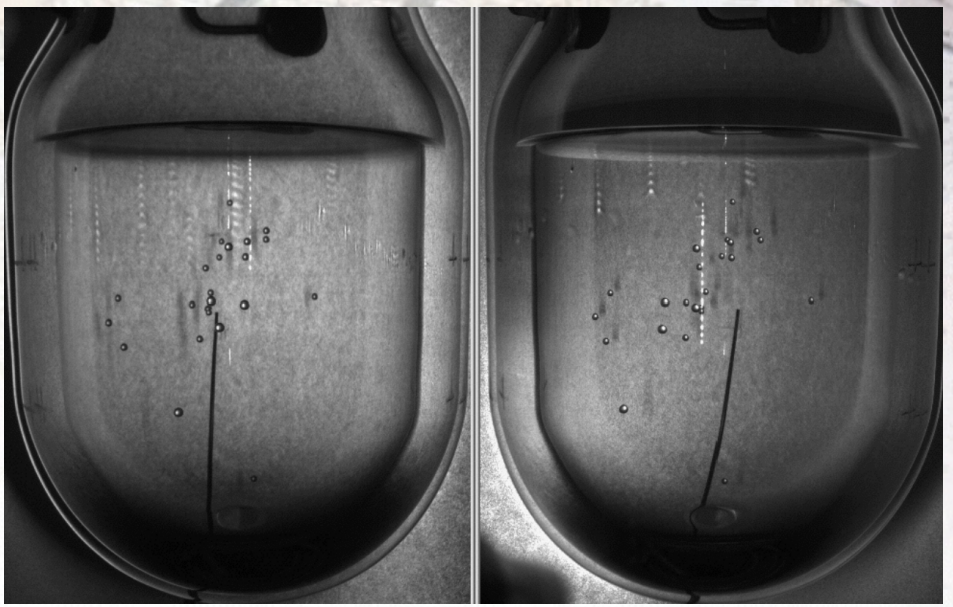
Under construction

- A cleaner version (from PICO-60L).
- No buffer liquid - to isolate the active mass from stainless steel.
- Thermal gradient makes target fluid not active near stainless steel parts.
- UdeM designed and built several sub-units for this detector.



Orthogonal Camera Views

- Z-coordinate
- Multiple neutron scattering
- Trigger for recompressing
- Frame rate is ~150 fr/sec



PICO-2L view

Can we see the growth of the bubble?

Even 3000 frame/sec high-speed cameras can't resolve the very beginning of the bubble growth.

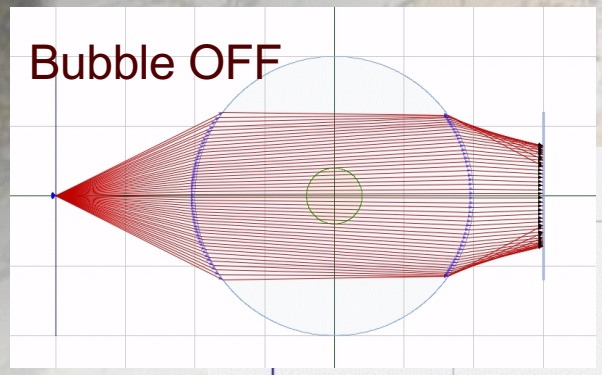
Faster cameras are much more expensive and require special electronics for producing a trigger.

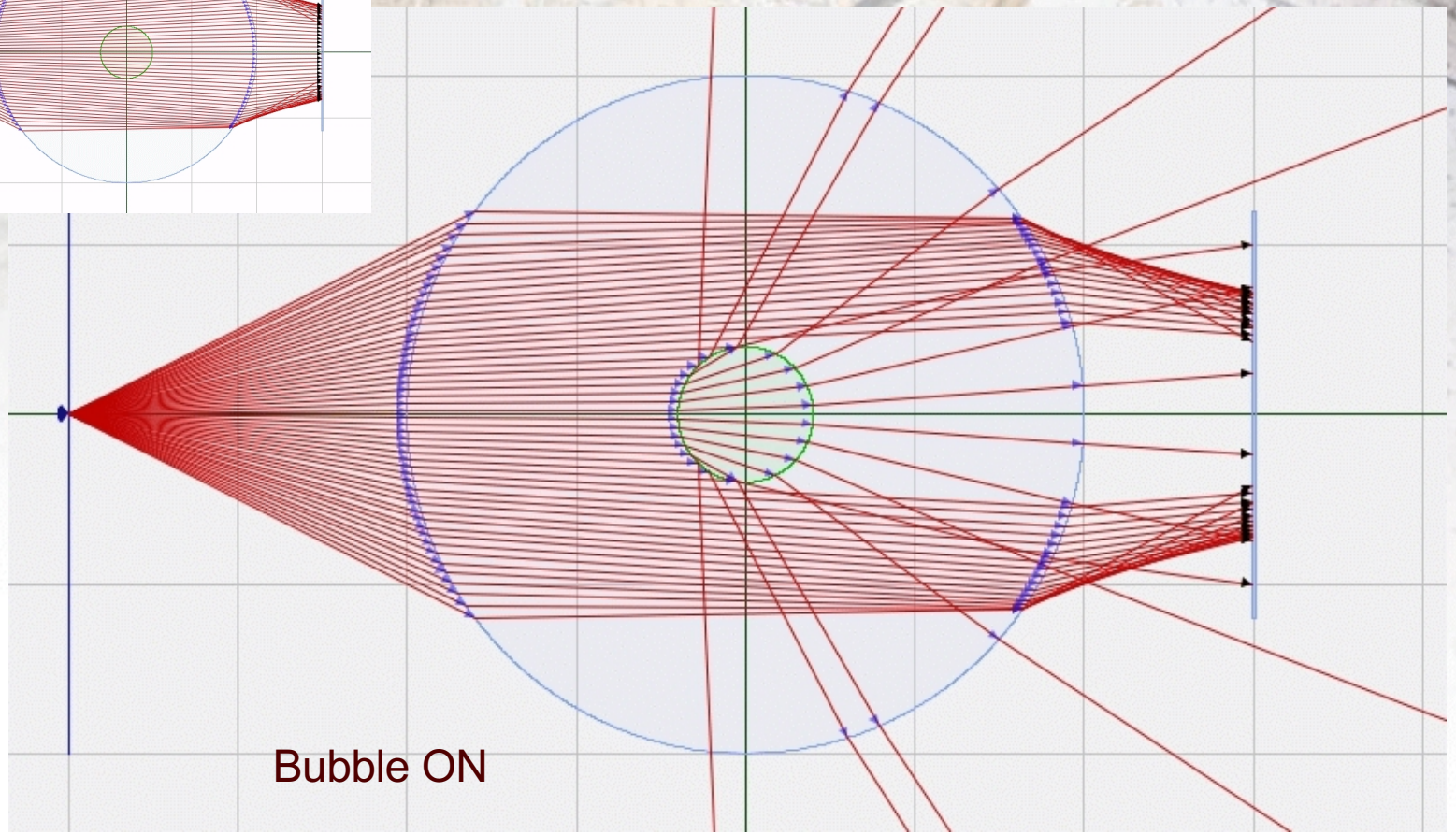
"Zoom-vs.-Field View" makes it impractical for large detector volume.

In the new PICO-500L use of piezo-sensors for alpha/neutron separation is questionable for several reasons.

Light scattering on a gas bubble

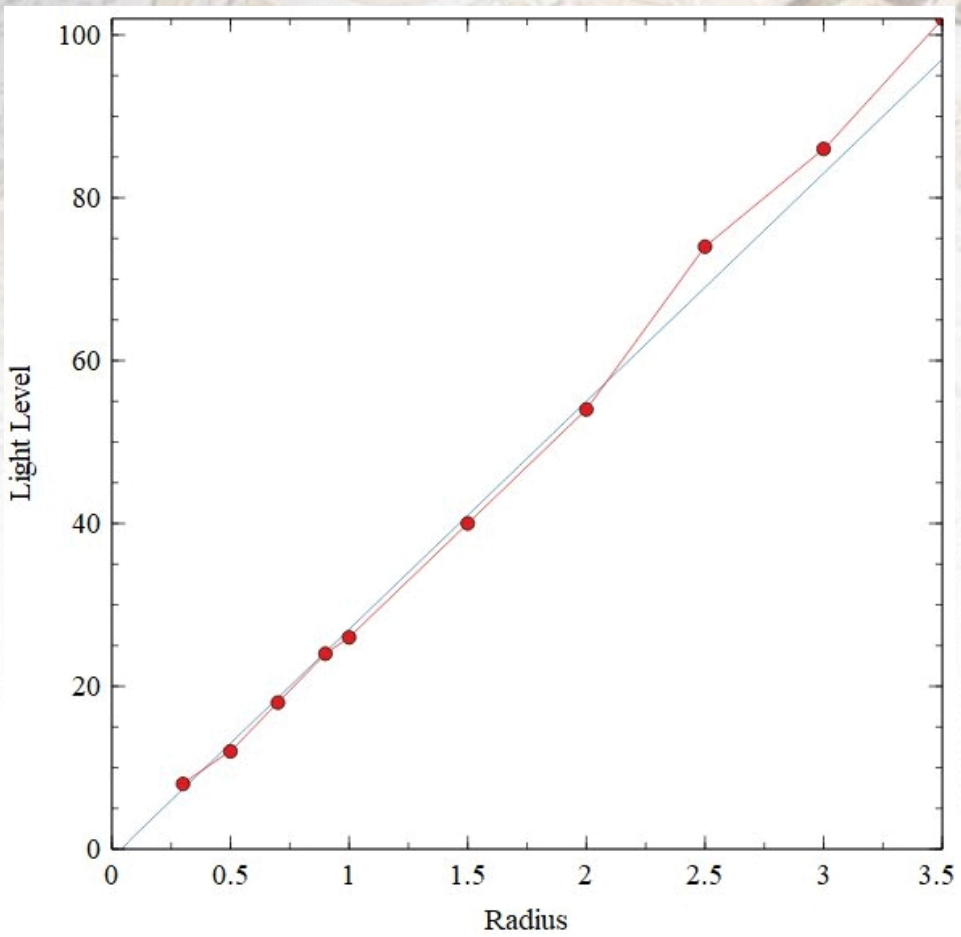
(Ray tracing simulation)





Light scattering (cont.)

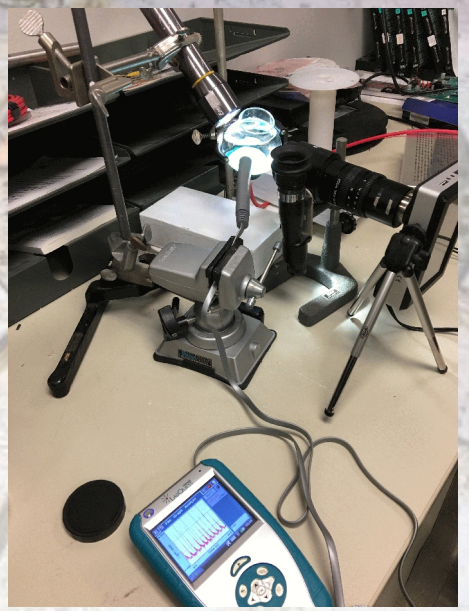
Planar simulation



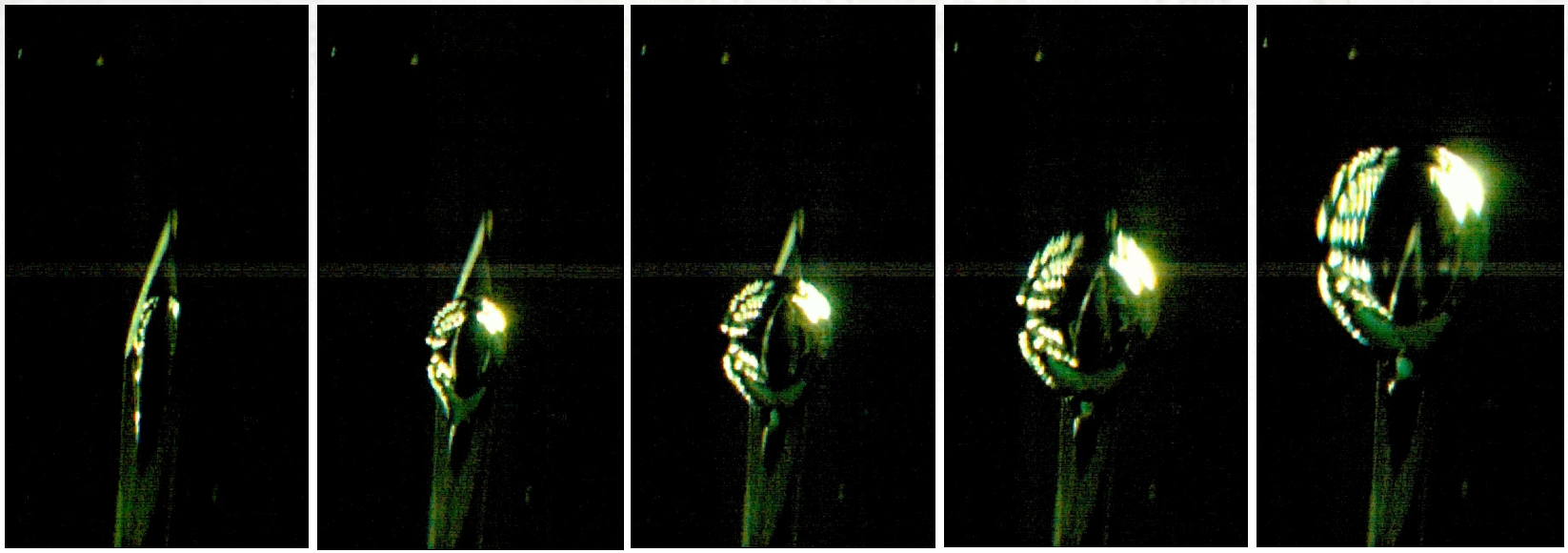
With:

$$\lambda_{LED} \approx 400nm$$

We can see the start of growth!

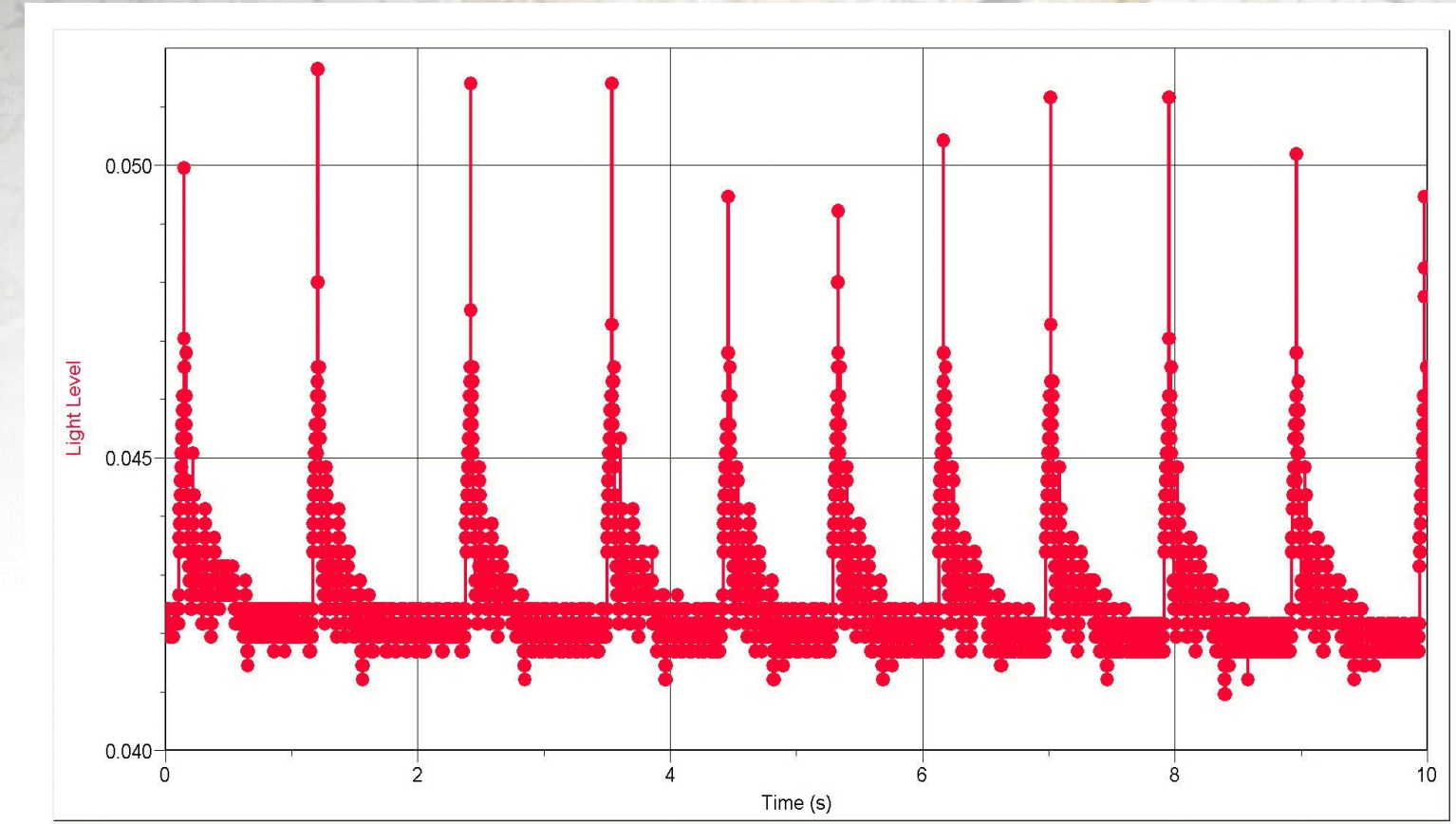


High-speed camera tests (~2000 fr/sec):



Light scattering on bubbles (cont.)

Air bubbles in the water - via photo-resistor:



Future Plans

- Continue to construct PICO-40L;
- New multi-channel DAQ for piezo-sensors with programmable gain amplifiers;
- Displacement Piezo-Sensor (R&D);
- A Large Solid Angle Light Detector Array(R&D);
- Cross-check analysis of the Light Sensor vs. High-Speed Camera images;
- This method puts ALL sensors out of the detector container!
- COMSOL simulations - full chain.