暗物质地下探测的前沿及预研

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2010.3.18

实验的发展方向

- 我们不知道暗物质是什么样的 --〉需要多方面的研究，特别理论上有创新性的研究;
- 暗物质的作用截面可能很小 --〉我们需要仔细想一想用什么样的技术，世界上的大实验室在认真讨论;
- 新思想、新技术层出不穷……

9th UCLA Symposium Sources Detection of Dark Matter & Dark Energy in the Universe ……

http://www.physics.ucla.edu/hep/dm10

Dark Matter @ DUSEL

Even if a discovery is made before DUSEL, we need a Dark Matter Observatory

Common Question,是否能够很快发现暗物质?在哪儿?被谁发现?发现后的实验怎么做?

Technologies are rapidly reaching the needed level of sensitivity/background rejection

- Bubble Chamber
- Ar
- Ge
- Xe

This should be a cornerstone of the DUSEL program

Proposed Program at DUSEL

Within the context of a unified strategy, **emerging consensus:**

In order to have a program

at the frontier of the field worldwide

resilient to potential political and technical delays of the facility

with strong flexibility

we should as a community propose two generation 3 experiments

2 different technologies, with at least 2 nuclei

with different technological risks

with different backgrounds

Technology choice to be made later on view of current and generation 2 results (flexibility)

Depth: the deeper the better, but adapt to facility availability

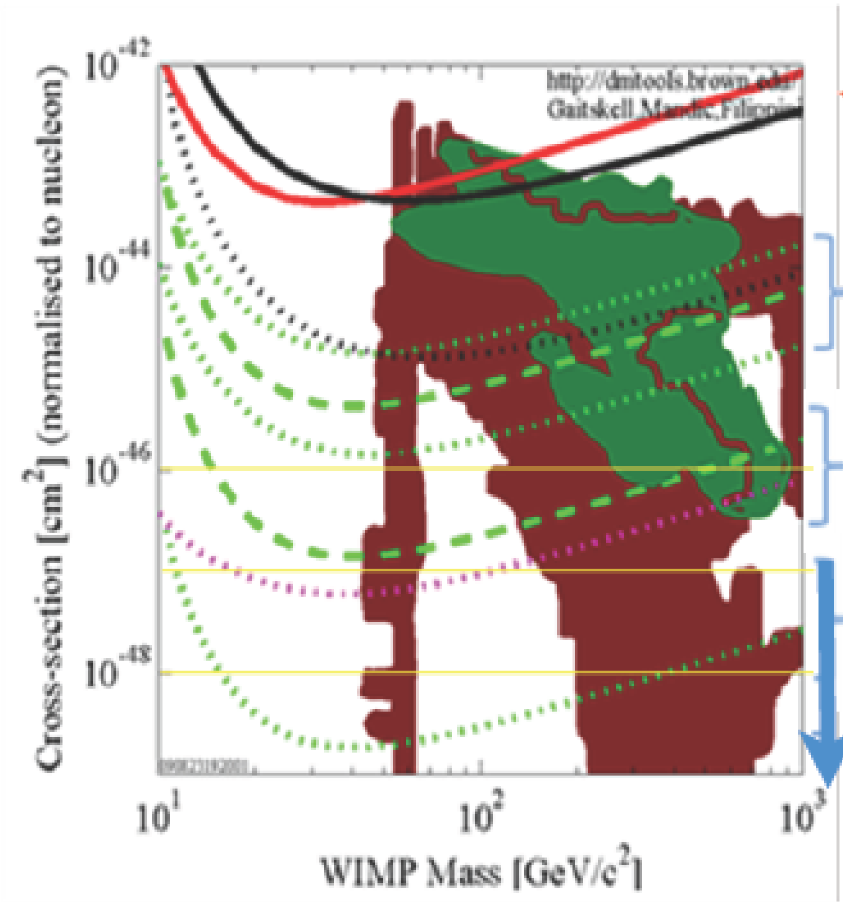
This presupposes a vigorous pre-DUSEL G2 program

Sanford lab (SUSEL-Homestake)

SNOLAB

Gran Sasso, LS Modane (Frejus)

Generation 2 and 3: PASAG definition



Current status ~10^{-43} cm^2

Current experiments

2nd Generation

3rd Generation

Pre-DUSEL

DUSEL

	G2	G3
Sensitivity	< 10^{-46} cm^2	< 10^{-47} cm^2
Target Mass	~ 1 Ton	~ 10 Ton
Cost	$15M - $20M	~ $50M

G2 ≈ 10^{-46} cm^2 or lower, construction and operation cost $15M-$20M, ≈ 2013

G3 ≈ 10^{-47} cm^2 or better, construction and operation cost $50M, ≈ 2017

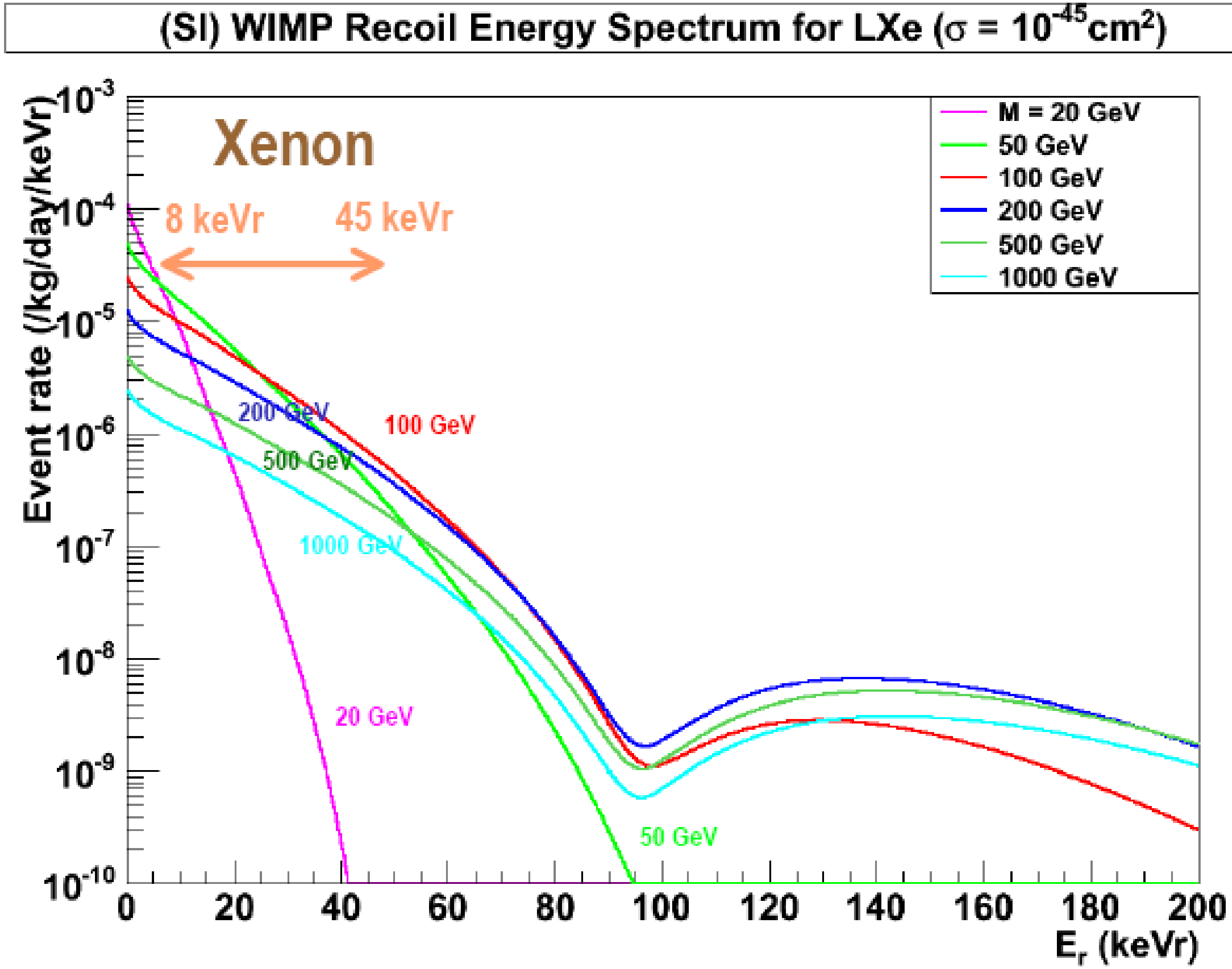
Note: slight disagreement between PASAG figure and text. Here the figure has been corrected

Scenario A: FY10 $84M, 3.5%/yr, $266M FY10-FY20 runout in FY10 dollars

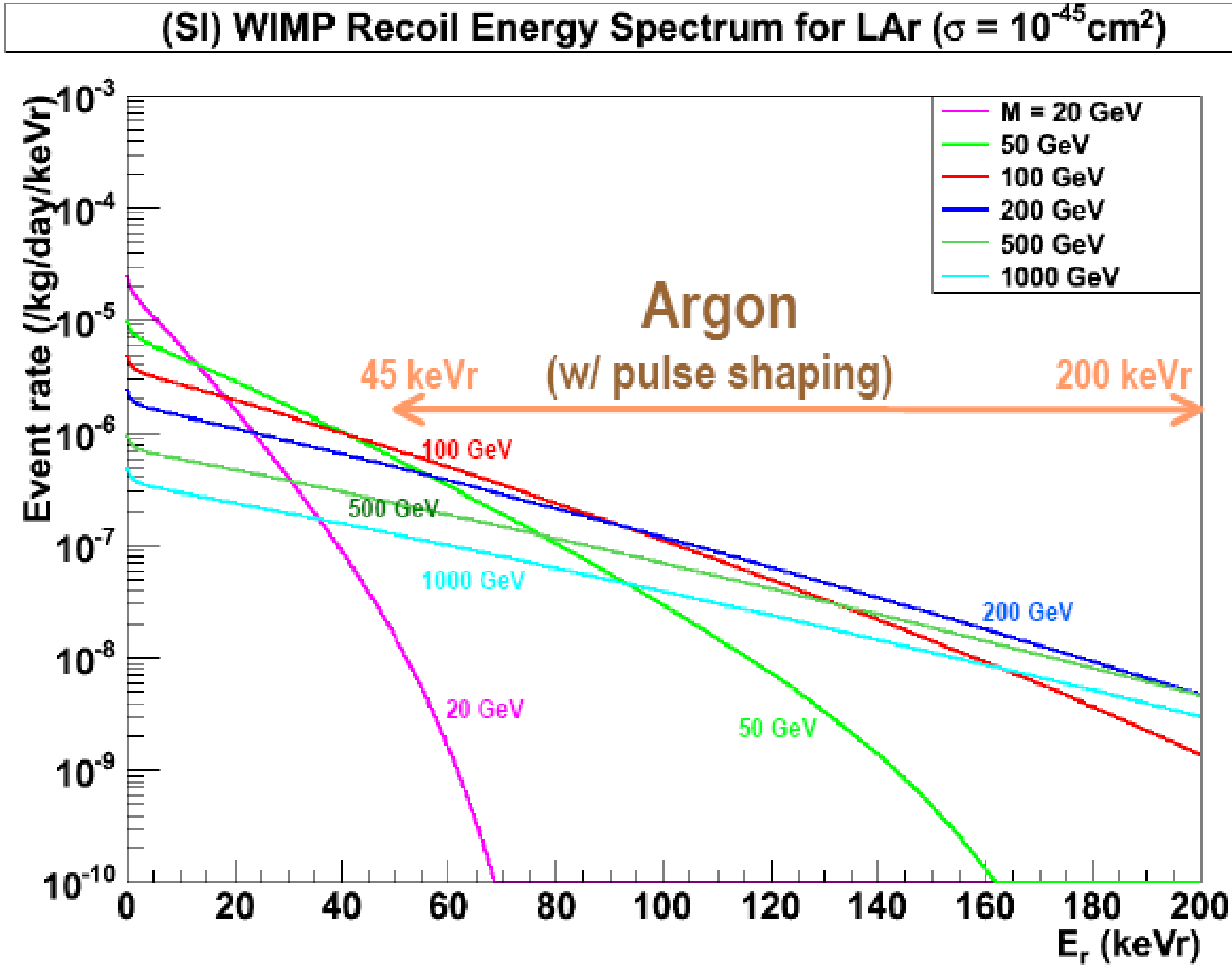
B: FY10 $94M, 3.5%/yr, $389M ...

C: FY10 $96M, 6.5%/yr, $640M ...

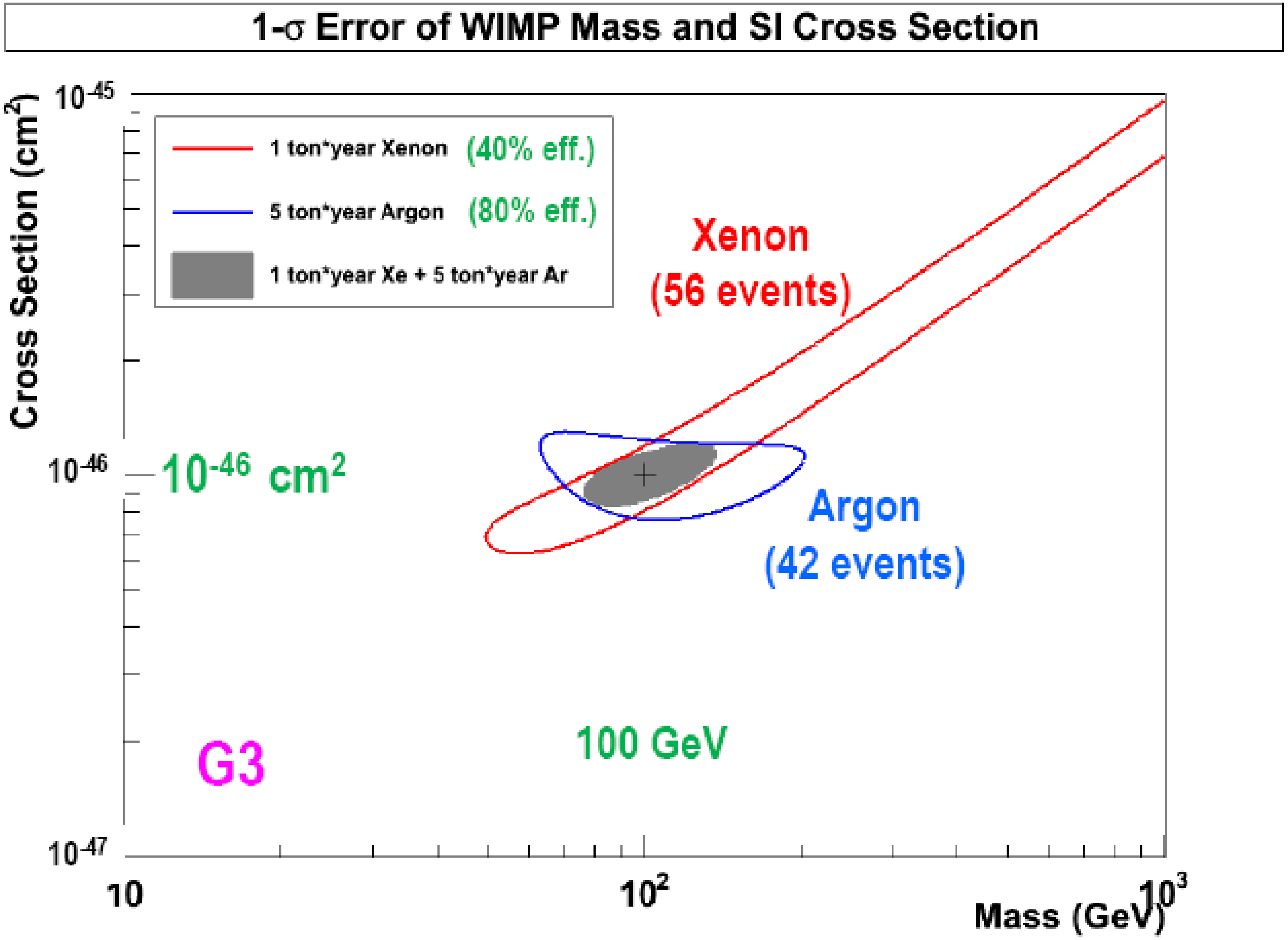
(SI) WIMP Energy Spectrum for LXe
(Cross Section = $10^{-45}cm^2$)



(SI) WIMP Energy Spectrum for LAr
(Cross Section = $10^{-45}cm^2$)



1-σ Error of WIMP Mass vs SI Cross Section
(10 ton*year Xe and 50 ton*year Ar)



1- σ Error of WIMP Mass vs SI Cross Section
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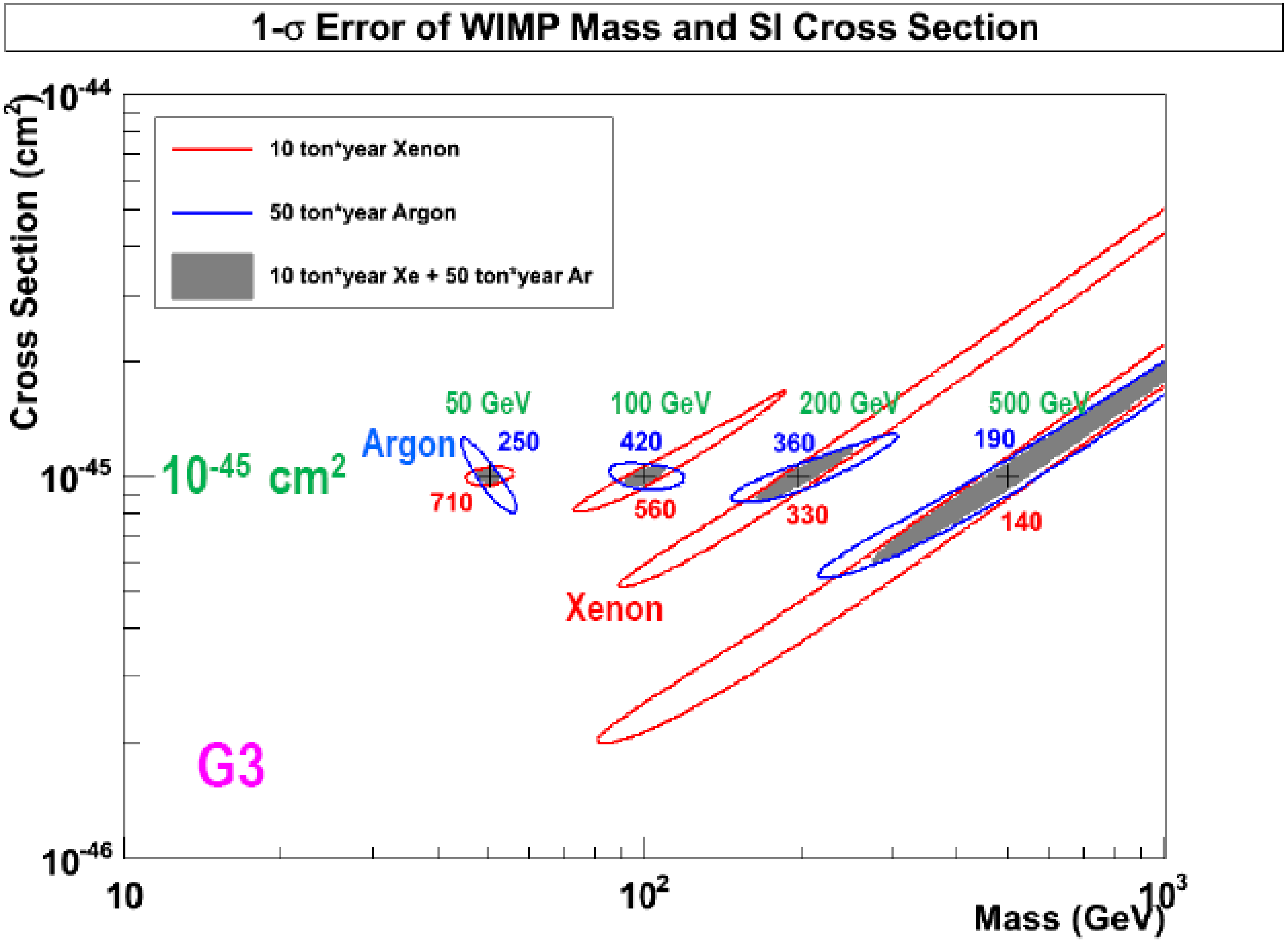
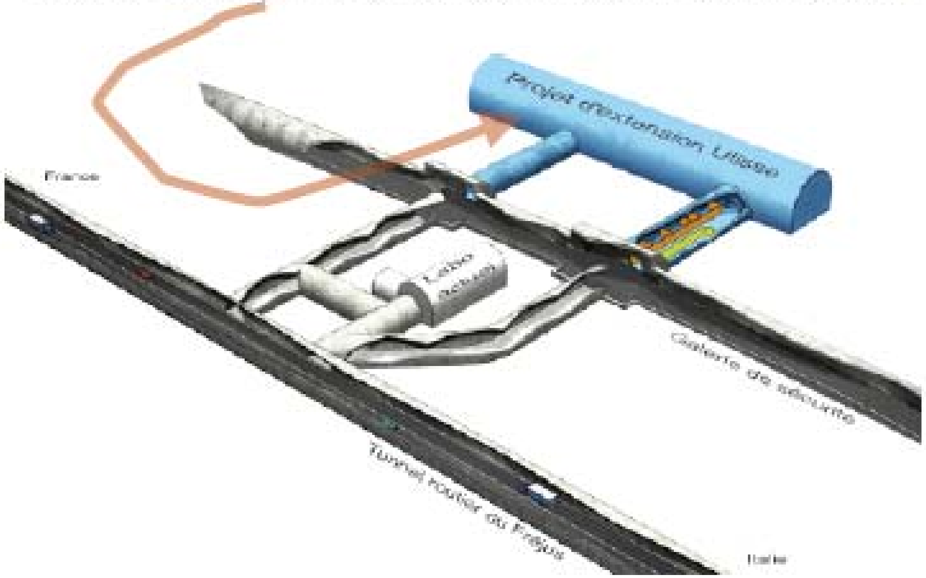
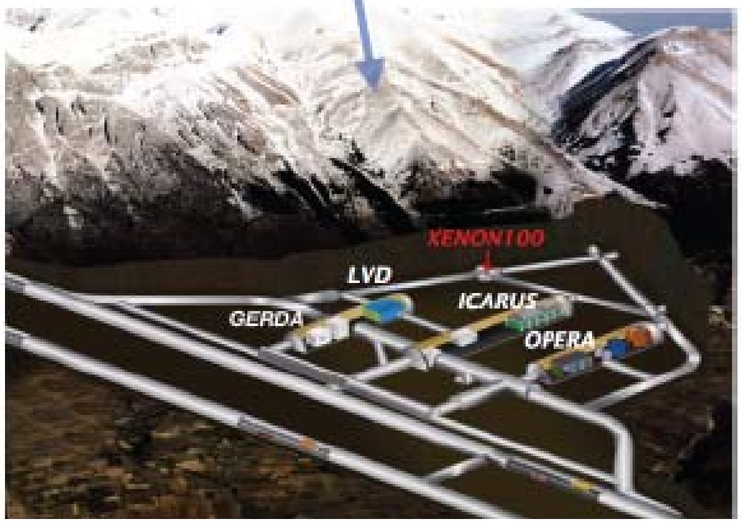


dark matter wimp search in noble liquids
DARWIN

What is DARWIN?

- R&D and design study for a **next-generation noble liquid facility in Europe**
- Approved by ASPERA (AStroParticle ERAnet) in late 2009
- Goal:
  - ➡ study ***liquid xenon AND liquid argon as WIMP targets***
  - ➡ make recommendation for technical design of facility in ***three years from now***
  - ➡ build on the added-value of uniting and coordinating the extensive, existing European expertise in liquid argon, liquid xenon and related technologies for astroparticle physics detectors within a global scenario
- Location: ULISSE (France) or Gran Sasso (Italy)

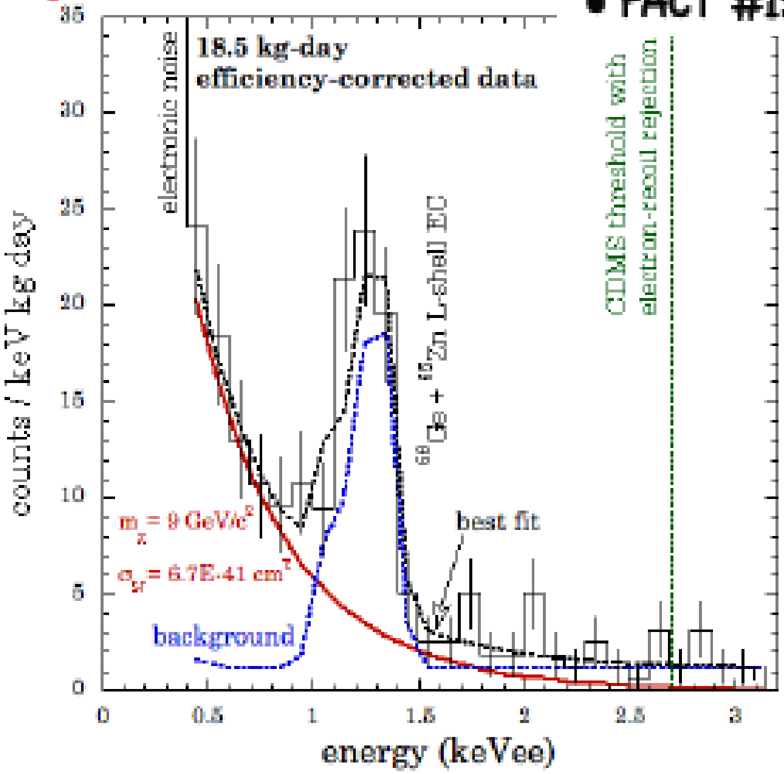




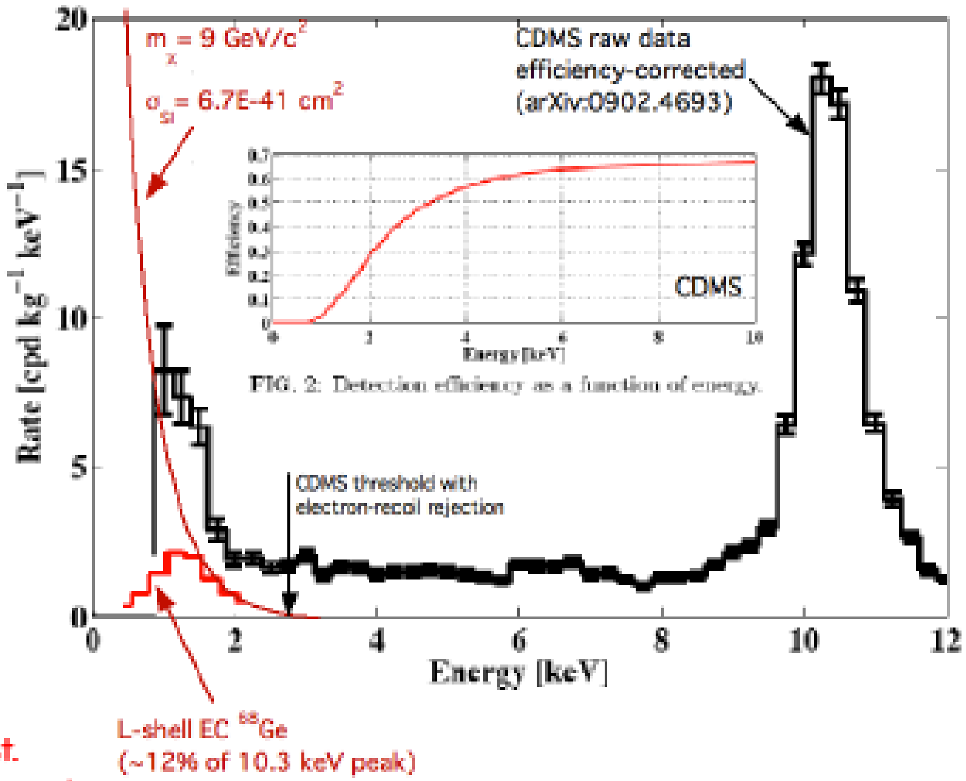
惰性气体探测器是暗物质直接探测的主流，但是…

An example WIMP mass in the region:

- FACT #1: DAMA may or may not be observing a WIMP effect.



Where is CDMS in all this?



Quotable: The excess of irreducible bulk-like events in CoGeNT is compatible with the WIMP hypothesis in a region where CDMS, DAMA and (several) phenomenological models (good thermal relics) can coexist. It is also equally compatible with any exponential background.

(Leo Stodolsky this morning:
We have >> 100 events we do not understand, WE WIN!!! ;-)

CRESST II

申请目标

液氩/氙探测器及探测技术的研究；过热液滴的气泡探测技术研究；CaF2（Eu）/BaF2复合晶体探测技术研究三种不同的探测方案。根据不同探测技术的特点，优化探测器的规模和经费，制作几公斤到百公斤以下的探测器模型进行不同类型的探测器研究，在经过不同模型探测器各方面性能的比较后，给出暗物质探测的下一步探测方案。

液氙/氙对比:“A Multi-Purpose Matrix”

	Xe	Ge	LS	Ar
DM	x	x	-	x
DBD	x	x	-	-
Solar ν	x	?	x	x
SN	-	-	x	x
p-decay	-	-	x	x
LBL	-	-	-	x

DM：暗物质探测
DBD：双贝塔衰变
Solar ν ：太阳中微子测量
SN：超新星中微子测量
P-decay：质子衰变
LBL：长基线中微子测量

上表可以说明一个事实：

液氙探测器技术是很有用处的。

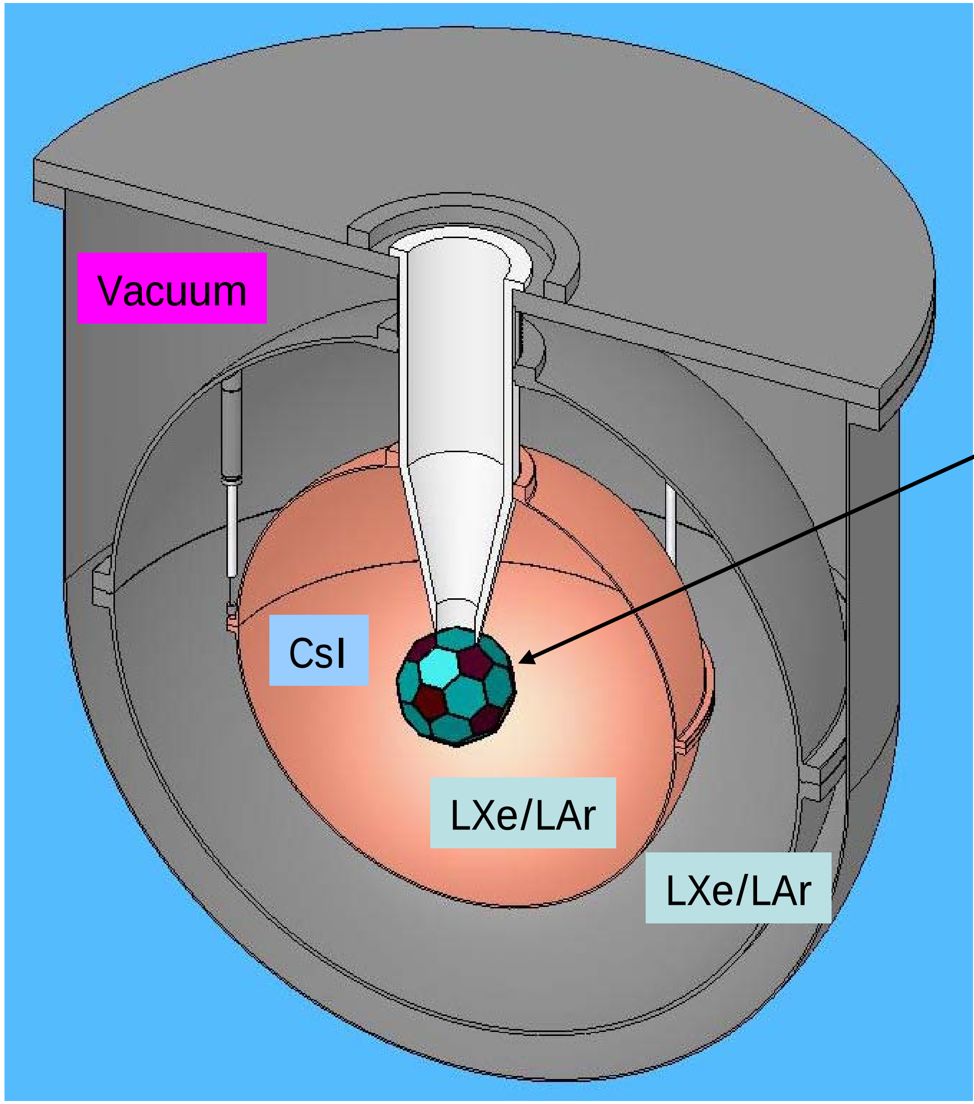
惰性气体研究内容

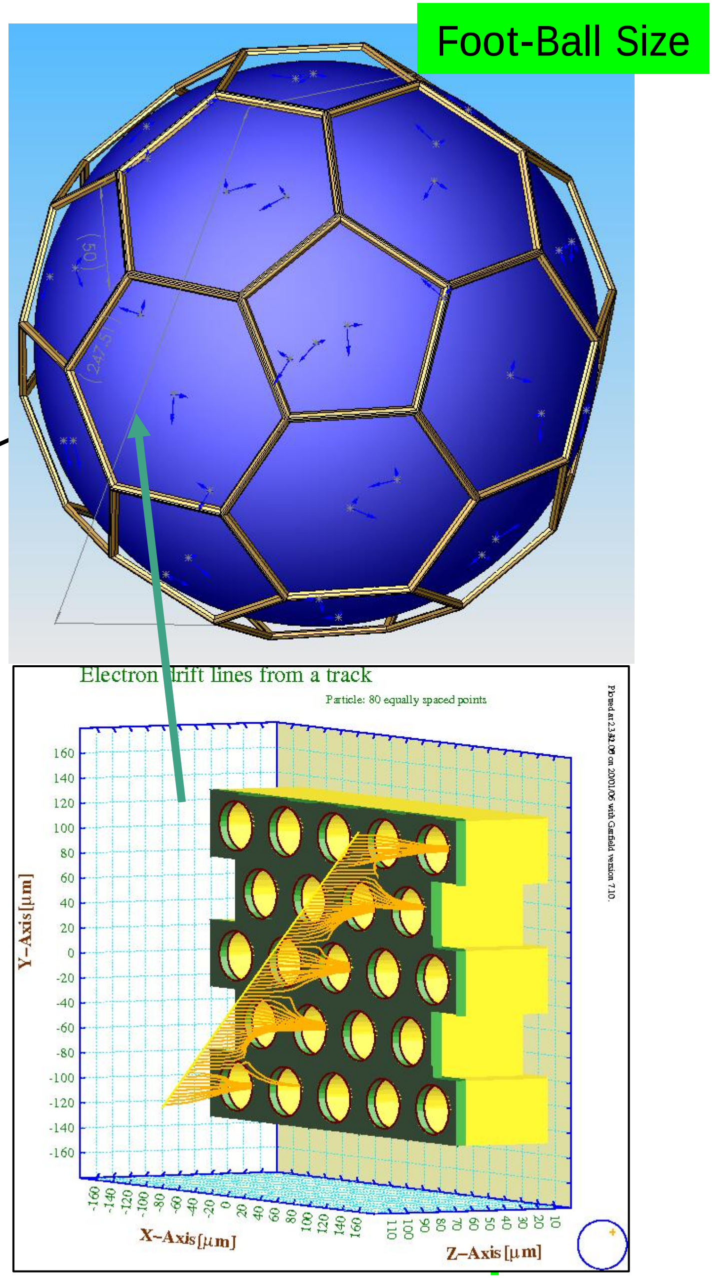
采用新型读出方法研究(便宜、探测器更大)

物理思想和工作原理:

设计和研制一个球形低温惰性液体探测器容器。充满LAr或LXe，容器中心有一高压圆球加高压，容器内壁由微结构气体探测器（厚GEM片（镀GaN或CsI光阴极）+微针探测器）阵组成，探测器为低负电压过度到地电压，与容器中心高压圆球构成电子漂移电场（TPC：达到250V/cm）。这样可以先后直接测量粒子作用事例的激发光子和激发电子的信号。

GEM技术用在ArDM实验上;微细丝结构的探测器工作液氩和液氙中在国外有研究结果报道,只是放大倍数较低（10倍）.





- CsI coated internal for 4pi light collection (>10 p.e./keV)
- 1.5 ton fiducial and 3.8-ton active Shield & veto

LXe/LAr 研究技术

ELSEVIER Nuclear Instruments and Methods in Physics Research A 525 (2004) 12–16
Section A
www.elsevier.com/locate/nima

High-performance microchannel plate detectors for UV/visible astronomy

Oswald H.W. Siegmund
Space Sciences Laboratory, University of California, Berkeley, CA 94720, USA

3. 光阴极研究

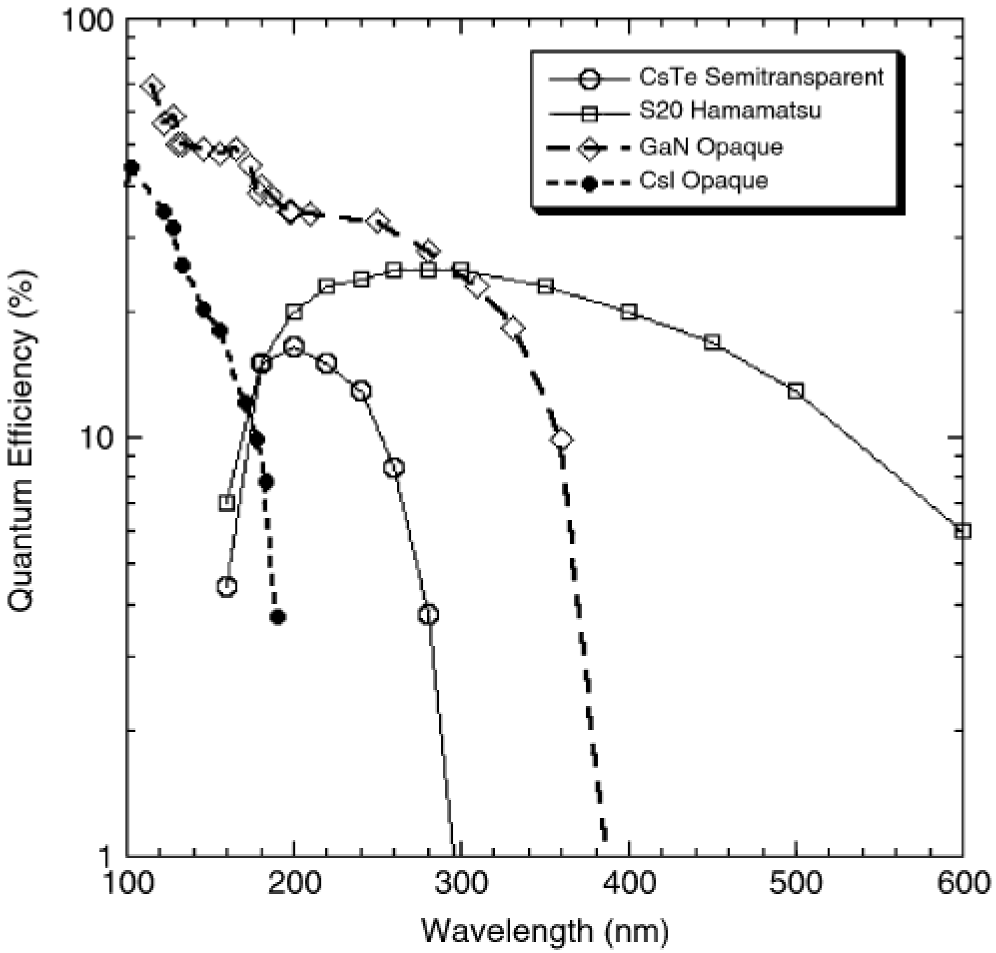
175nm

Qe CsI~20%

Qe GaN~40%

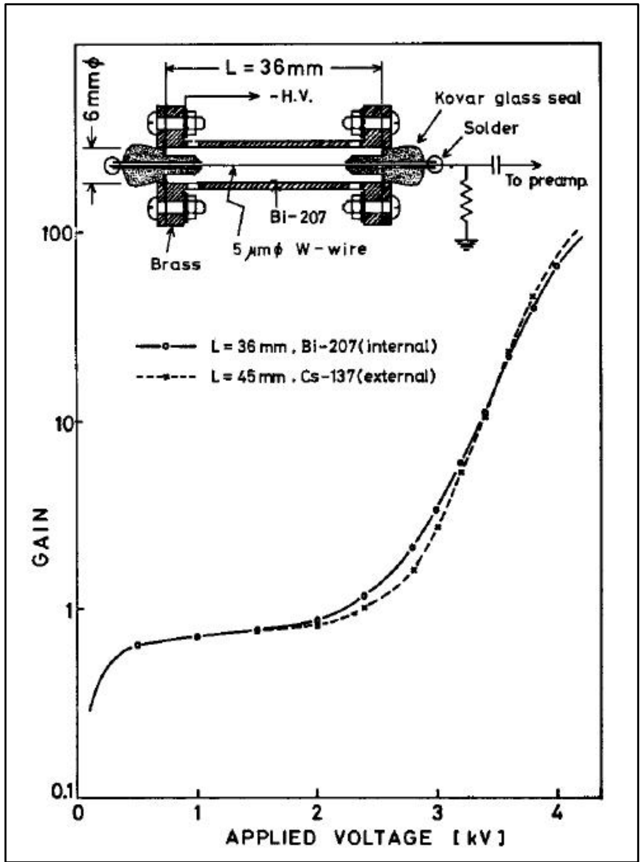
LAr更高

同时进行光和电子测量

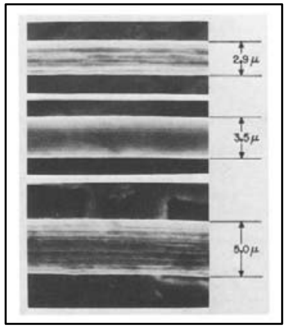


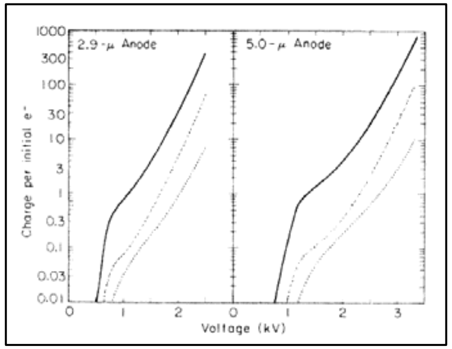
Charge amplification - wires

M.Miyajima et al. NIM Vol 134 ,1976 maximum gain : 100

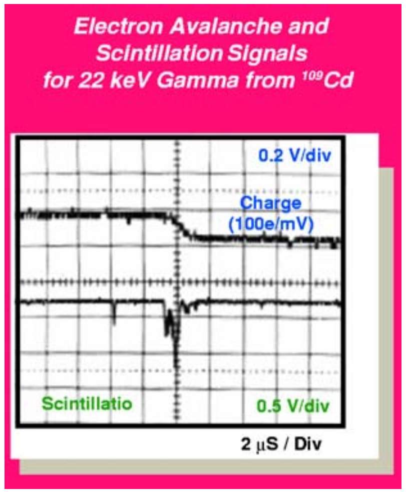


S.E Derenzo et al. Phys. Rev. A Vol 9,1974 maximum gain : 400





H.Wang et al. 1991 gain : 40



Charge readout - microstructures

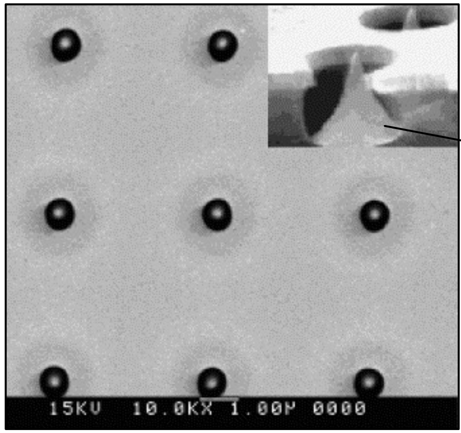
High electric field ~ 1MV/cm with small differential voltage

Cold field emission device:

Already used in LAr

(no gain due to discharges)

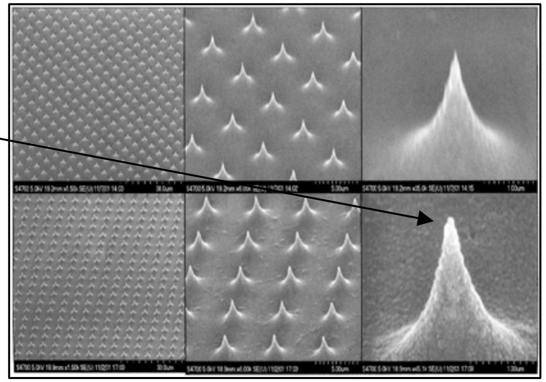
(J.G. Kim et al. NIM A 535 2004)



Micropattern detectors :

- micromegas
- micro-dot
- MSGC (already used in LXe with gain =10)

(A.P.L. Policarpo et al. NIM A 365 1995)



课题研究基础

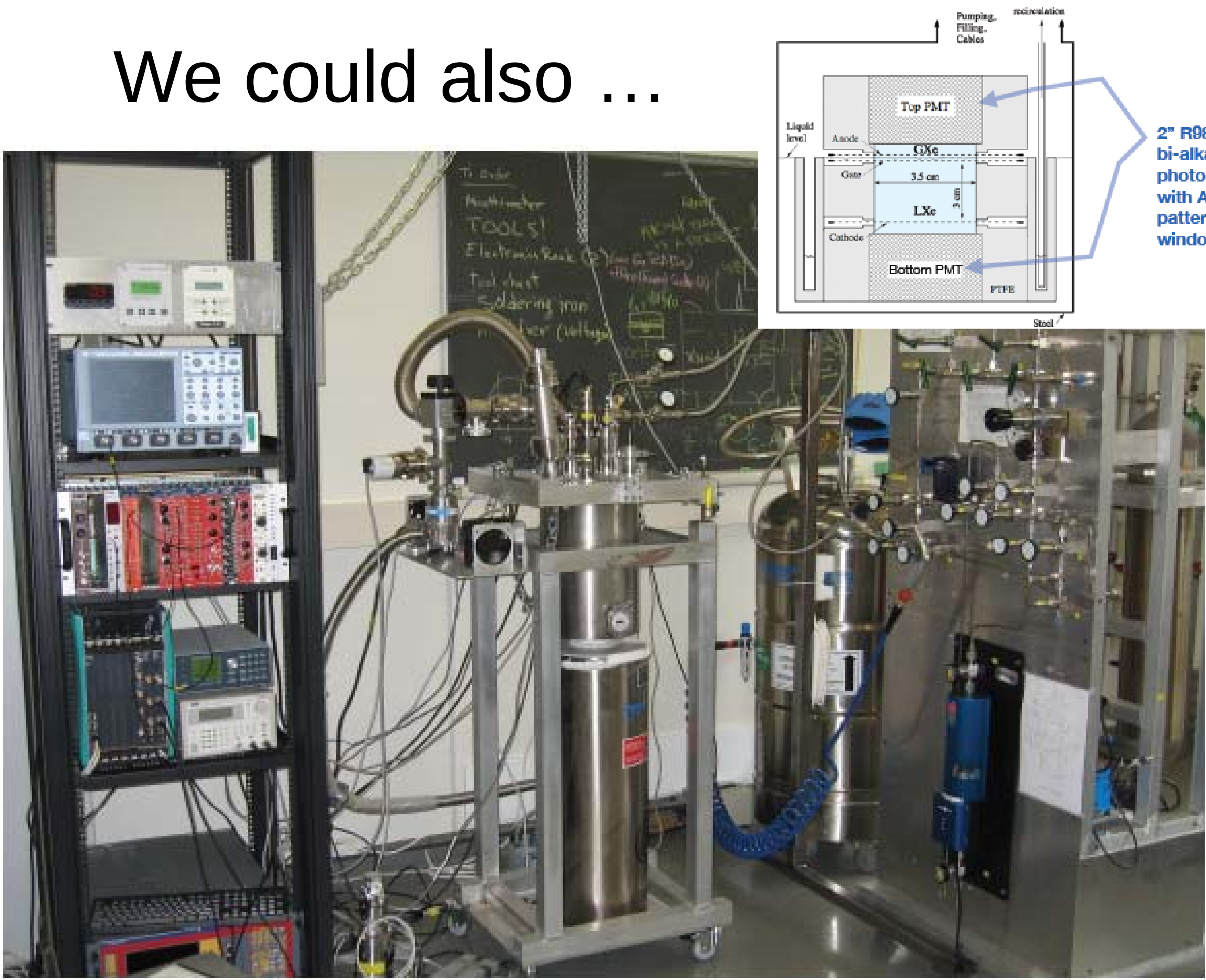
1. 厚GEM片气体探测器单层放大10^3
2. 微针阵列气体探测器放大10^6
3. 在厚GEM片初步镀上对紫外响应的GaN光阴膜

若微结构气体探测器可以工作在LAr、LXe中，就可以不用光电倍增管阵测量，将目前国外的两相测量技术合为一体。此探测器若成功，无论探测效率，能量低阈，减低本底，探测器结构和降低造价都有可观的改变。

研究内容

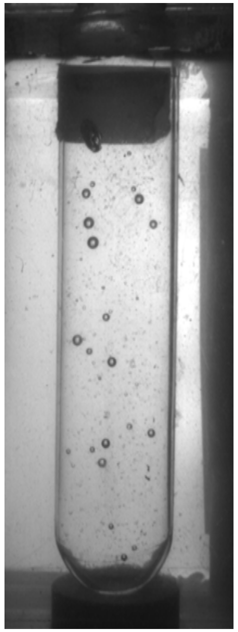
1. 对粒子在液体中激发光光强的研究
2. 对PMT光电转换效率（液氩：128nm；液氙：175nm）的研究
3. 激发光在液氩和液氙的衰减长度
4. 不同粒子（n/γ）在液氩和液氙中发光衰减时间的研究
5. 粒子的弱光触发和粒子鉴别研究

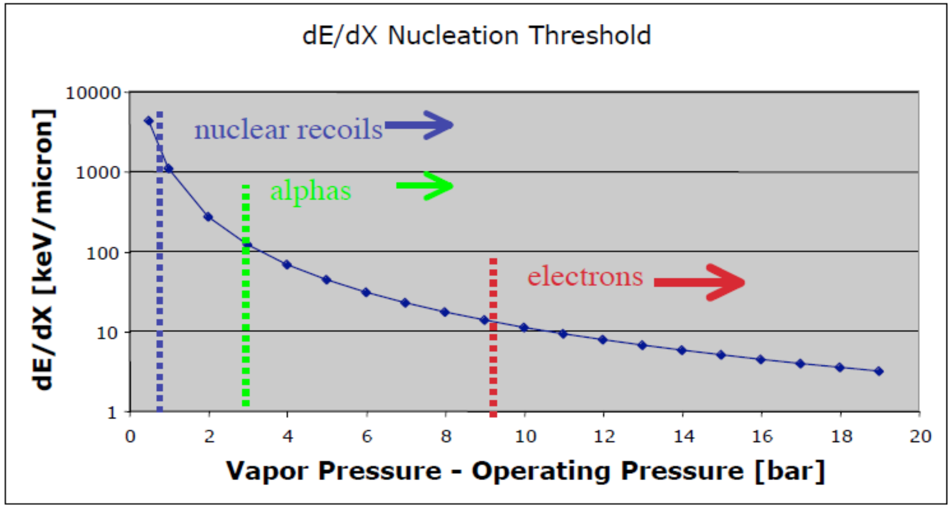
We could also …



2" R9869 PMT:
bi-alkali photocathode with Al-strip pattern and quartz window

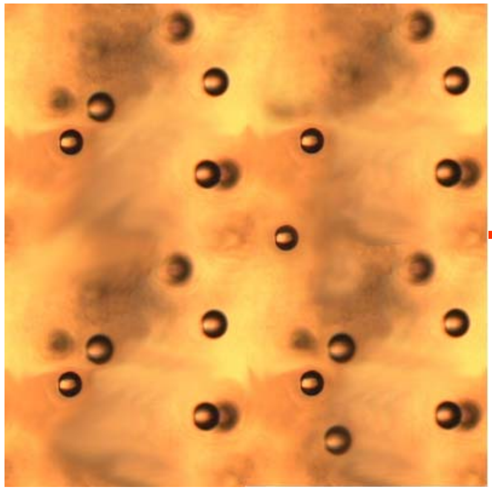
过热液滴的气泡探测技术研究

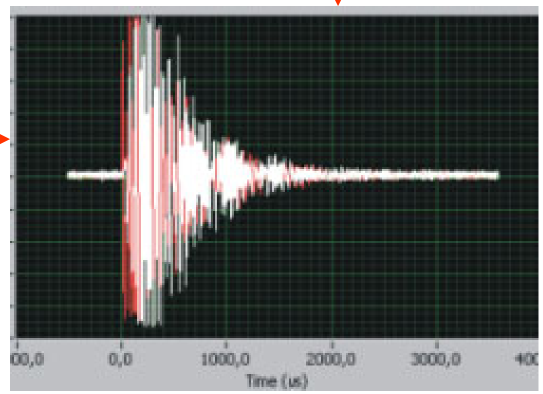




中国原子能科学研究院

探测器容器

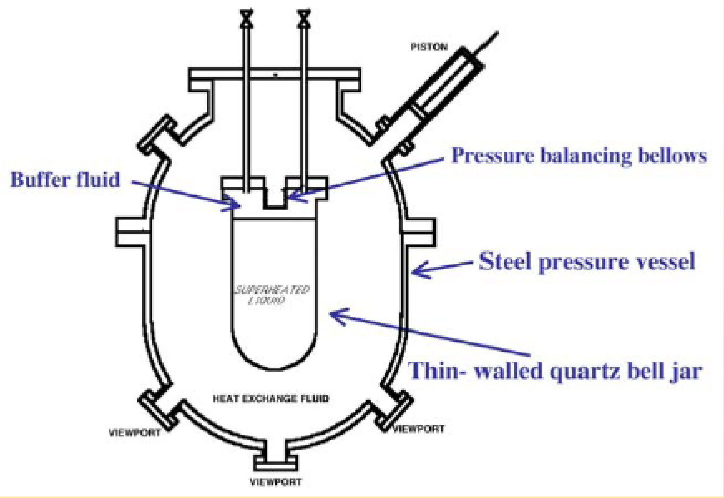


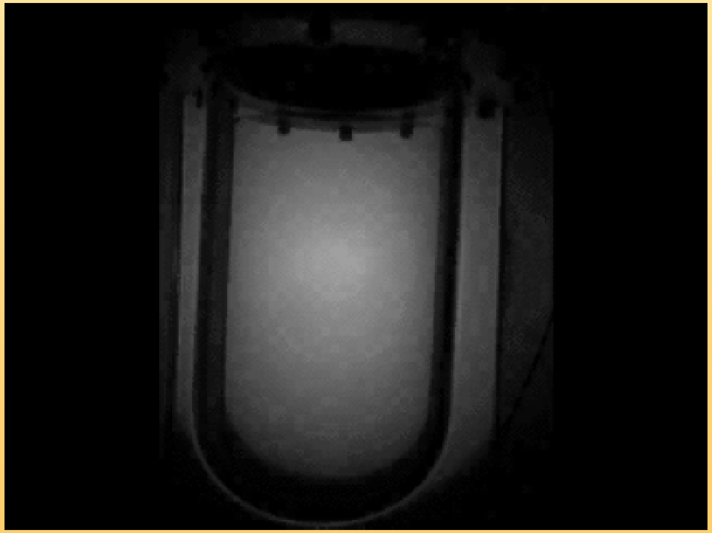


重液泡室工作原理

- 离子集团能够作为汽化中心，当带电粒子穿过过热液体时，在液体中粒子经过的地方发生了原子的电离，当离子和邻近的分子碰撞时，动能直接转化为热能，从而使局部过热程度更大一些，最后便形成了“胚胎”气泡,围绕这些中心逐渐形成极小的气泡。
- 带电粒子在泡室中形成径迹的首要条件：液体必须处于过热状态
- 用于WIMP粒子探测研究的关键：如何使胚胎气泡存在较长时间
- 制作气泡室最关键的问题：过热状态

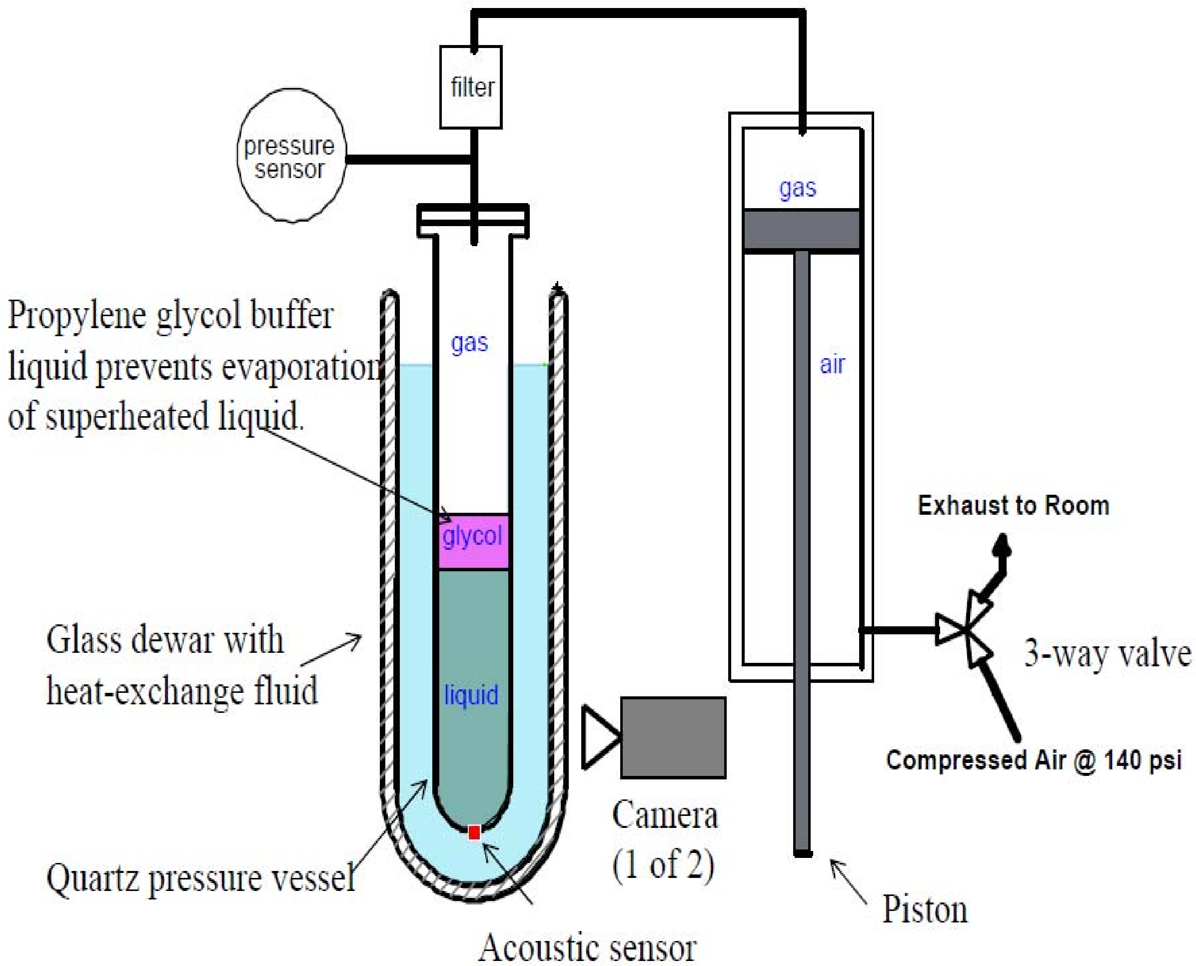
COUPP探测器: 2kg 靶液体





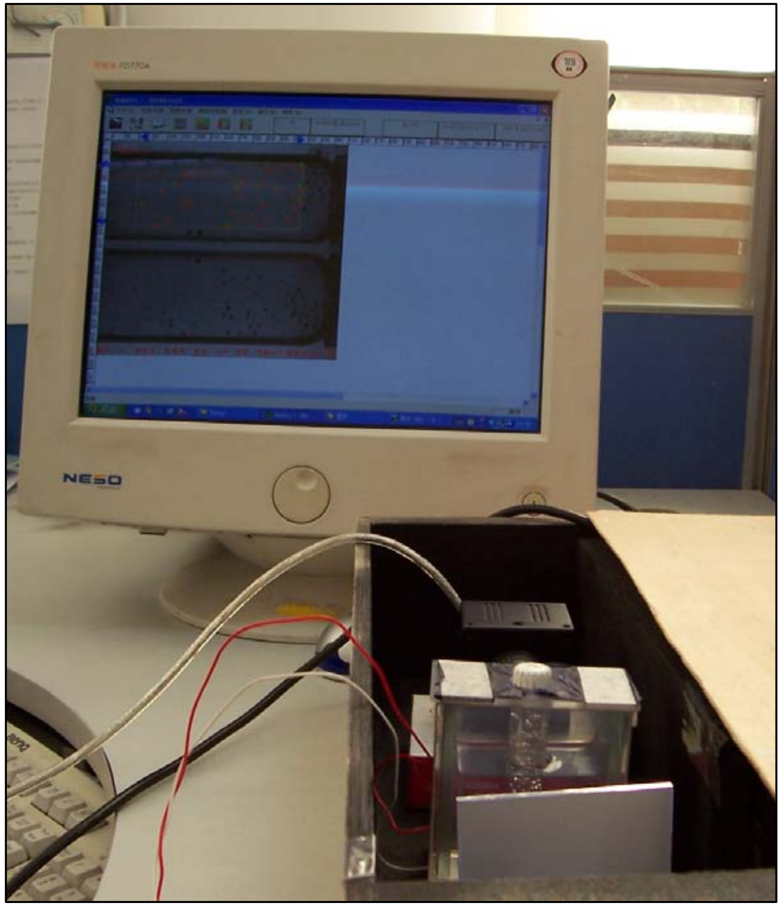
概念设计 (参照COUPP)

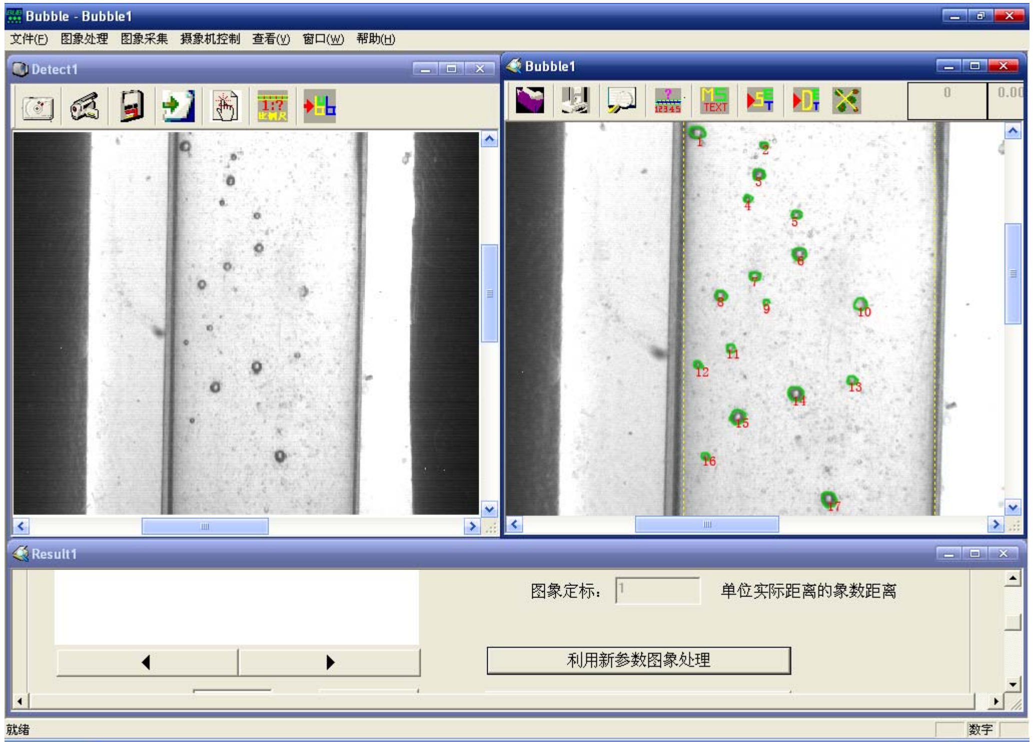
室本体
照明照相系统
膨胀系统
充气系统
热调节系统
压力调节系统
控制系统
安全设备



信号获取方法1——图象

摄像头，驱动器，软件，计算机

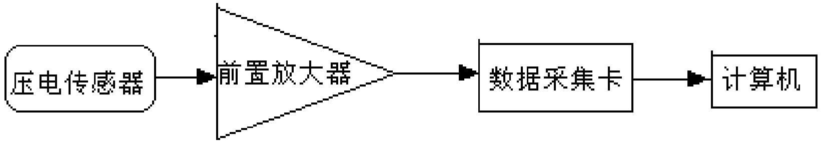


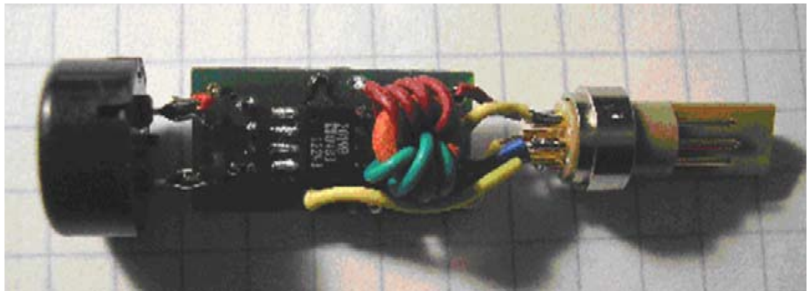


信号获取方法2---声频

- 声频获取系统组成：

- 1、压电陶瓷
- 2、前置放大器
- 3、采集卡
- 4、计算机及相关软件





Summary

惰性气体探测器是暗物质直接探测的主流,其中液Ar探测技术具有更广泛的应用，采取国际合作的方式将能够比较快的进入到这一领域的前沿，仅靠自己力量的R&D可能需要较长的时间(>2年).

晶体是比较常规的探测技术，通过短时间的研究，我们能够给出一个合理，可行并且有效的方案(1-10keV)，能够比较快的得到物理结果.

将进一步关注国际上过热液滴及泡室的发展动向,力争做出有创新性的研究成果.