XENON Experiment
Development of Xe Dual Phase Prototype for Dark Matter Detection

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see information at

http://www.astro.columbia.edu/~lxe/XENON/

http://particleastro.brown.edu/

XENON Dark Matter Collaboration

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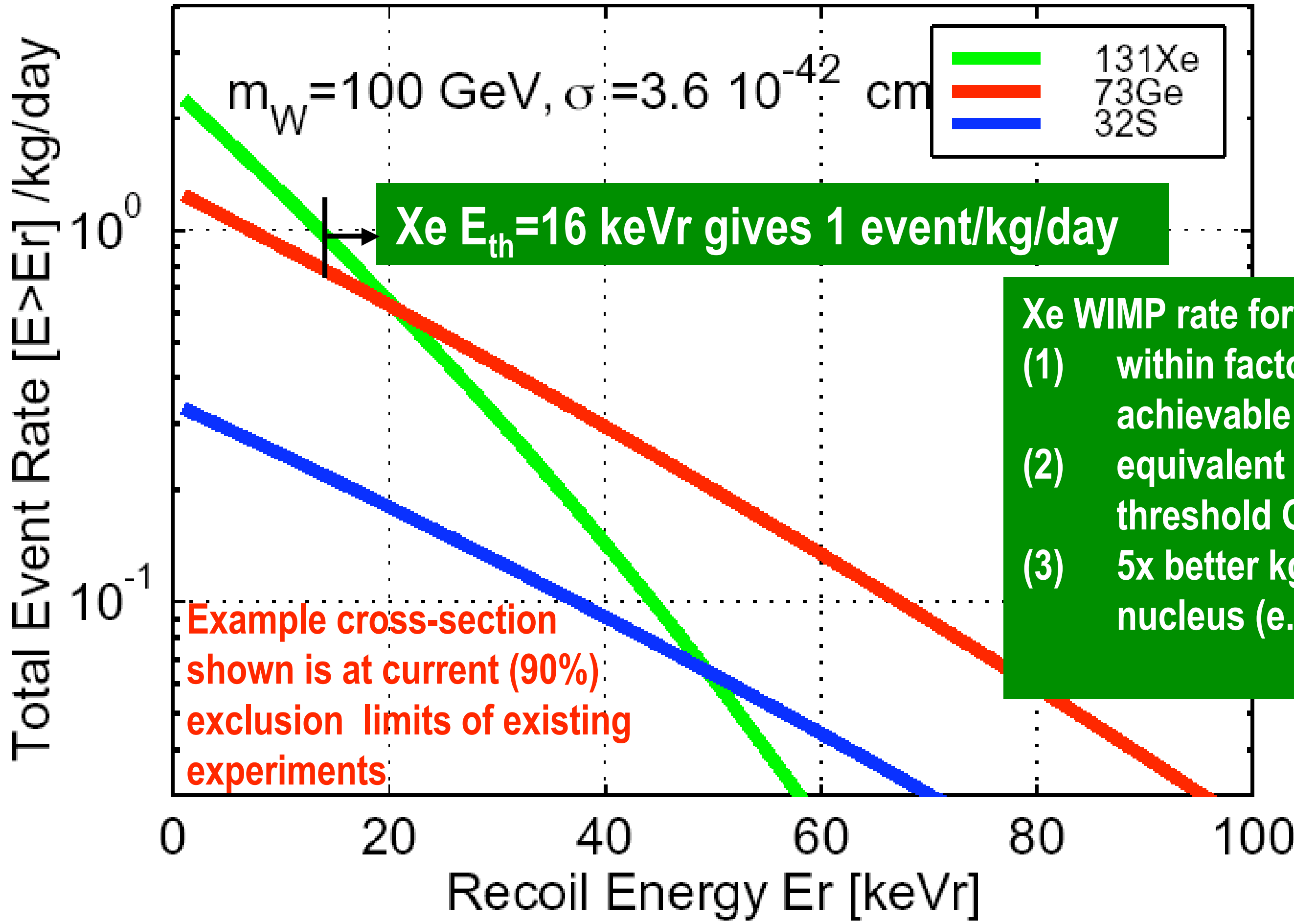
Very Typical WIMP Signal

- Low Thresholds Vital
  - Graph shows integrated event rates for E>Er for Xe (green), Ge (red) and S (blue)
  - Large nuclei enhanced by nuclear coherence, however, in reality <<A^2 …

$$\int_{E_r}^{\infty} \frac{dN}{dE}$$



Xe WIMP rate for Er > 16 keVr is
(1) within factor 2 of maximum achievable rate (Er>0)
(2) equivalent kg/kg to low threshold Ge detector
(3) 5x better kg/kg than light nucleus (e.g. S in CS_2)

XENON Event Discrimination: Electron or Nuclear Recoil?

Within the xenon target:

- **Neutrons, WIMPS => Nuclear recoils**

  => Scintillation, little Ionisation

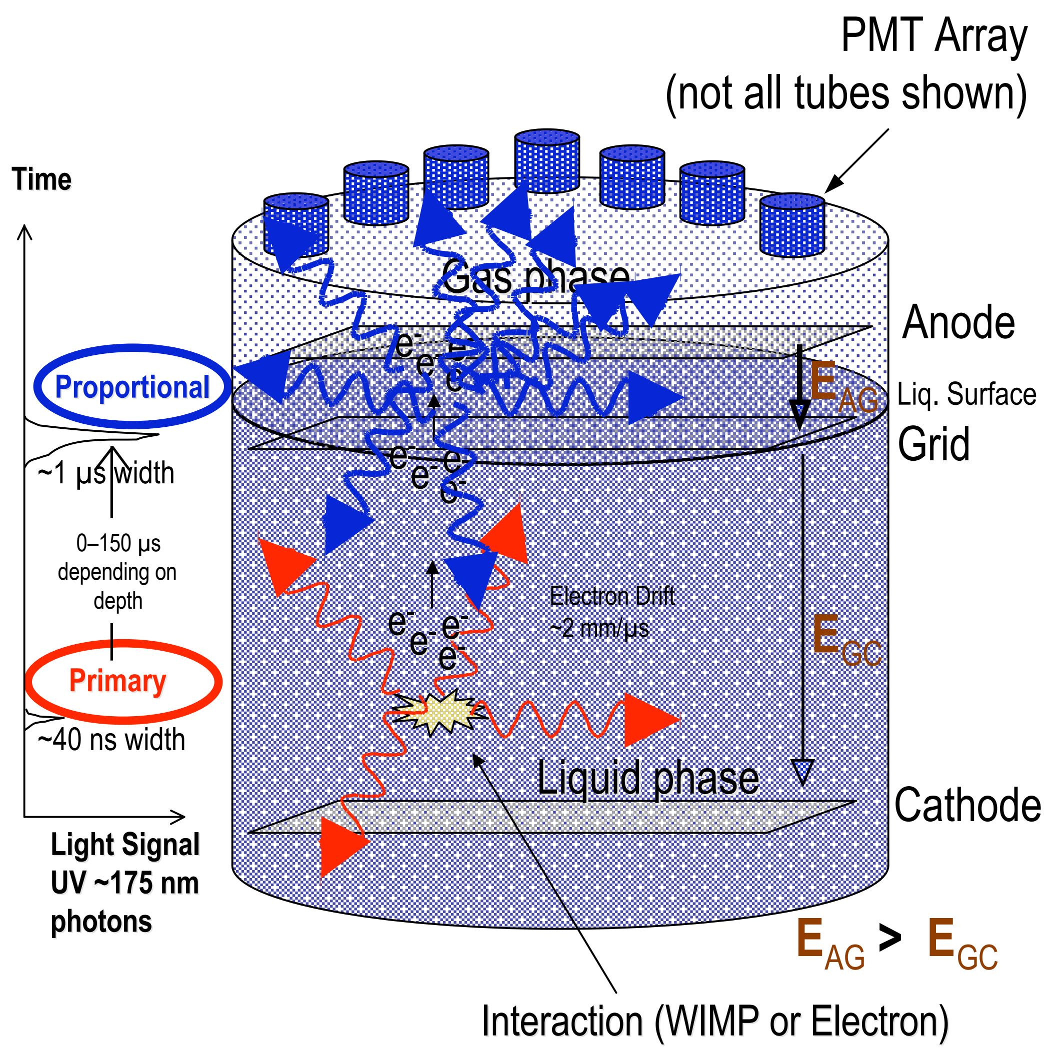
- **g, e-, m (etc) => Electron recoils**

  => Scintillation, substantial Ionisation

Ionisation electrons are
drifted by field E_{GC} and
extracted to the gas phase by field E_{AG}.

Due to increase in field E_{AG} around anode wires electrons increase kinetic energy => proportional scintillation via collisions with gaseous Xe.

The result is a large proportional light signal, which gives event-by-event discrimination against background.



Addition of CsI Photocathode at base

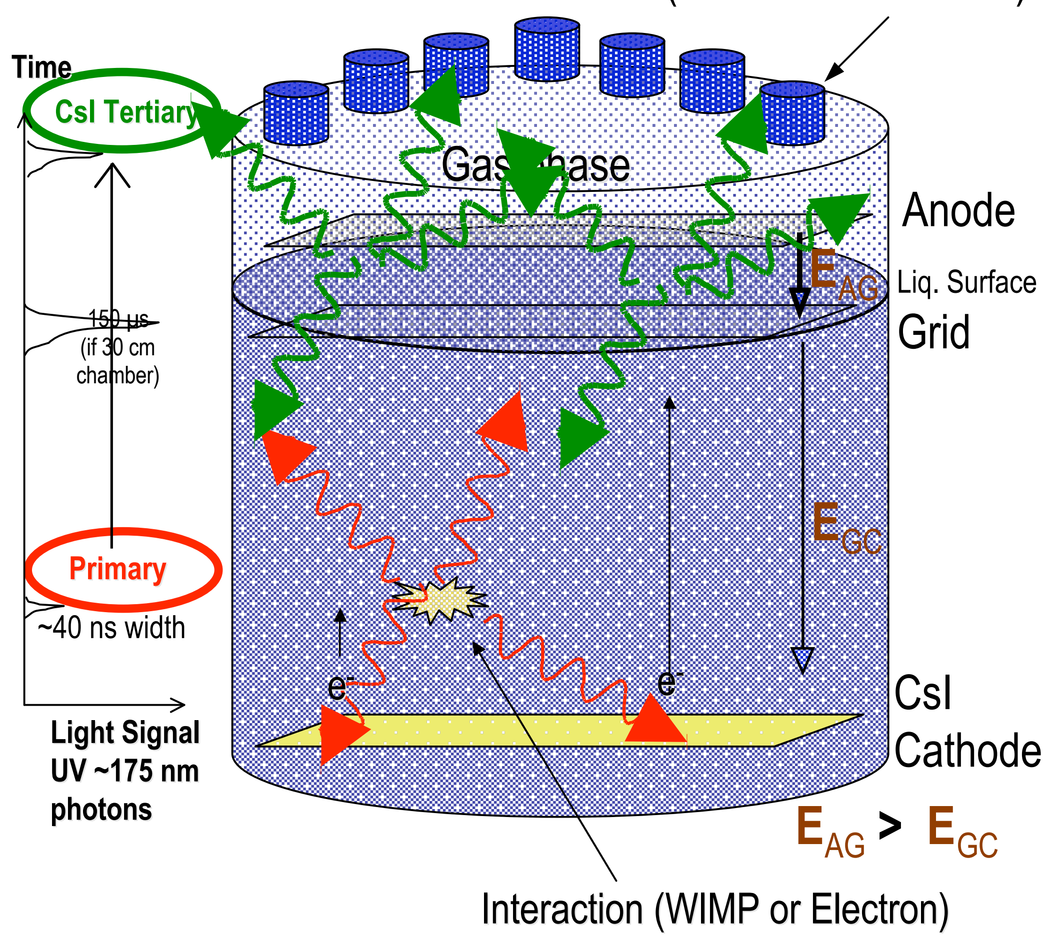
CsI is possible option being evaluated for prototype design

A Tertiary signal can be generated from absorbing primary photons into CsI photocathode

Efficiency very good
- **Geometry Solid Angle**
- **In Liq (No TIF transmission loss)**
- **CsI QE 30%**

Note: 16 keV nuclear recoil:
≈ 200 photons
before applying efficiencies for geometry and PMT QE.

Also ionization signal
≈ 7-20 electrons
(assumes high field 8 kV/cm)



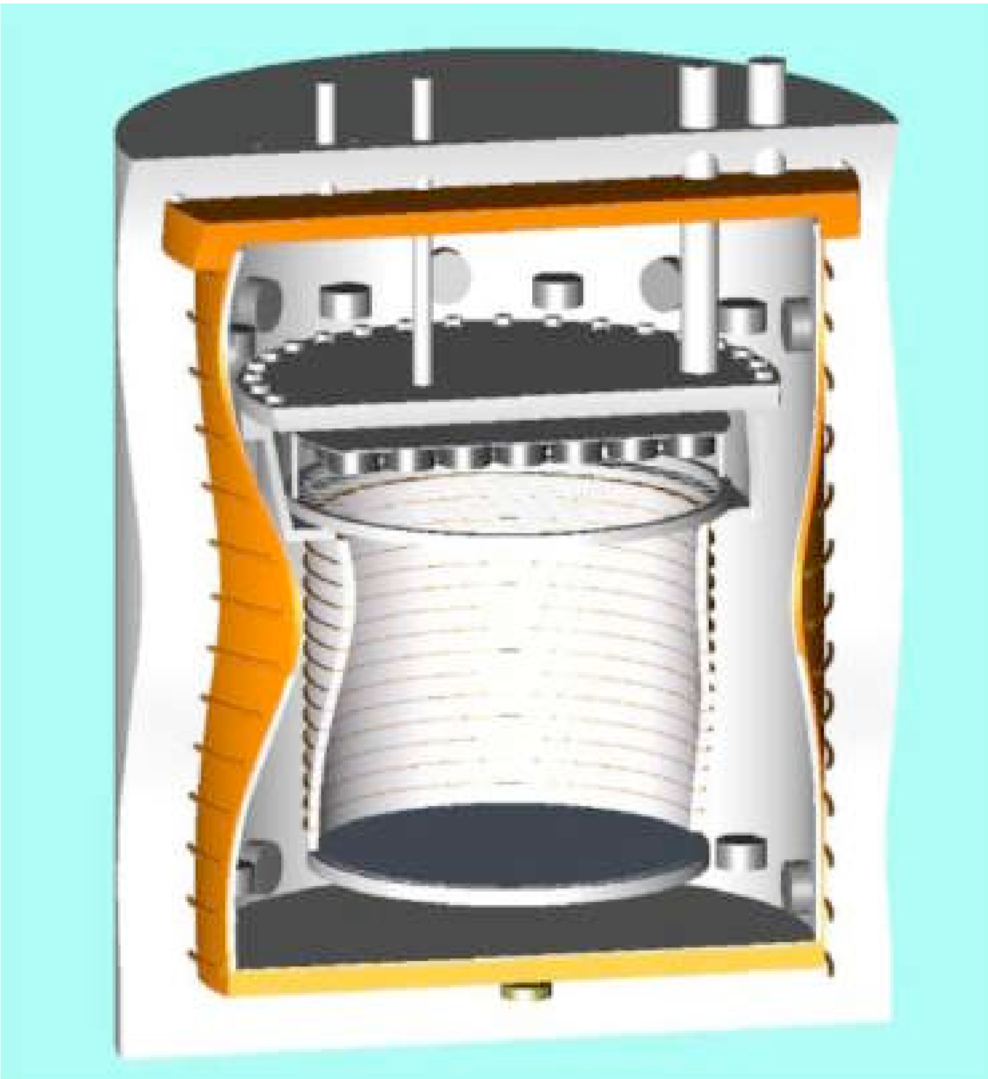
Available Signal in Liq. Xe (# of photons & electrons for 1 keV event)

SUMMARY OF PARAMETERS FROM EXISTING MEASUREMENTS

	Zero Field 0 V/cm	High Field 8 kV/cm
GAMMA EVENT - 1 keV electron equivalent energy		
UV Photons Electrons+Ions	60-75 UV [60-75 elec]	20-30 UV 50-60 elec
NUCLEAR RECOIL EVENT - 1 keV recoil energy		
UV Photons Electrons+Ions	12-18 UV [12-18 elec]	11.6 UV 0.4-1.2 elec
EFFECTIVE (NR/GAMMA) "QUENCHING FACTOR"		
UV Photons Electrons+Ions	20-25% [20-25%]	30-50% 0.8-2%

- Summary
  - The ranges shown reflect spread in existing experimental measurements
  - Note that the table considers signal from either 1 keV gamma or nuclear recoil event
  - 60 excitations / keV is equivalent to ~16 eV / excitation
  - Zero field electron-ion #'s in [ ] are inferred, but are signal is not measured (extracted) directly

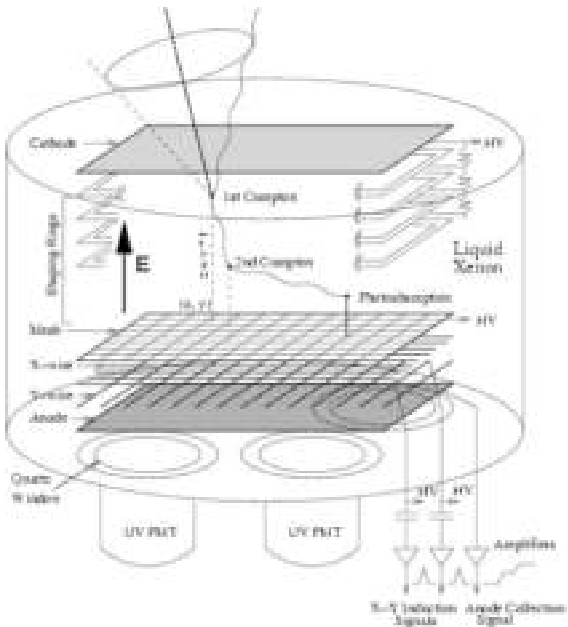
The XENON Experiment : Design Overview

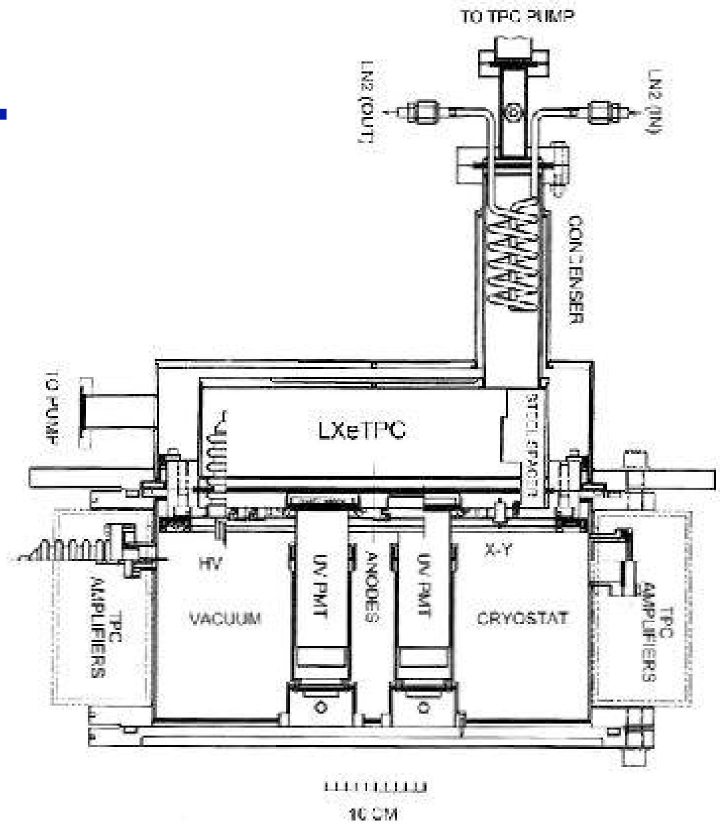


- Dual Phase Liq/Gas Xe
- The XENON design is modular.

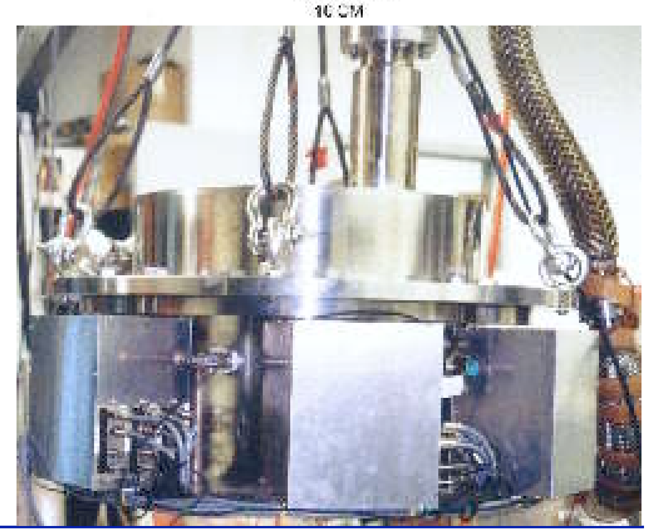
  Multiple 3D position sensitive LXeTPC modules, each with a 100 kg active Xe mass --> 1-tonne scale experiment.
- The 100 kg fiducial LXe volume of each module is shielded by additional 50 kg LXe. Active shield very effective for charged and neutral background rejection.
- Columbia, Brown, Livermore, Princeton, Rice.
  - Funded Sept. 2002.
  - Currently - R&D towards 10 kg prototype.
  - Deployment goal: 100 kg

The Columbia LXeTPC - DM Prototype "0"

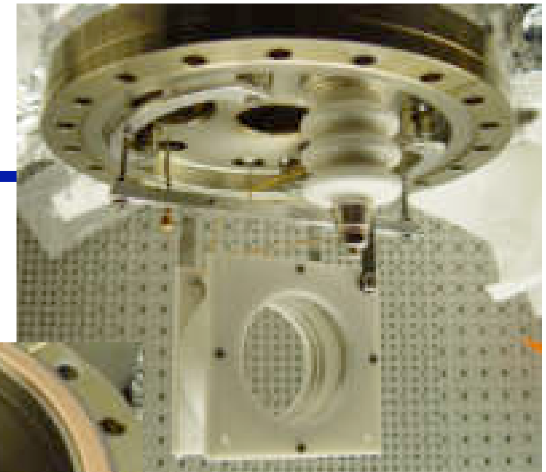




- LXeGrit ballon g telescope
- 30 kg active Xe mass
- 20 x 20 cm^2 active area
- 8 cm drift with 4 kV/cm
- Charge and Light readout
- 128 wires/anodes ADC
- 4UV PMTs

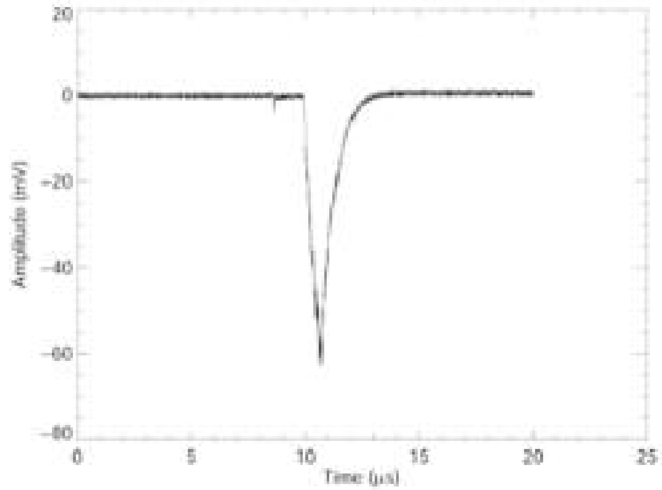


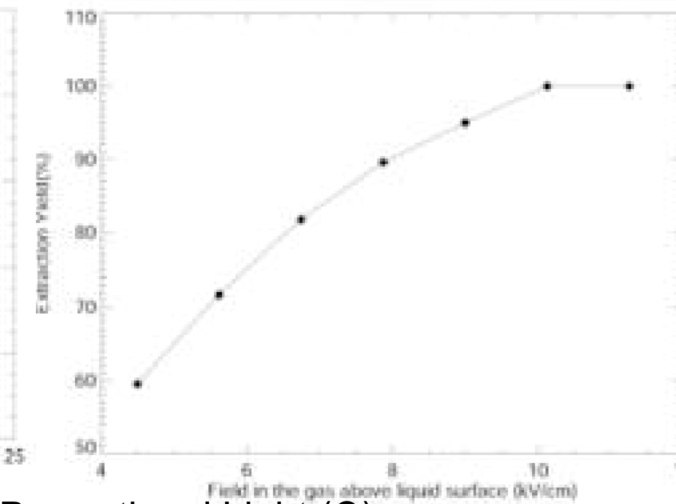
XENON R&D Program



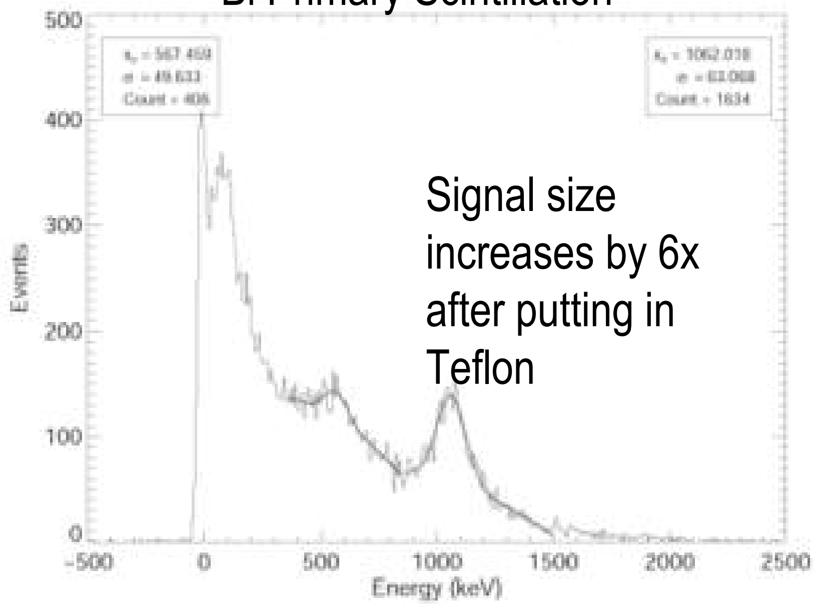
- Single Phase (Liq) + 2-10 cm Q drift (Qamp readout)
  - Testing different PMTs (Mech/QE/Elec)
  - Data for Light Collection Model (included Teflon reflectors)
    - Q drift good with teflon
  - Check Xe Contamination of components
  - DAQ Config.
- Dual phase, 1 cm Q drift (Prop scin readout)
  - PMT in gas
  - Study Electric Fields
  - Light Collection
  - Extra CsI Cathode
- Additionally
  - ≈ 10 cm drift length measurements
    - Demonstration of good electron drift with Teflon
- Also new setups being built at Brown, Princeton, Rice
- Construction of new Columbia 10 kg prototype underway
  - 7 PMTs
  - Pulse-tube cooled cryostat

Two Phase System (Columbia/ K. Ni)



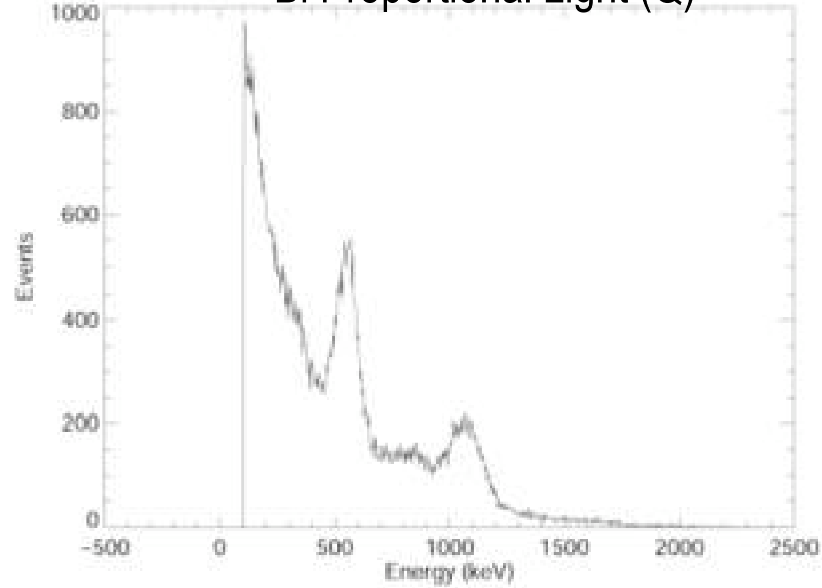


^{207}Bi Primary Scintillation



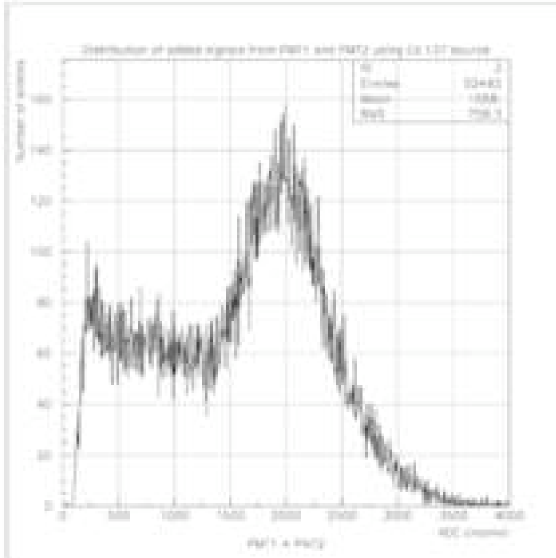
Signal size increases by 6x after putting in Teflon

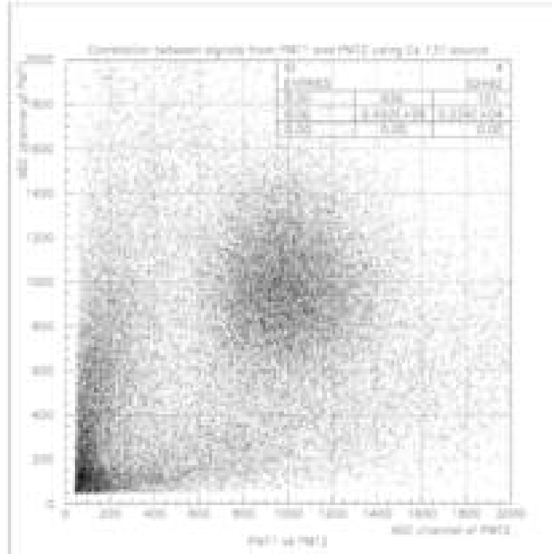
^{207}Bi Proportional Light (Q)



Single Phase

Just add Liq Xe & 662 keV γ's

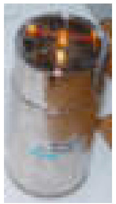




Xenon Purity

- Need to drift charge >>1 cm places most severe constraint on Xe purity
  - Electronegative impurities <1 ppb level
  - This is more stringent that levels required for observation of UV scintillation only
- Routinely achieving required levels
  - Using SAES Getter (Also evaluating Ti arc getter)
  - Chamber baked ~70 degC / pipes somewhat hotter
- Now evaluating contamination arising from various new components being introduced
  - Steps to reduce contamination
e.g. PMT bases -> Ceramic -> Kapton
Cables replaced / PMT enclosures scrubbed

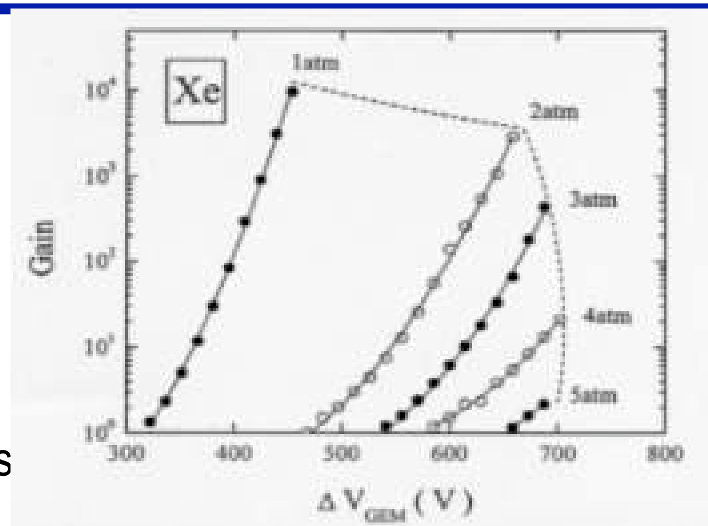
Hamamatsu PMT Selection (Baseline design)

Model	Photo (not same scales)	Dimension & QE	Radioactive Background * [mBq/tube]	Comment
R6041		ø5 cm x 4 cm QE 5-8%	6000 mBq (Dominated by glass seal at base)	Specifically designed for ops in LiqXe TPC
R9288		ø5 cm x 4 cm QE 20%	150 mBq (Use of Kovar for most of base)	Evolution of 6041
R8520		$(2.5\text{ cm})^2$x3.5cm QE >20%	15 mBq	Square/quad anode-good fill factor. Columbia tested at 150K/4 atm
R8778		ø5 cm x 12 cm QE 26%	31 mBq (expect further improvement)	Designed for XMASS. Columbia tested at 150K/4 atm

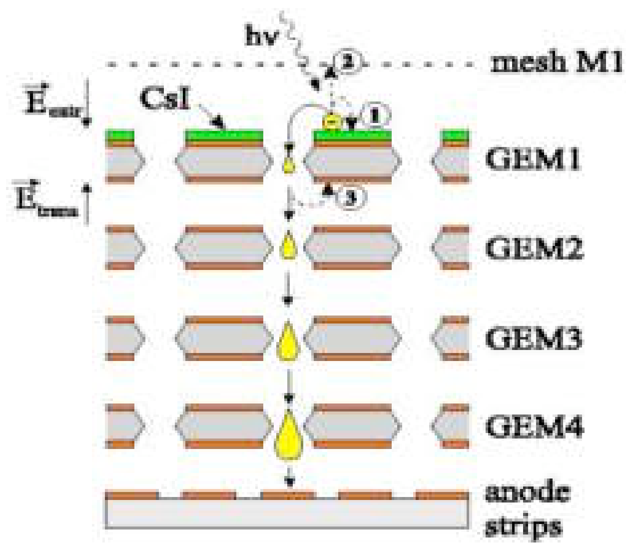
* 1 mBq/ø5cm project goal

Advanced readout schemes - Summary

- Charge readout
  - GEMs (Rice)
  - MWPC (Princeton)
- Light detectors
  - Burle MCP (Brown)
    - Constructed new cryogenic housing for MCPs
    - Expect first test in Liq Xe in Aug
  - Hamamatsu low-background PMTs
    - Quartz windows, limited ceramics
    - Backgrounds ≈ 10 mBq/PMT - 1000 x better than standard.
  - LAAPD (Brown)
  - CsI (Columbia)

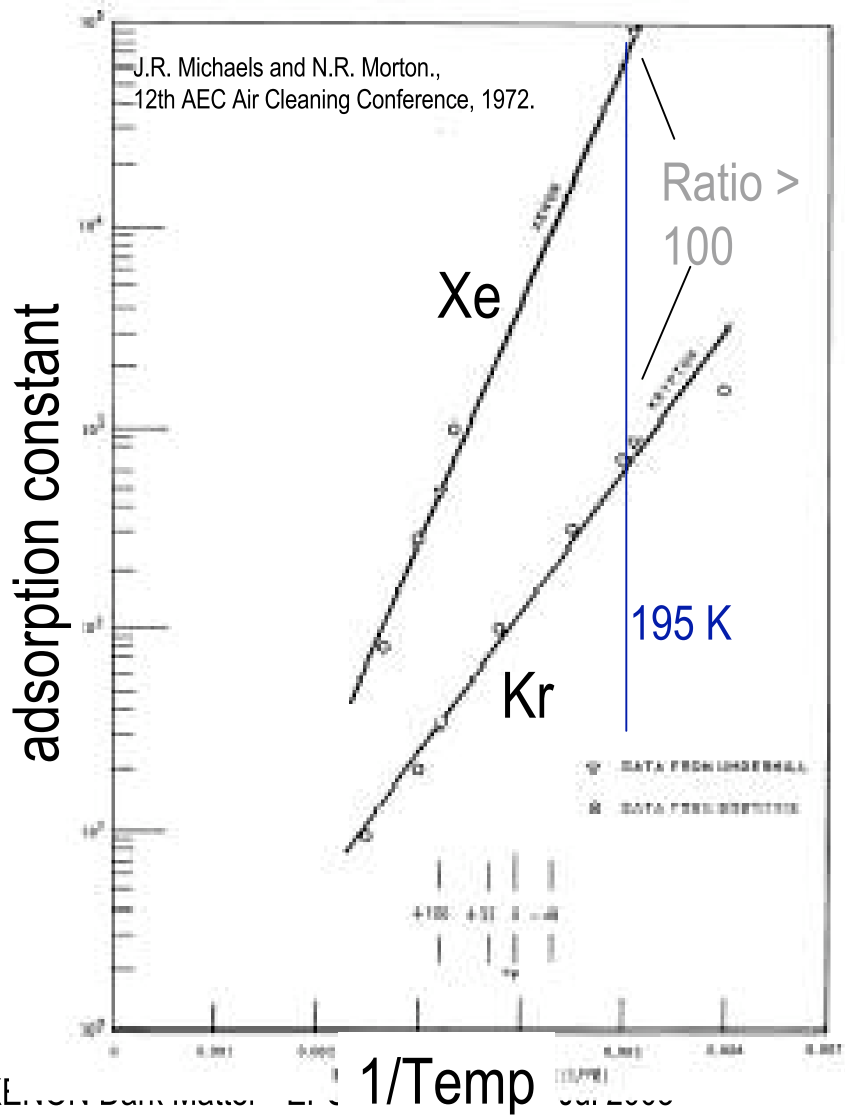


(A. Bondar et al., prepr. physics/0103082)

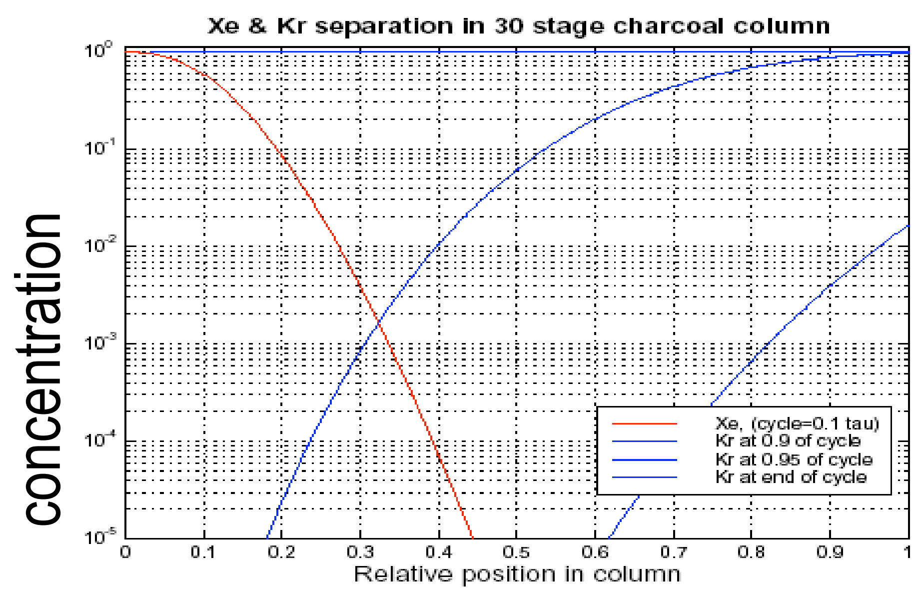


Removing Kr (+Ar) with chromatographic adsorption

Adsorption constant

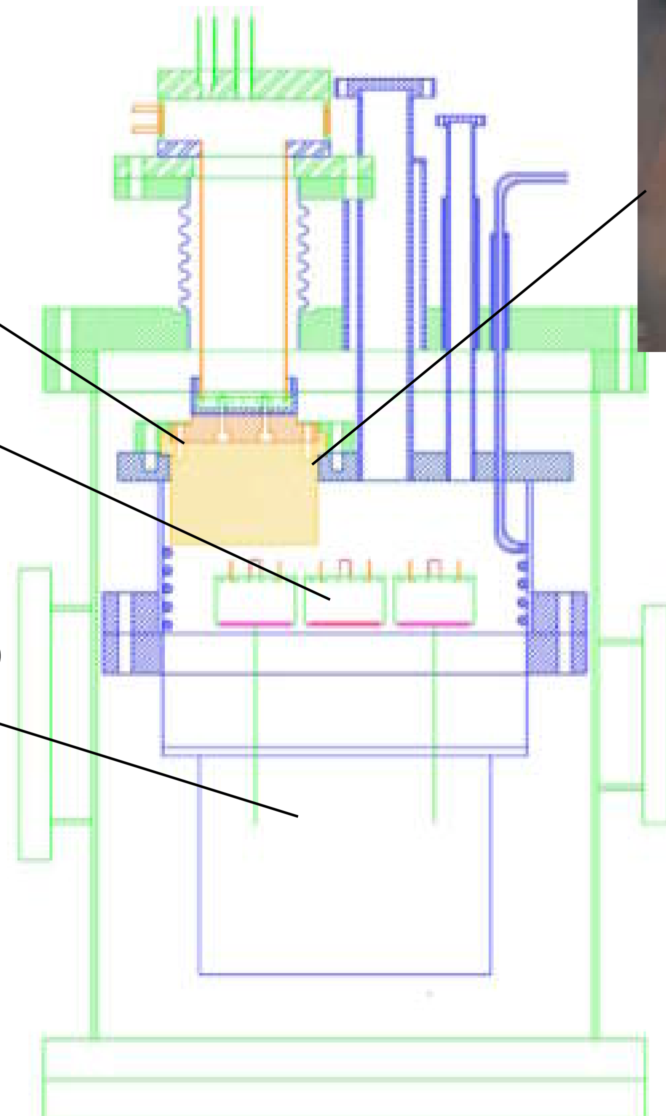


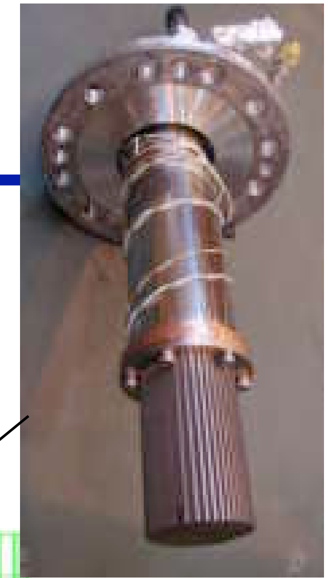
- ^{85}Kr in Xe
  - Xe Commercial grade 5-10 ppm Kr
  - Projection for 10^{-46} cm^2 sensitivity needs 100 ppt Kr
    - Goal 1 ppt possible
- Chromatographic separation:
  - Kr moves through column faster
  - Use He (or Ne) carrier gas
- Princeton Group



10 kg Dual Phase Prototype System

- Construction started of 10 kg dual phase system (assemble Aug '03)
- Temperature Control Using Pulse Tube Cooler
- Mechanical region for 7 x ø5cm photodetectors - can accommodate different length PMTs discussed
- Fiducial / Drift Region ≥10 cm deep
- Note: Materials are not low background selected (this is next phase)



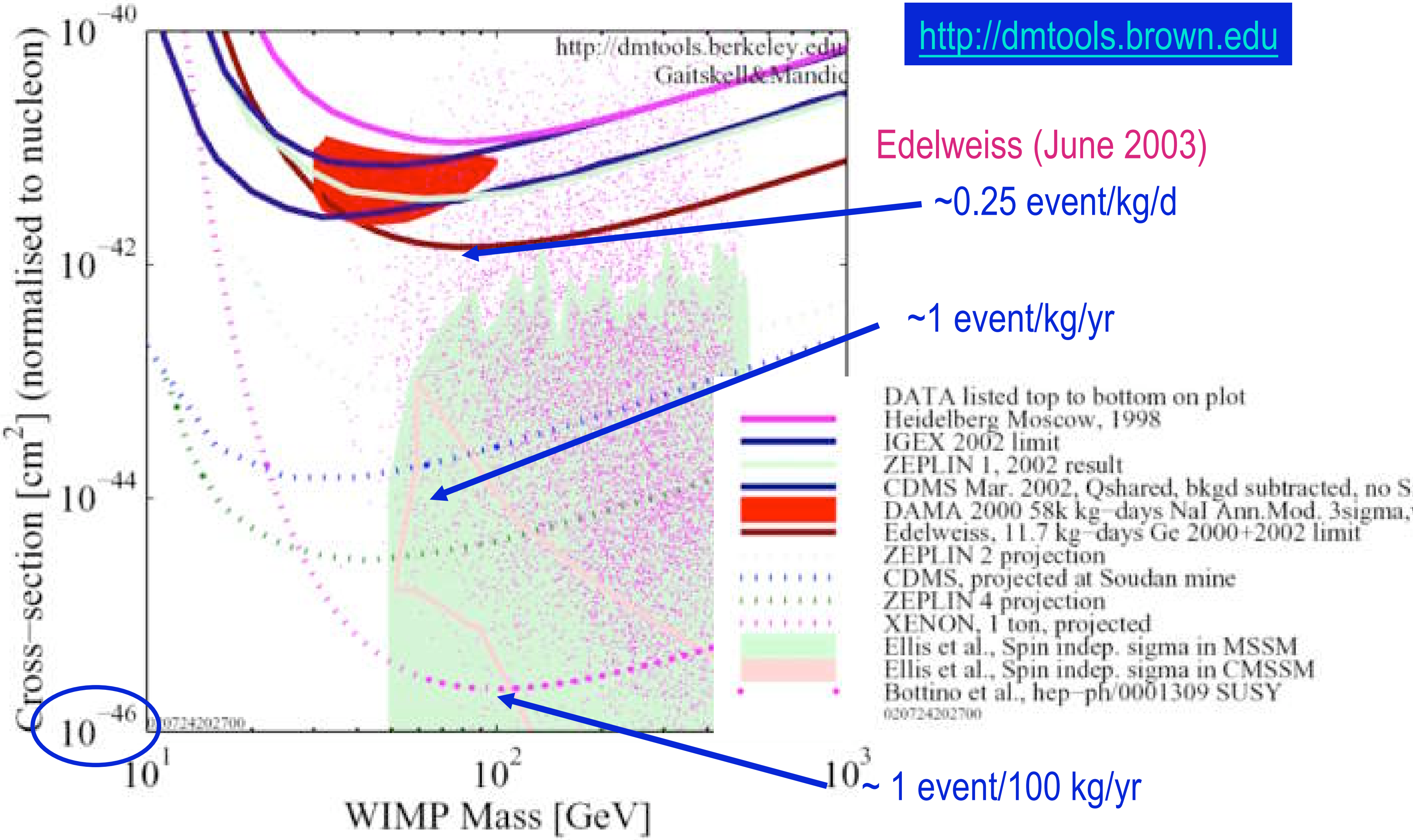


XENON Collaboration Summary

- Routinely Operating Two Xe Test Rigs at Columbia
  - Additional rigs being constructed at Rice / Princeton / Brown
- Testing Components for 10 kg Prototype
  - Baseline Design
    - Two phase demonstrated / necessary fields being studied
    - Collecting Data for Light Propagation Monte Carlos
    - PMT Selection - improvements in QE & radioactive backgrounds
    - Xe Purity - Q drift - routinely achieved (but often perturbed when inserting new components)
  - Additional Technologies being investigated
    - Photodetectors / Alternative Q readout
- Building 10 kg Prototype
  - Two phase with ≥7 PMTs and 10 cm drift
  - Neutron measurement and gamma discrimination
  - Test additional technologies/materials needed for low background version

Current & Next Generation Experiments & SUSY Theory Range

http://dmtools.brown.edu



Edelweiss (June 2003)

~0.25 event/kg/d

~1 event/kg/yr

~ 1 event/100 kg/yr