Dark Matter and Dark Energy

Summary,
prospectives
and remarks

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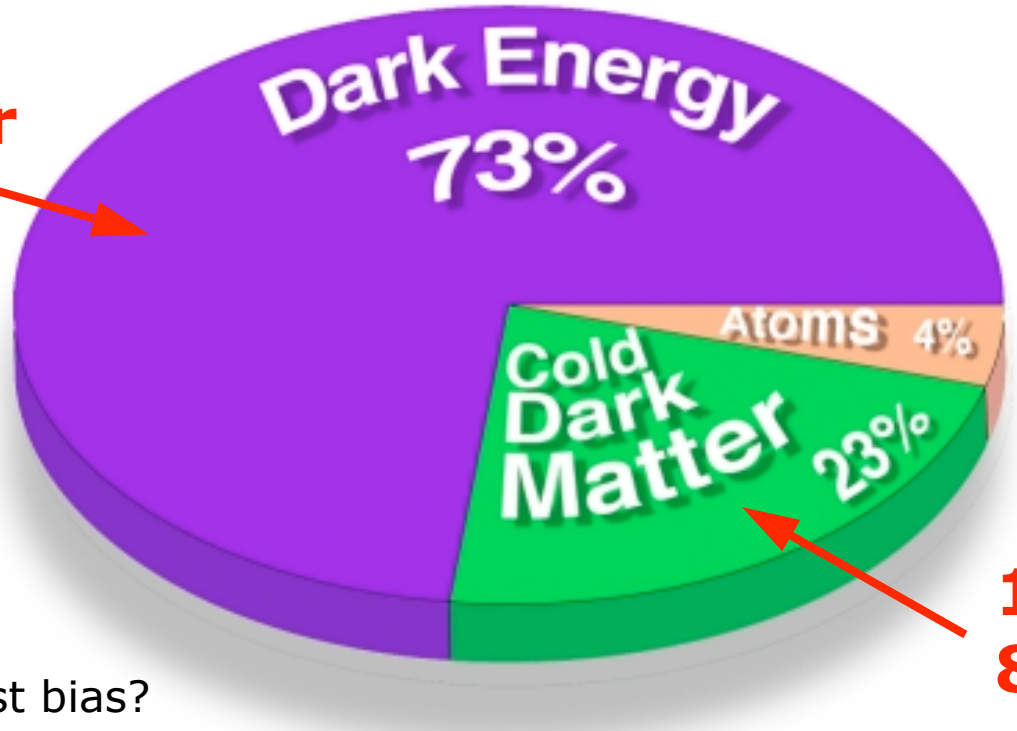
Summary of summaries…

- Dark energy and (cold) dark matter: summary of 15 talks, 9 posters
- Many talks already excellent summaries…

3 talks,
1 poster

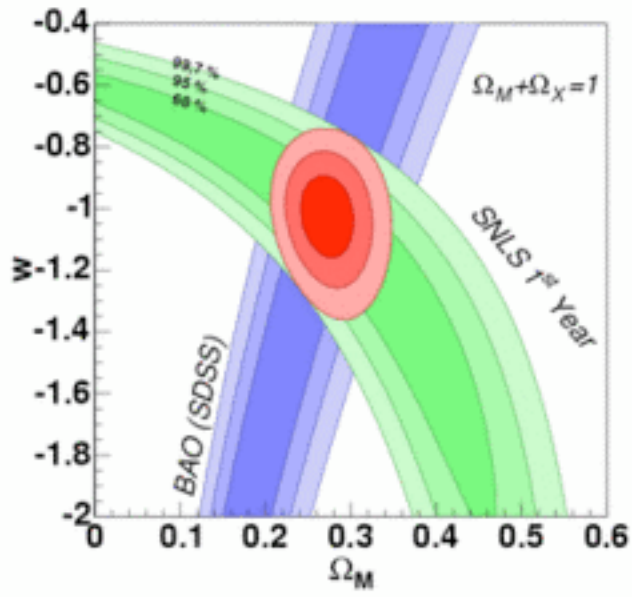


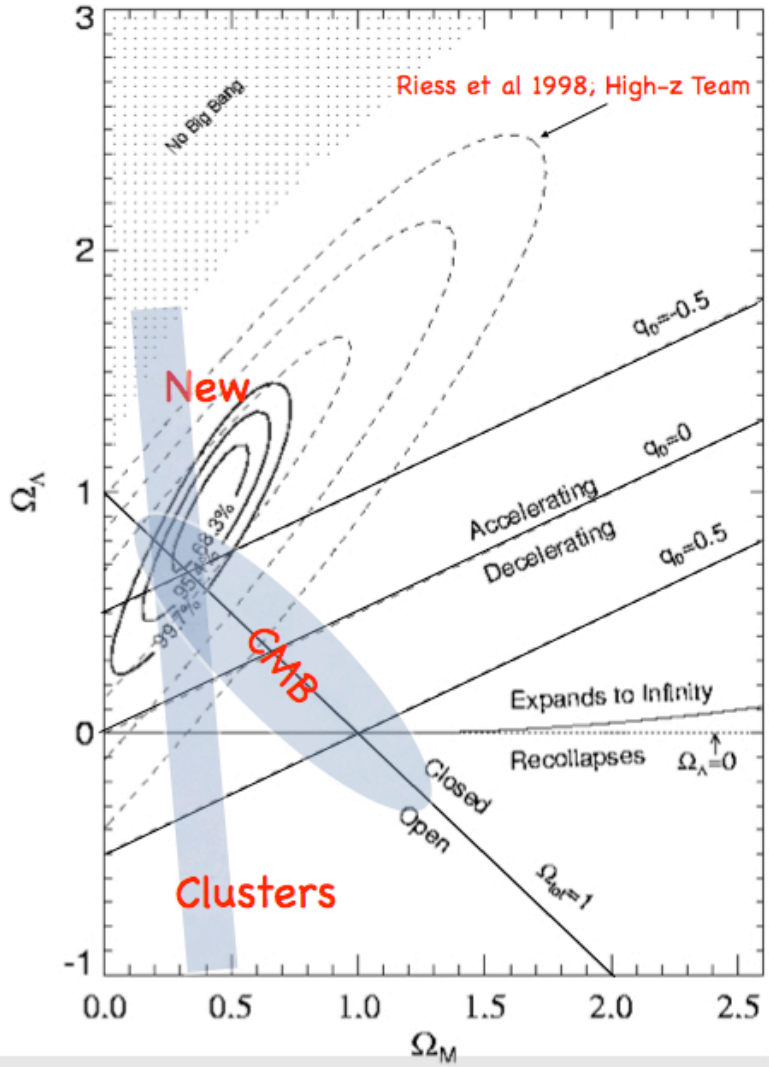
11 talks,
8 posters

Mamquist bias?

Dark Energy is there

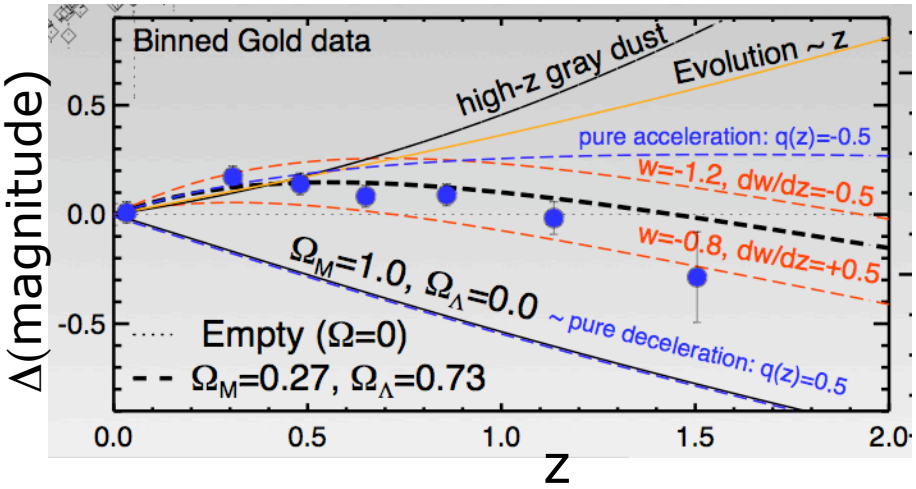
- $\Omega_\Lambda \sim 0.74$, $w \sim -1$ needed to explain WMAP + clusters data
- Consistency with supernovae from HST and SNLS (Strolger, Regnault)

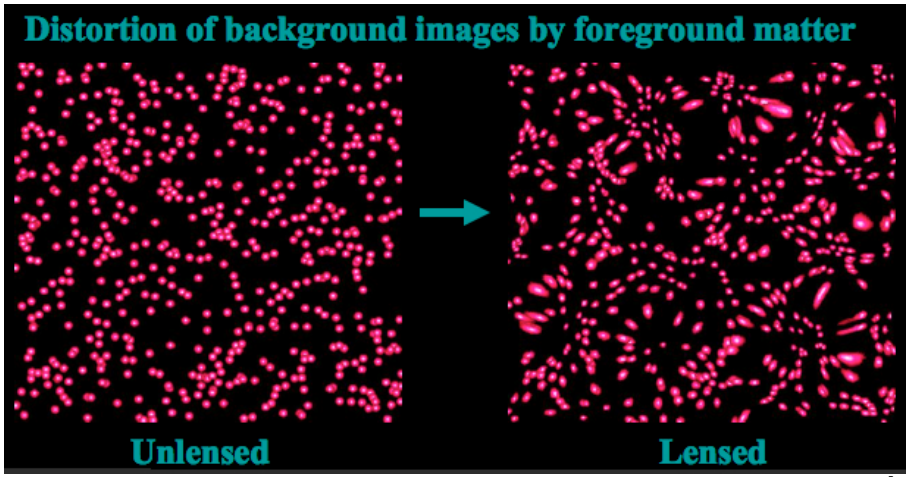




Supernovae and weak lensing

- What is this Λ? Does it vary in time (redshift z)?
- SN history now shows transition from Ω_m to Ω_Λ dominance… with constant constant
- Weak lensing provides history of structure scale vs time and is sensitive to time-dependence of dark energy (once systematics are under control)





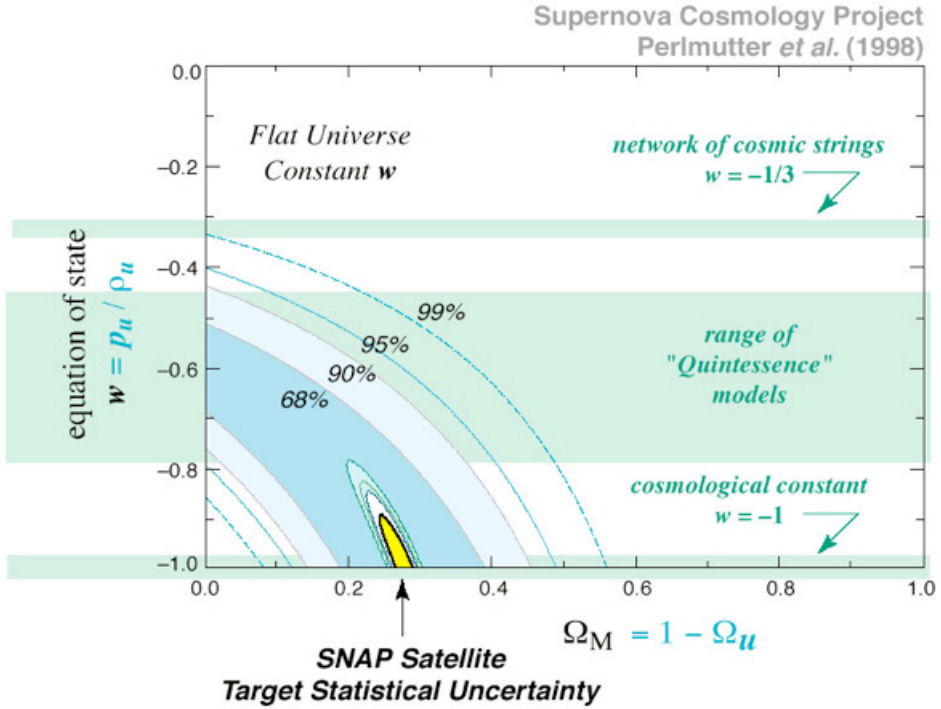
Hannestad

Nature of dark energy

- Established effect, consistent measurements. What is it?

Future surveys to improve knowledge of *w* and d*w*/dz (synergy between supernovae and weak lensing projects)

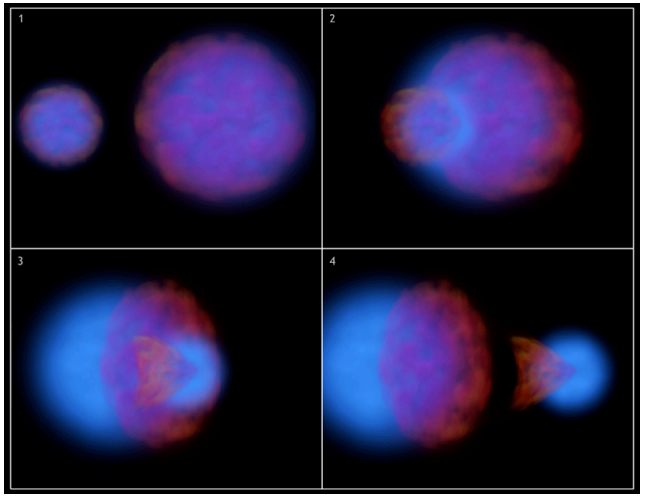
Also in store: Planck CMB, structure surveys at large z,



- Growth of structures vs time also affected by neutrinos: constraining *w* helps constraining m_ν (<0.7 eV).

Identification of Dark Matter

- Ω_{CDM} measurement very robust
- Most searches focused on χ-like WIMPs… is that robust?
  - Direct/Indirect searches almost fruitless if they end with the discovery of an "orphan" WIMP only observed with a single detector technique: SUSY yields framework for comparisons.
- WIMPs survived that type of p-p collision:



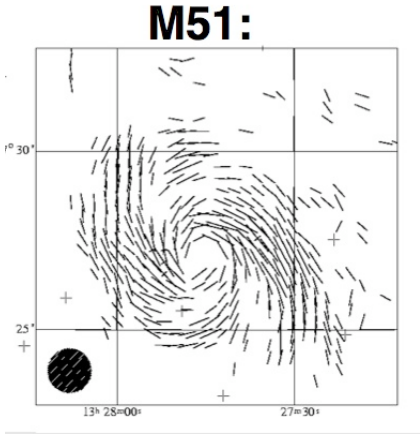
Chandra+HST

- Will they survive pp collisions in the coming years at LHC?

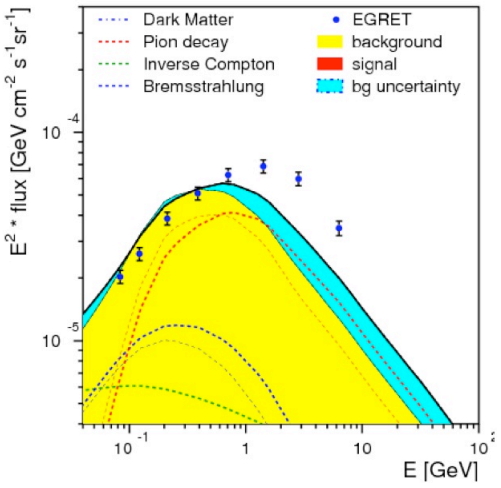
Indirect searches

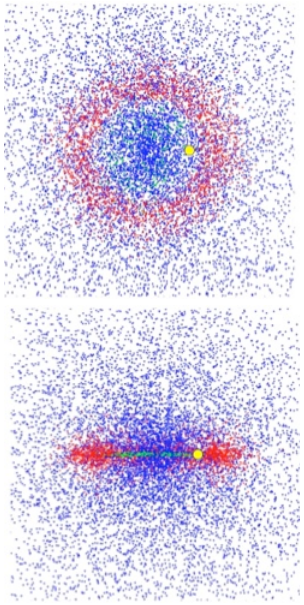
Cf C. Sanders's review:

- Charged probes (e^+, p, D)
  - AMS (Pannicia;s talk), Pamela (launched 06/06)
  - Study of propagation in magnetic fields
- Neutral probes (ν, γ)
  - Neutrinos in AMANDA (3x statistics), *IceCube;* ANTARE
  - EGRET excess (and its interpretation)
  - GLAST (launch 2007)



Strong interplay with many astrophysics questions

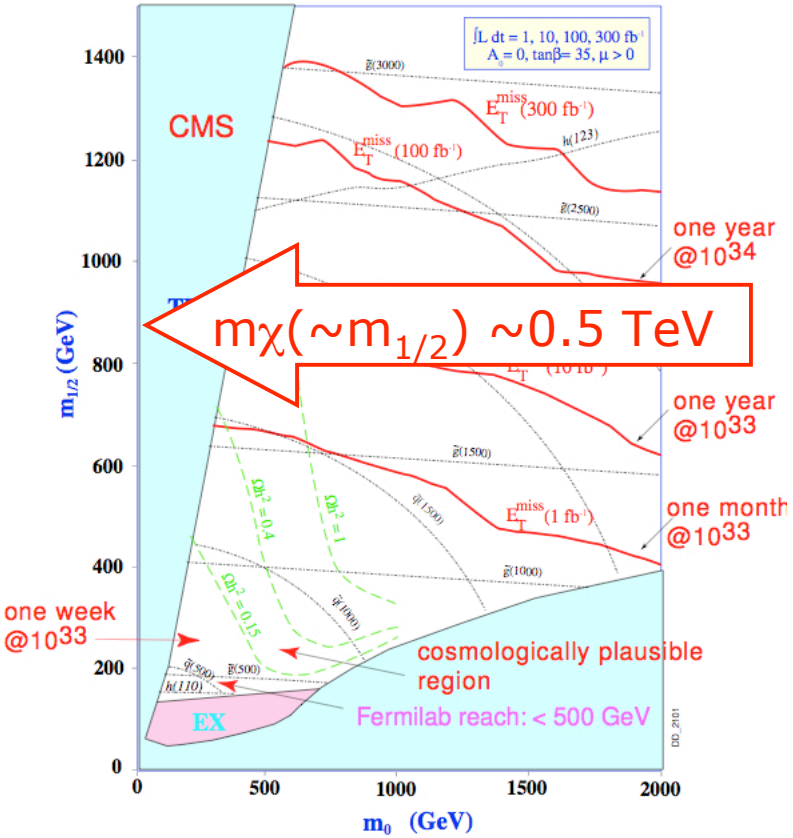




Dark Matter search at LHC

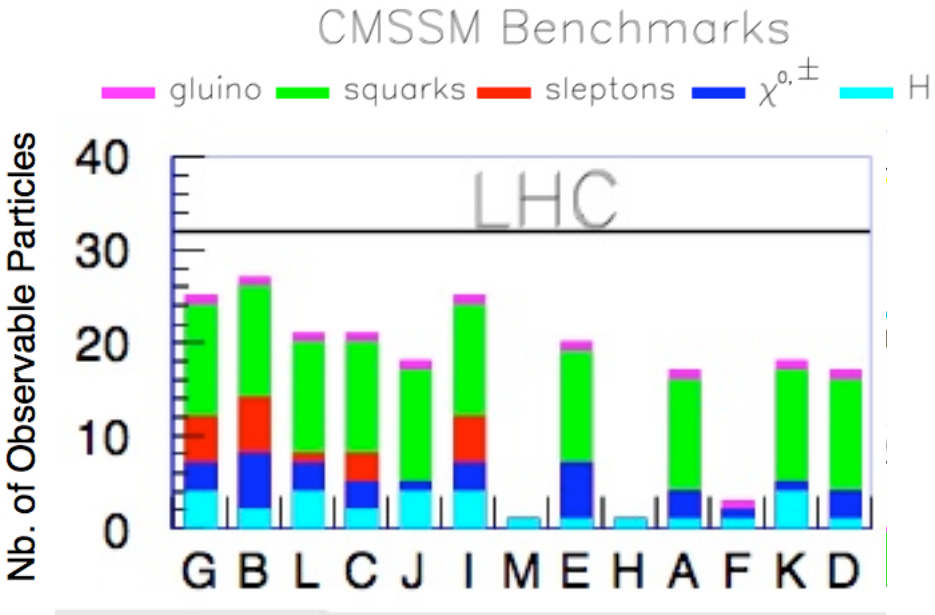
- Best experiment to look for it? Maybe LHC!
- Importance of SUSY framework for search strategy
  - SUSY at LHC: precise mass and cross-section predictions are possible (astrophysics uncertainties remain…)
  - No SUSY at LHC: many paths to follow for WIMP identification:
    - *Axions? … (CAST discussion)*
    - Spin/isospin dependent? …
    - SuperWIMPs?…

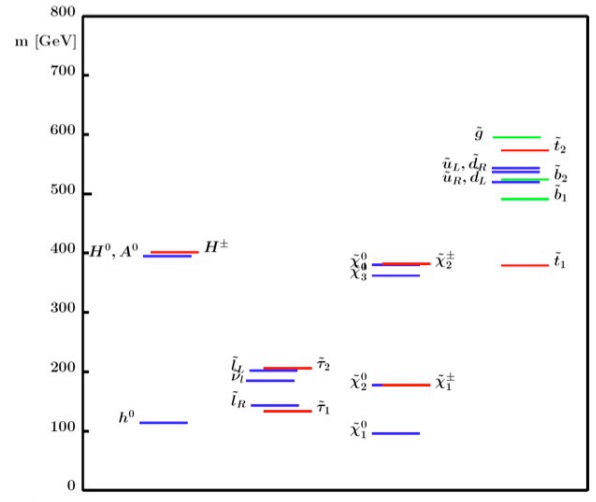
LHC SUSY reach

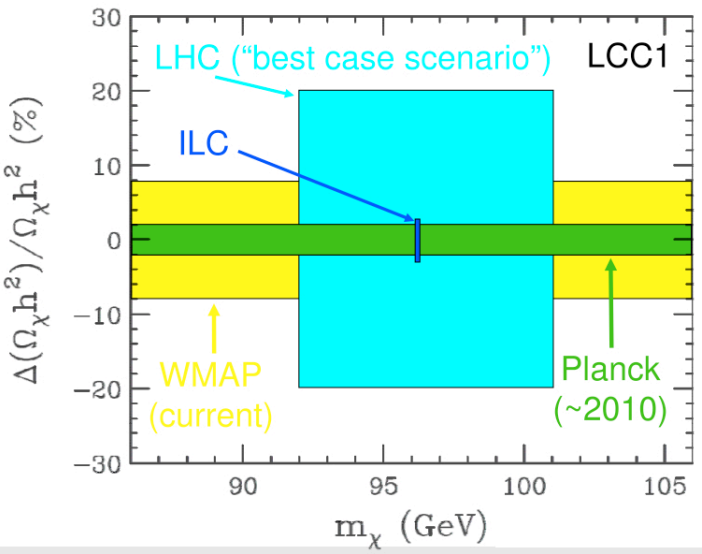


see also D. Akerib review

SUSY at LHC

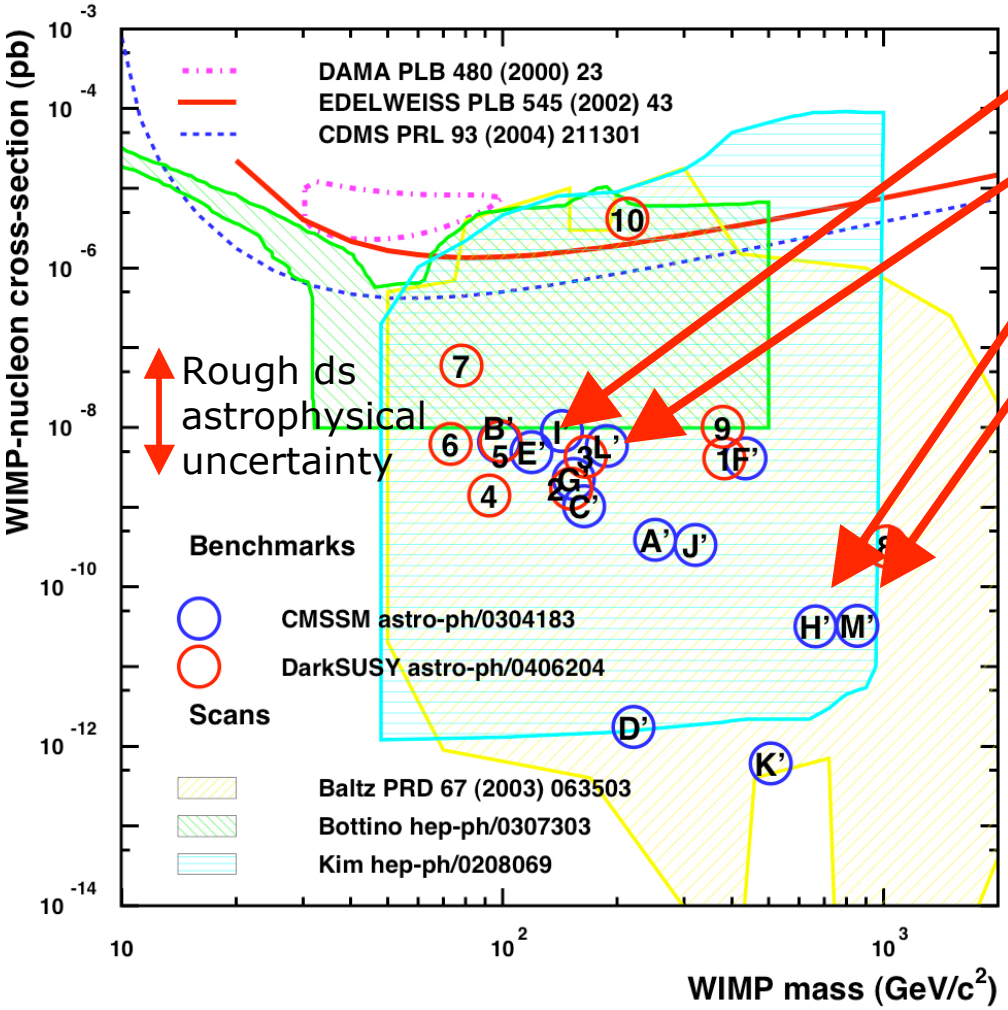






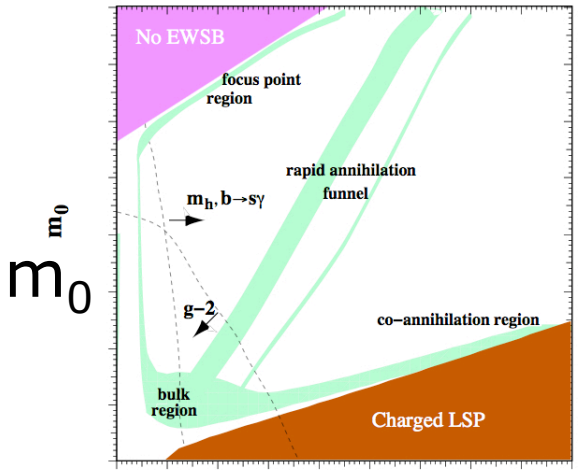
In many (cosmologicaly interesting) scenario, full SUSY spectroscopy

Direct searches vs LHC



- Bulk
- Funnel
- Stau coannihilation
- Focus point

(large $m_{1/2}$, no χ at LHC?)



Feng astro-ph/0511043

Direct search: Simplicity

- Less model-dependent than indirect search
  - Fair correlation between elastic scattering σ and Ω_{CDM}
  - Linear dependence on *average* WIMP density & kinetic energy
- "Simple" counting experiment
  - 5 kg x 2 weeks sufficient to reach the present CDMS limits
- Easy? "Just design a background-free experiment!"

  "What do you see when you close your eyes?"

  Theoretician's (correct) answer: "Nothing"

  Experimentalist's answer:"The instrumental background from my eyes"
- Just design a (known-background)-free experiment *AND* prepare to (identify / discriminate against) the new backgrounds you will discover

Direct search: complexity

- Extreme low radioactivity
  - 10^{-3} - 10^{-4} counts/kg/day (human body ~10^{10} /kg/d)

- Understand/control of low energy backgrounds

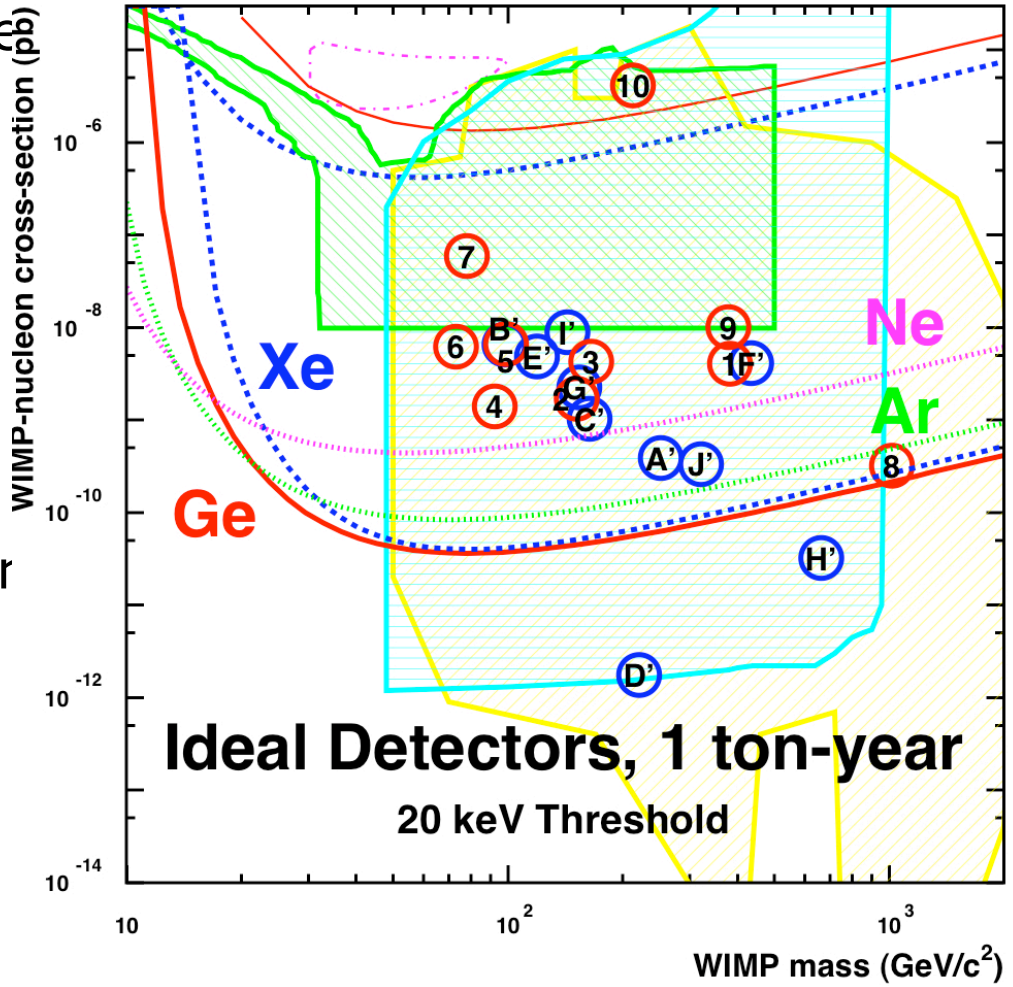
  10 keV vs ~ MeV in large ν detectors… and $\beta\beta0\nu$!

  (cf Fiorini's review)

- Discrimination of nuclear recoils
  - ~10 nm range in solids/liquids

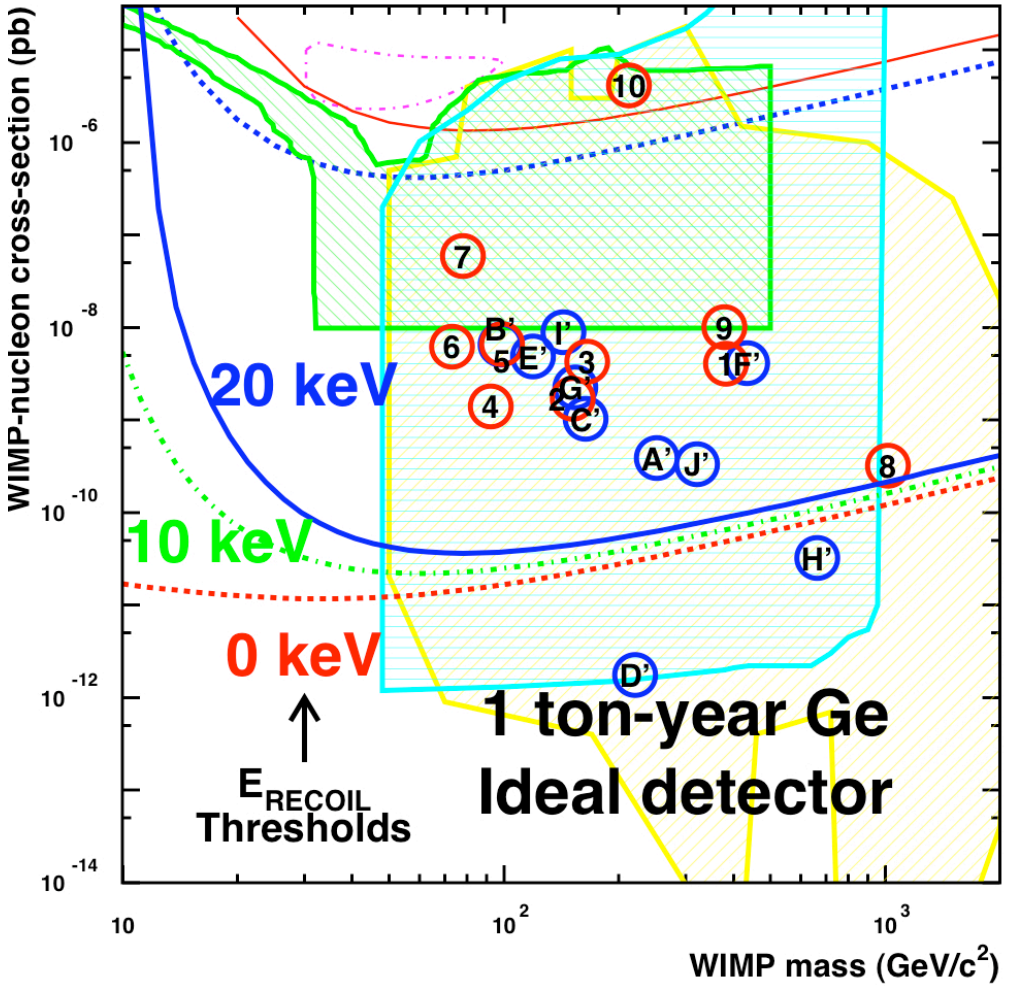
Choice of target mass

- Coherence favors large atomic masses A
- … until form factor takes its bite
- A>~40 is ok
- Lower A is fine too if increasing the detector size is ok
- Variety of target essential to check A dependence



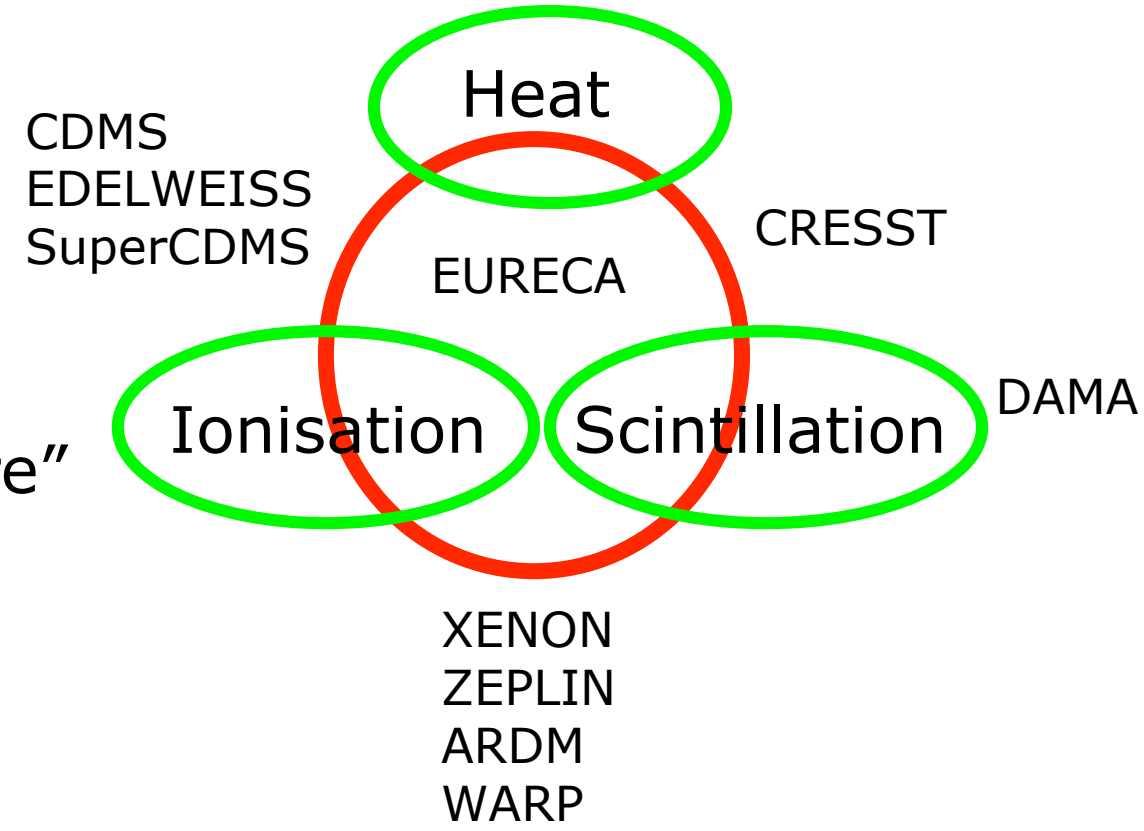
Direct search - threshold

- Low thresholds: 20 keV is ok for most interesting range
- … much more important for the control of systematics
  - Having most of the signal JUST at threshold is dangerous



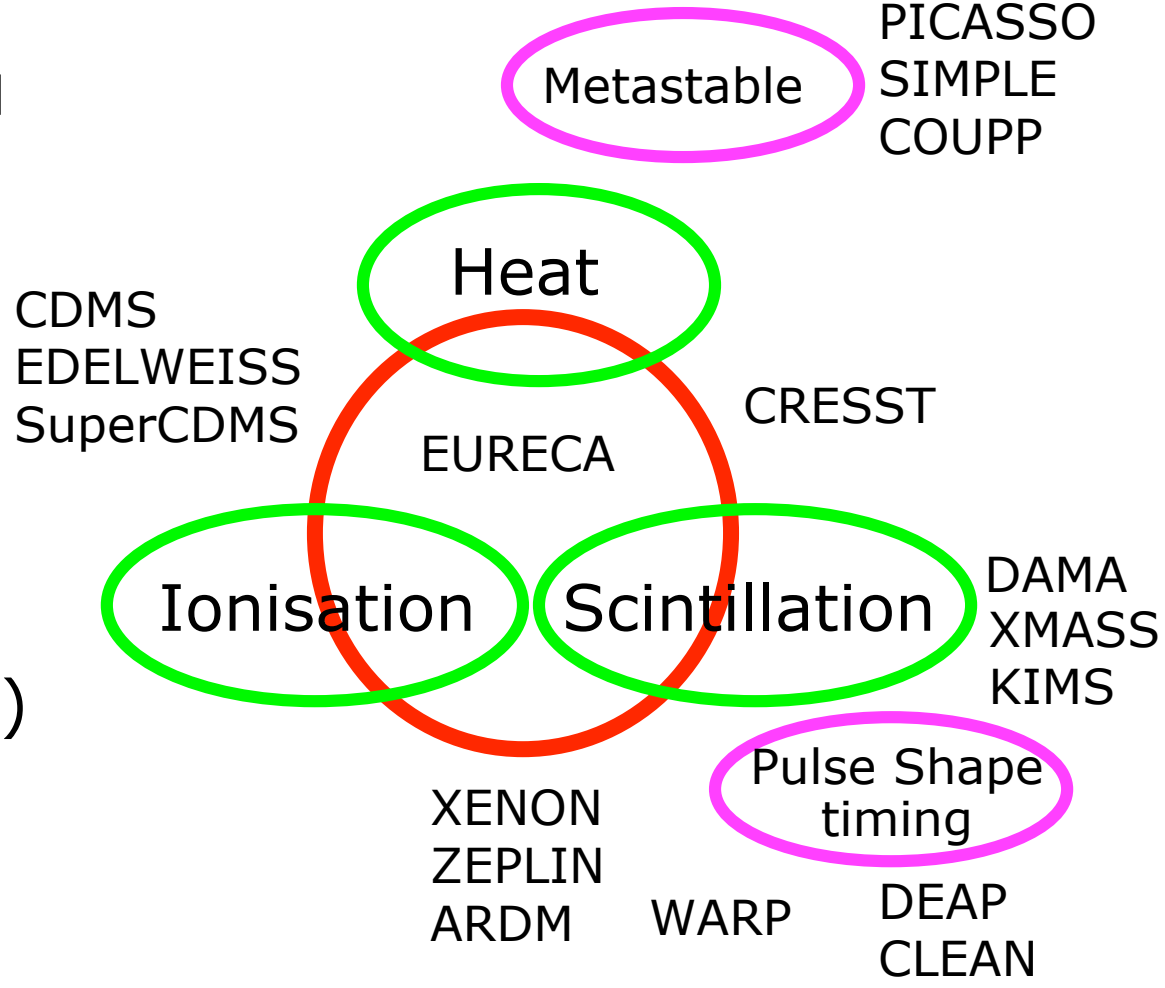
Direct search - techniques

- "Triangle" of mainstream (mature & massive) techniques
- Emergence of "Large Structure" after initial BigBang?

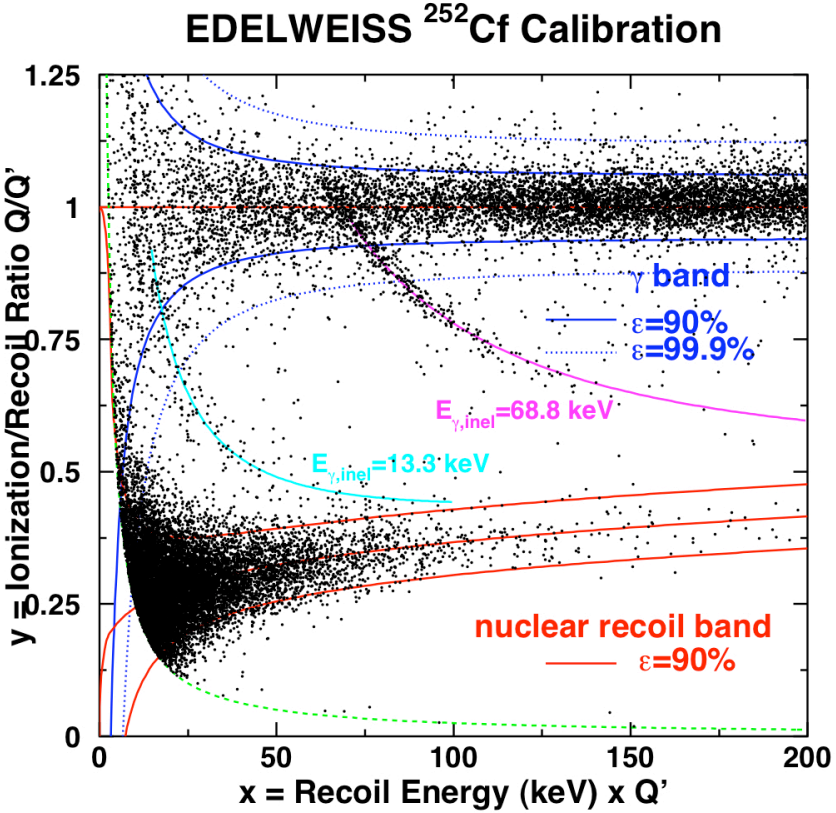


Direct search - techniques

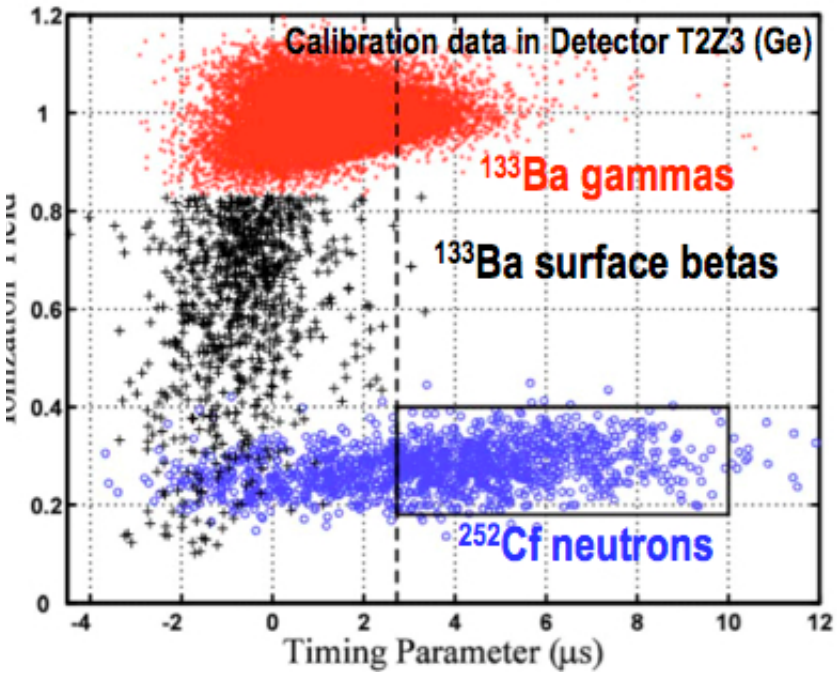
- D. Akerib review, Thursday talks and posters: ongoing progress on many alternative techniques
- Detector (& environment) purity
- Discrimination



Ge cryogenic detectors discrimination

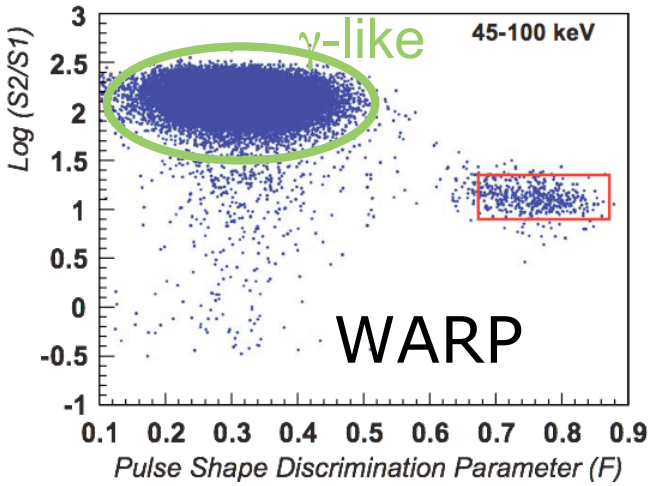


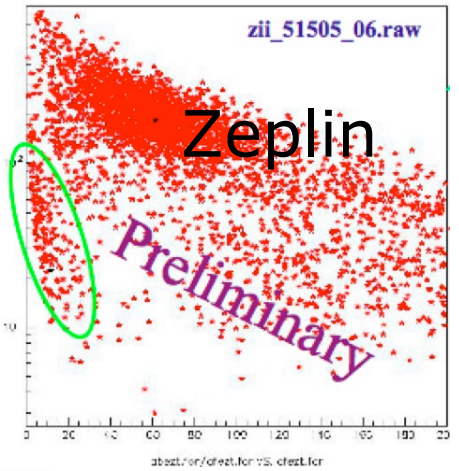
CDMS



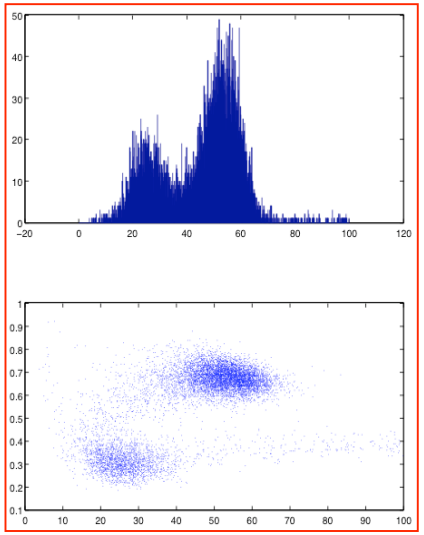
- Discrimination and good resolution also helps understanding any remaining backgrounds

Discrimination in LAr, Lxe



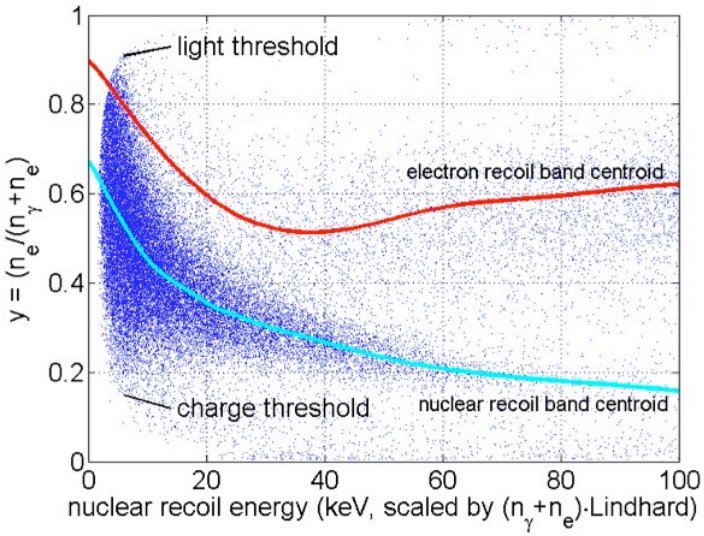


^{252}Cf dataset at 4.0 kV/cm



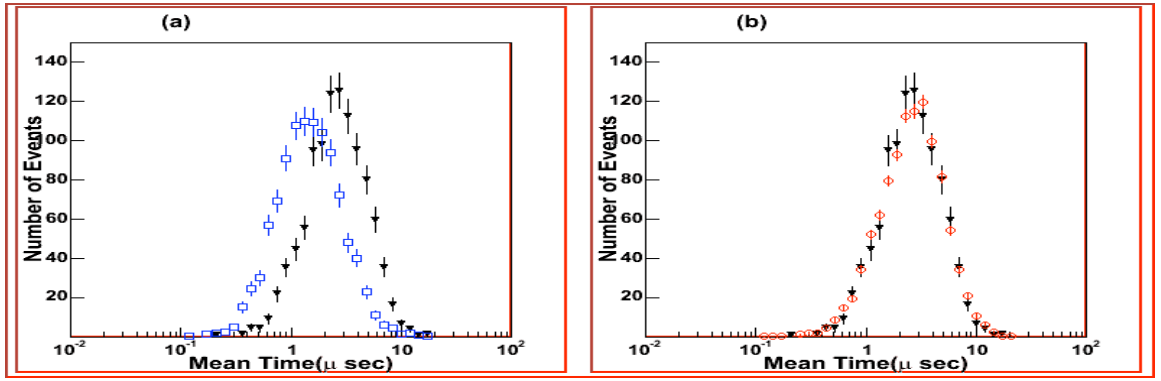
ArDM

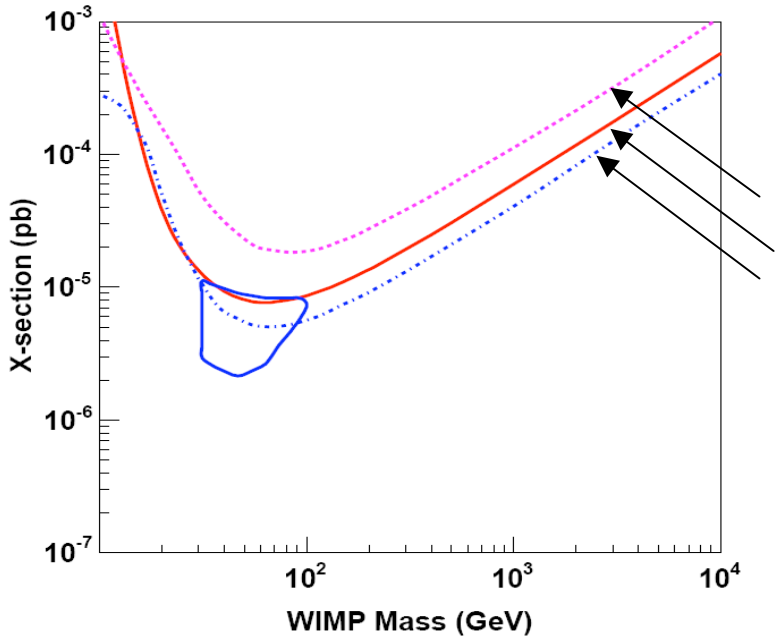
XENON



CsI check of NaI?

PSD (statistical) discrimination

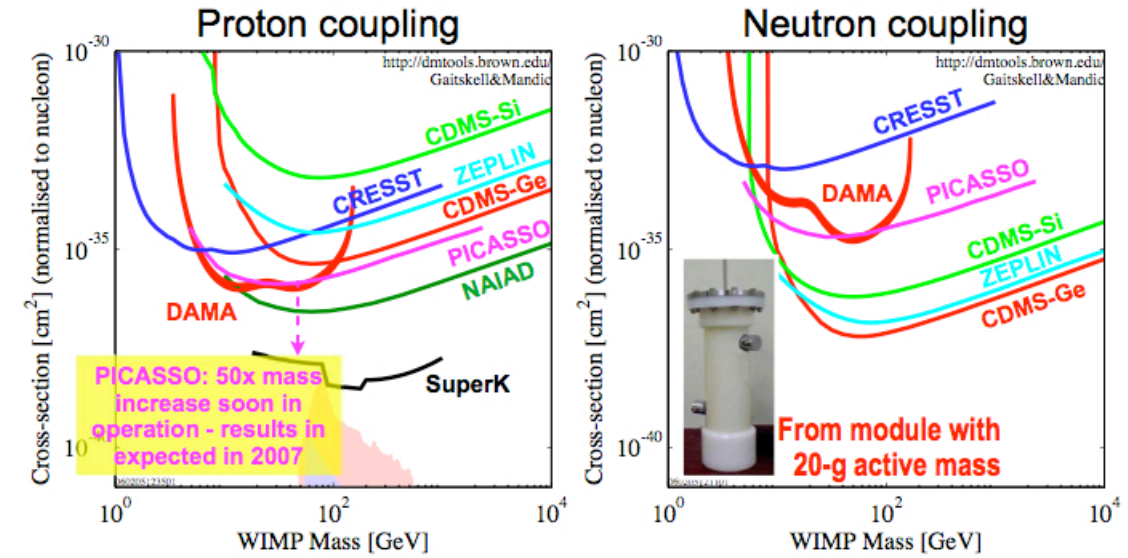




3879 kg days NAIAD - NaI(Tl)
237 kg days KIMS - CsI(Tl)
4123 kg days DAMA - NaI(Tl)

Crystal purification

Metastable detectors

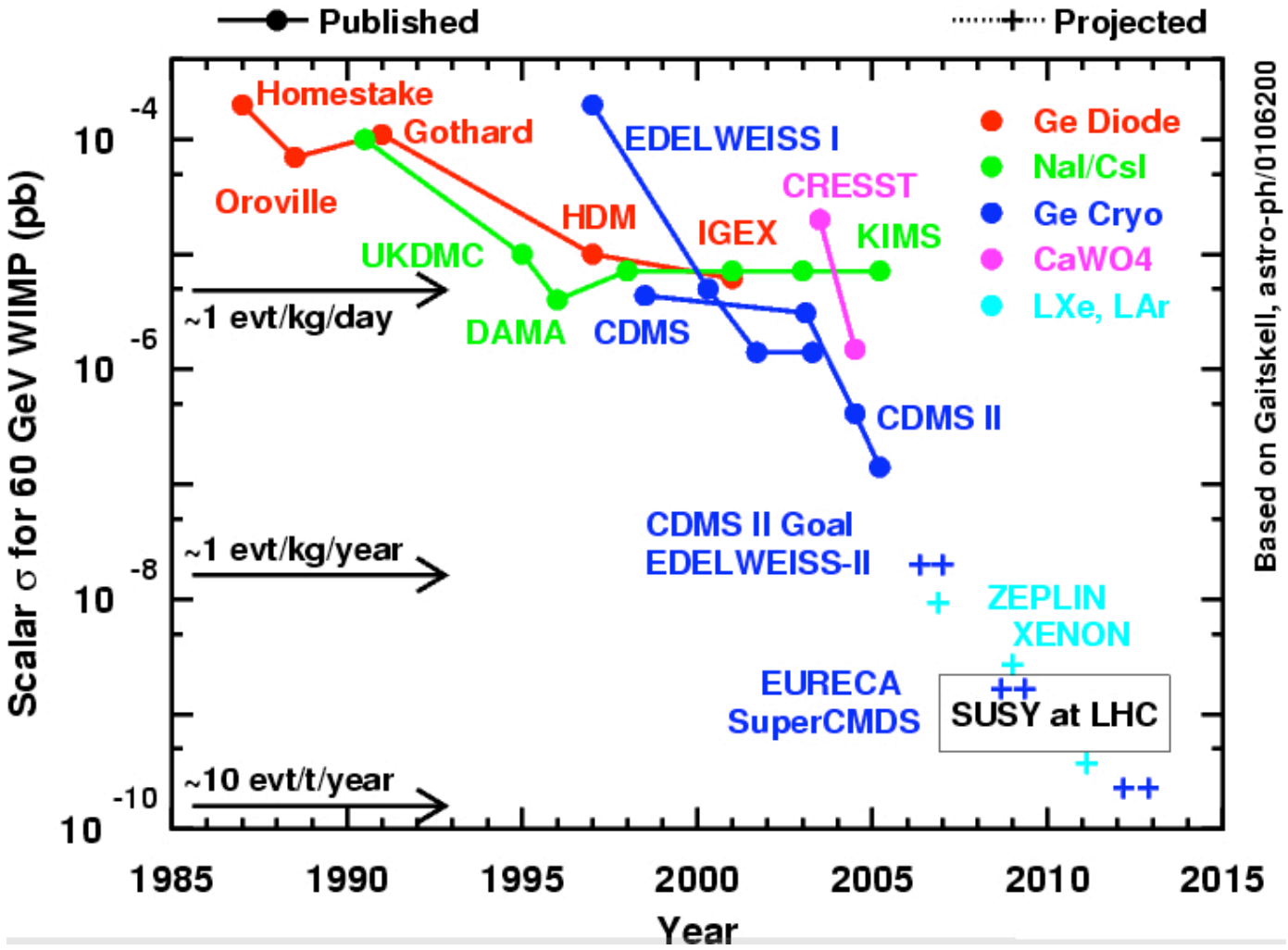


PICASSO

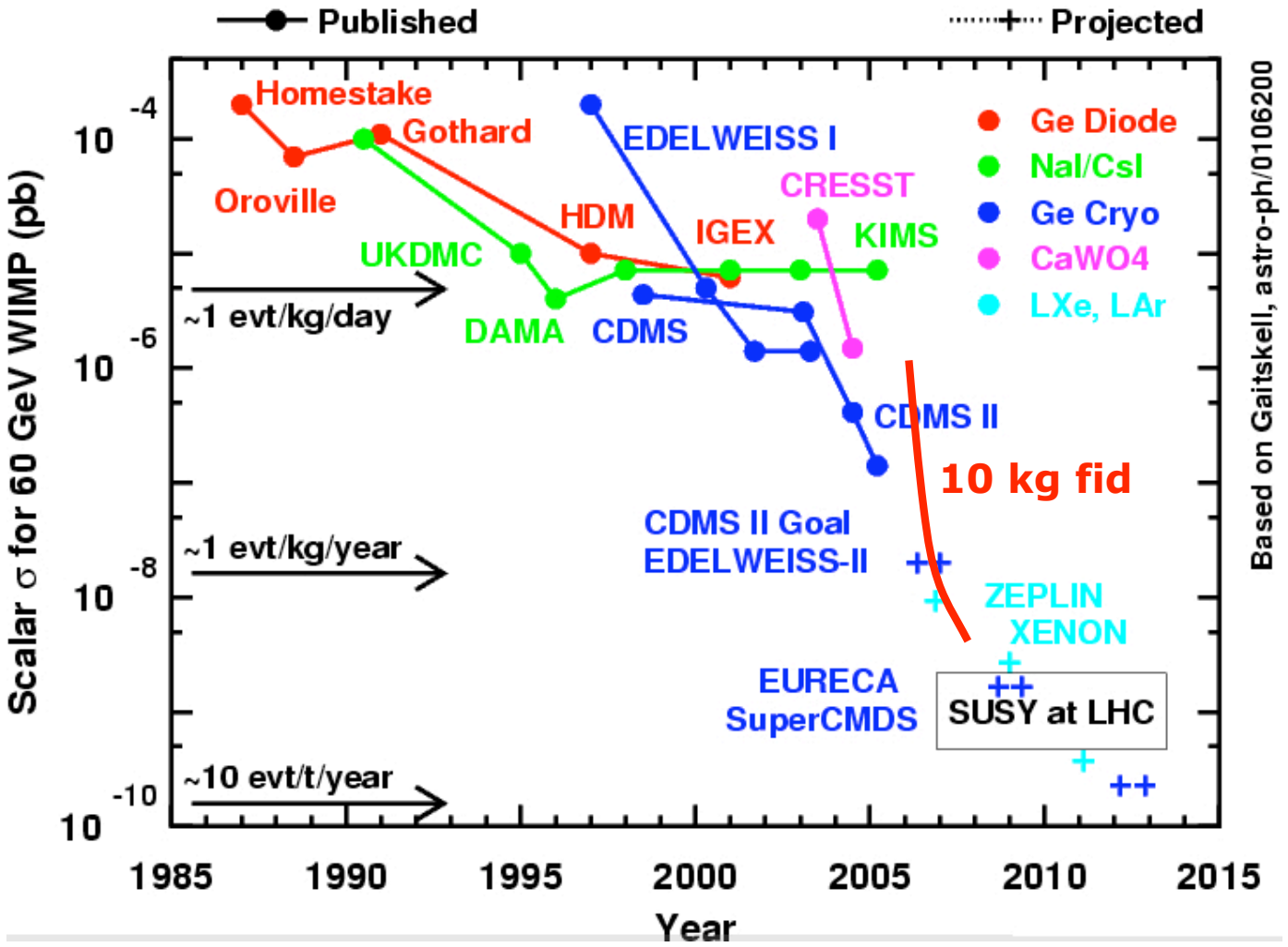
COUPP

- No gamma background
- Probe of alternative models

Evolution of direct searches



Evolution of direct searches



Conclusions

- The future is dark!
- Dark energy: new physics is there
- Dark matter:
  - Indirect searches: challenges to our understanding of galaxy dynamics, particle propagation in galactic medium, high-energy phenomena… lot's to learn!
  - Direct searches: maturity of cryogenic (bolometer) detectors, rapid growth of cryogenic (liquid) detectors. Alternative techniques also very active.
  - LHC startup may alter drastically the search context!