

# Astrofisica e particelle elementari

aa 2009-10

Lezione 12

Ricerca diretta di materia oscura

Antimateria primordiale

Decadimento del protone

Ricerca antimateria

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# Esperimenti per la ricerca diretta di materia oscura

# Strategia degli esperimenti per la rivelazione diretta

- **Soglia in energia nella regione del keV**, limitata in basso solo dal fondo.
- **Soppressione del fondo eccellente.** Uso di materiali a bassa radioattività, schermaggio efficiente in luoghi sotterranei, schermi attivi e passivi, discriminazione dei segnali elettrone/nucleo.
- **Grandi masse del bersaglio.**
- **Operatività stabile a lungo termine.**

# Metodi sperimentali

- **Rivelatori bolometrici.**  $T \approx 10\text{-}20$  mK, aumento della temperatura per effetto dell'interazione
  - CRESST (G. Sasso): 3Kg  $\text{CaWO}_4$ , fononi e luce
  - EDELWEISS (Frejus): 9 Kg Ge, fononi e ionizzazione
  - CDMS (Soudan): 250 g Si, fononi e ionizzazione
- **Rivelatori Xe/Ar.** Rivelazione della scintillazione e della ionizzazione in gas nobili liquefatti.
  - Xenon10 (G.Sasso): 10 Kg Xe
  - ZEPLIN (Boulby): 10 Kg Xe
  - WARP (G.Sasso) Ar
- **Rivelatori NaI.** Scintillazione dai cristalli di NaI.
  - DAMA (G.Sasso) 100 Kg NaI  $\Rightarrow$  250 Kg
- **Rivelatori a liquido sovrarisaldato.** Gocce sovrarisaldate disperse in gel subiscono nucleazione (cambiamento di fase in bolle gassose) per effetto del rinculo di un nucleo.
  - SIMPLE:  $\text{C}_2\text{ClF}_5$
  - PICASSO:  $\text{C}_4\text{F}_{10}$



# Carattere del segnale

- Modulazione annuale del segnale. cambiamento della velocità dei WIMP rispetto al rivelatore dovuto al moto della terra attorno al Sole e del Sole rispetto al centro della Galassia.
- Direzionalità. Distinzione del segnale rispetto al fondo terrestre con asimmetria avanti/indietro. Richiede un rivelatore capace di misurare la direzione del rinculo del nucleo, ovvero un rivelatore gassoso.
- Dipendenza dal bersaglio. Dipendenza dell'interazione del WIMP da diversi nuclei in frequenza e diversa forma dello spettro dell'energia di rinculo.

# RIVELAZIONE DIRETTA

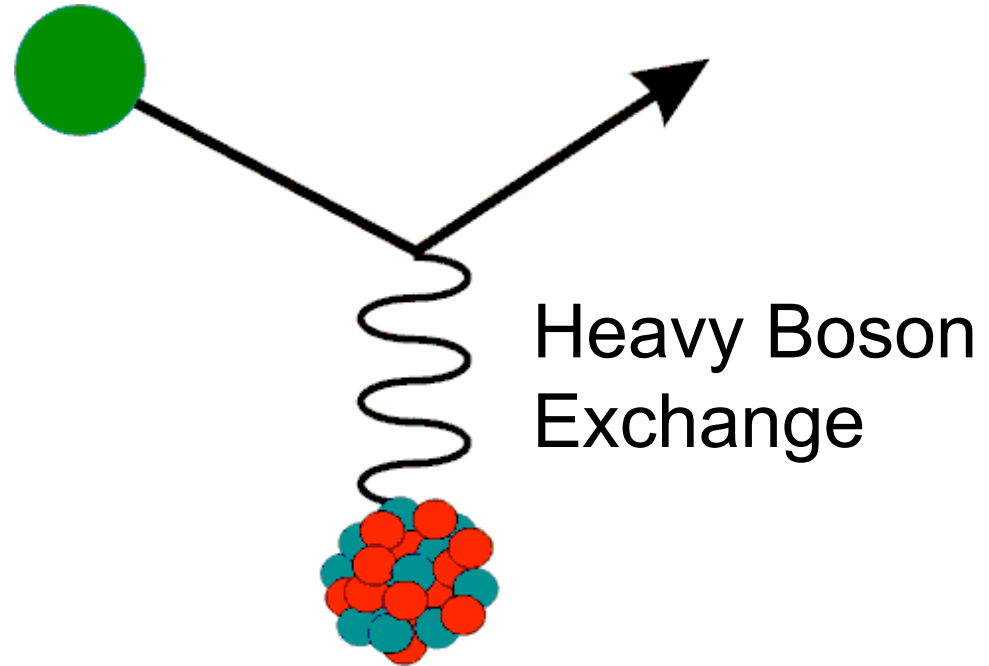
## WIMP

$$30 < M_W \text{ [GeV]} < 1000$$

$$46 < \lambda_W \text{ [fm]} < 1.4$$

$$v_{\text{rms}} \sim 270 \text{ km/s}$$

$$\rho_{\text{CDM}} \sim 0.3 \text{ GeV}/c^2 \text{ cm}^{-3}$$



$$E_R = E_0 \cdot \frac{4 M_W M_N}{(M_W + M_N)} \cdot \frac{1}{2} (1 - \cos \theta^*) \approx 0.4 \text{ keV} \cdot \frac{M_W}{\text{GeV}}$$

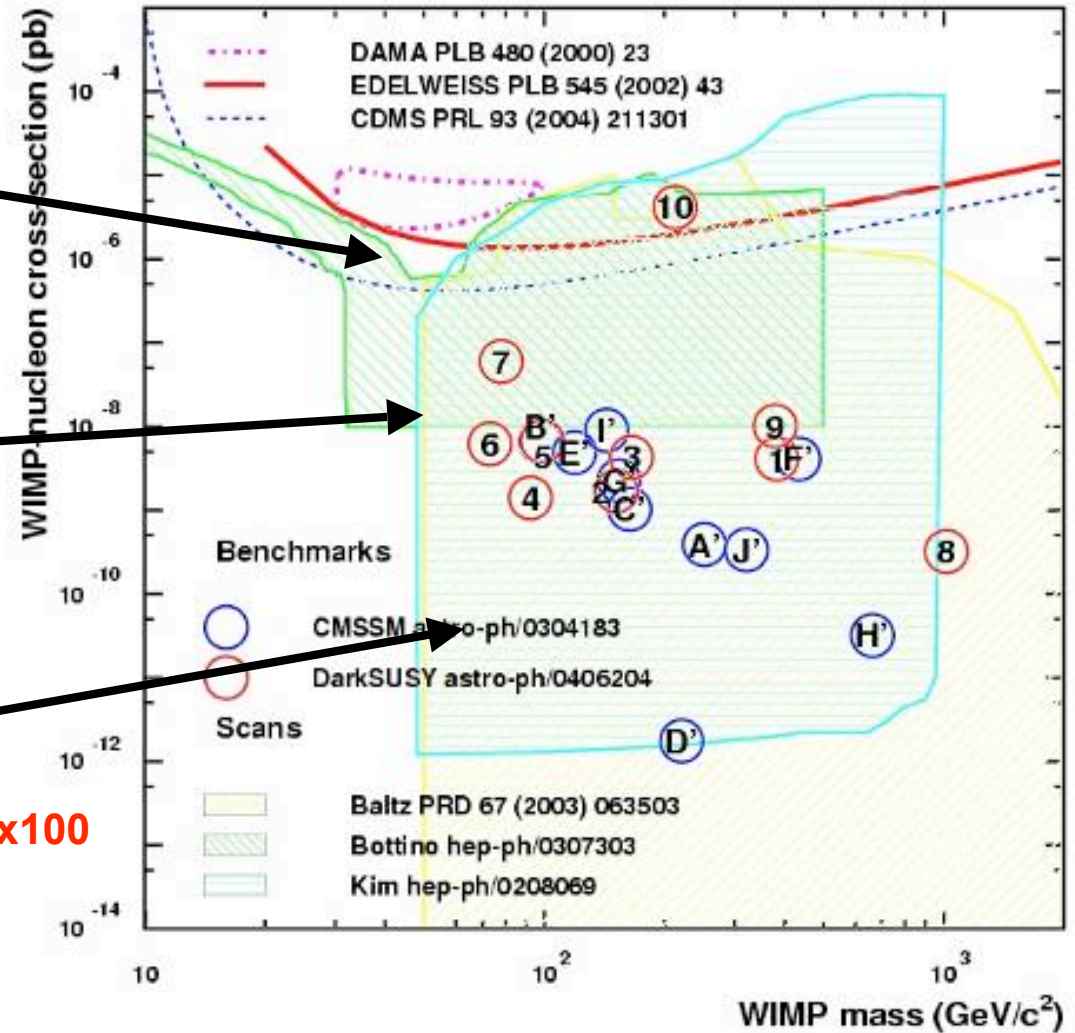
Direct detection via WIMP scattering by nuclei:  $E_R \sim$  tens of keV

# ESPERIMENTI - PREDIZIONE MSSM

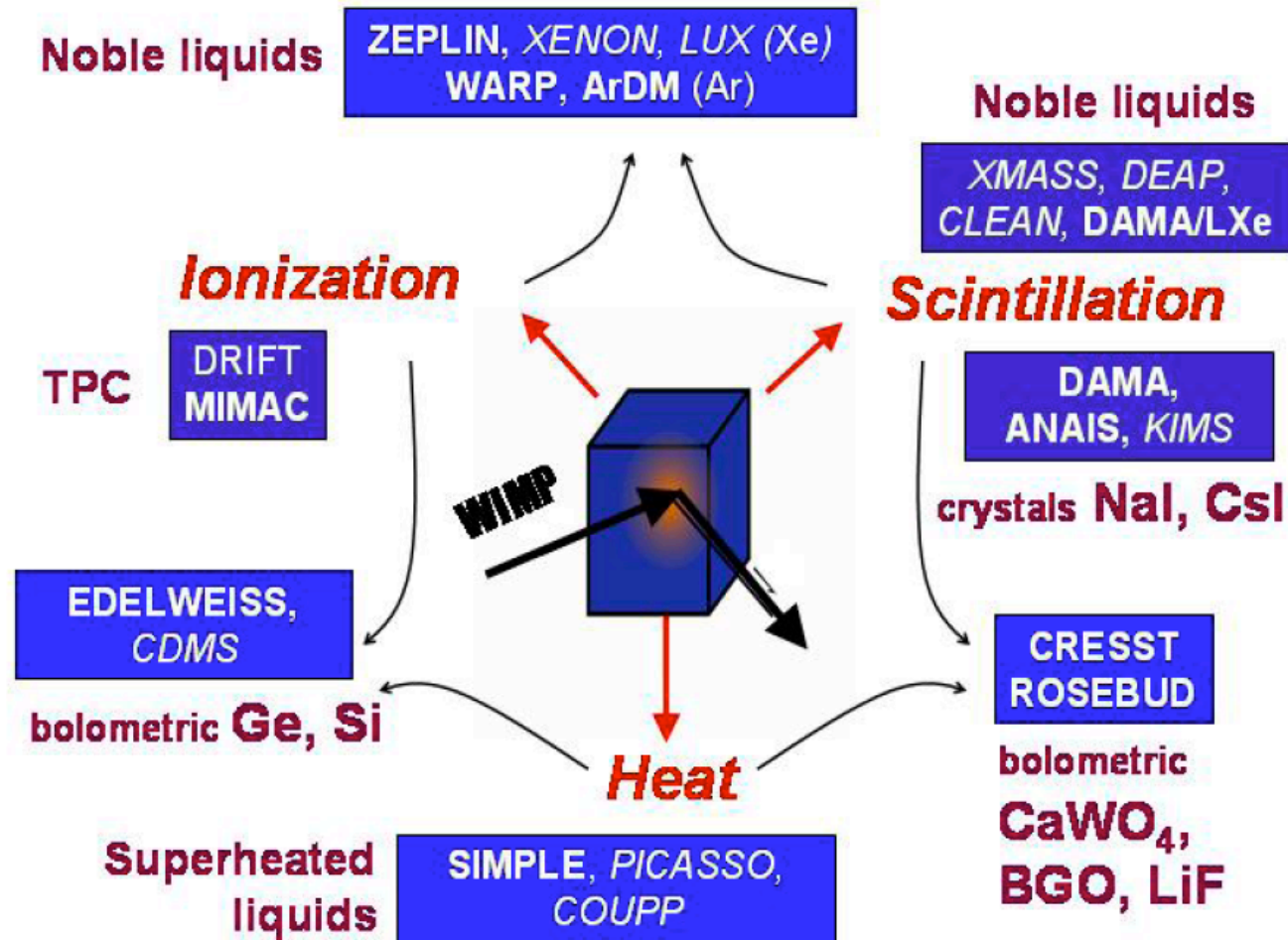
$\sigma = 10^{-6}$  pb:  
 ~1 event/kg/day  
 ~0.1 now reached

$\sigma = 10^{-8}$  pb:  
 ~1 event/kg/year  
 Aims of phase II experiments

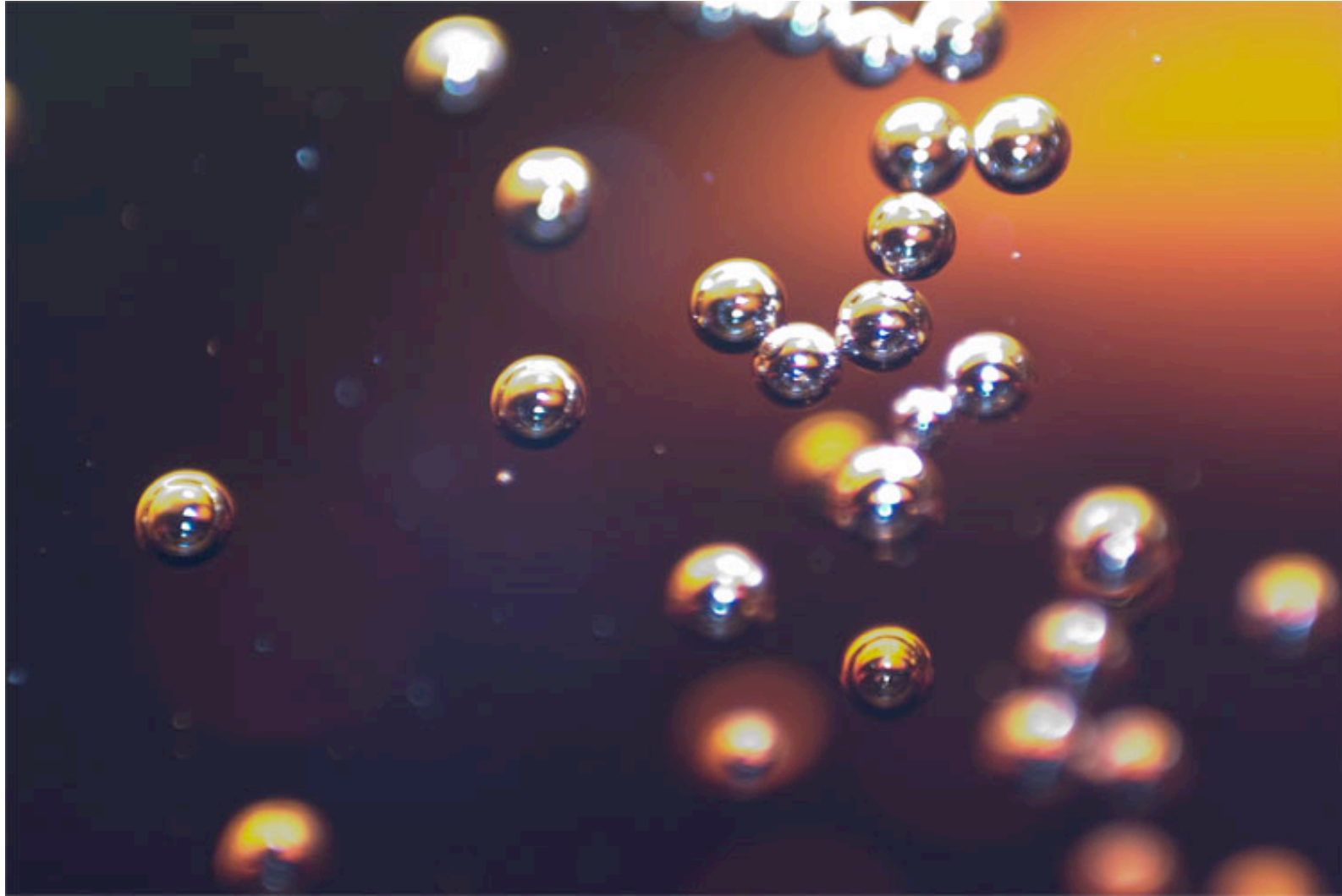
$\sigma = 10^{-10}$  pb:  
 ~1 event/ton/year  
 Next generation requires further x100 improvement!



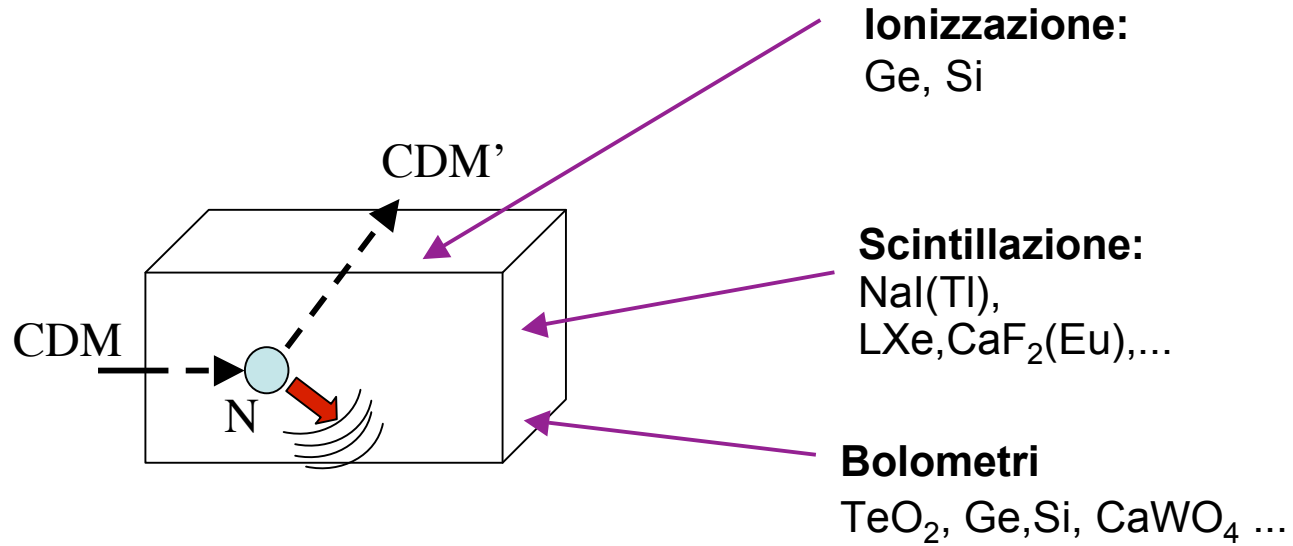
# Metodi sperimentali per la ricerca diretta



# Nucleazione di bolle di soda per effetto della diminuzione della pressione esterna

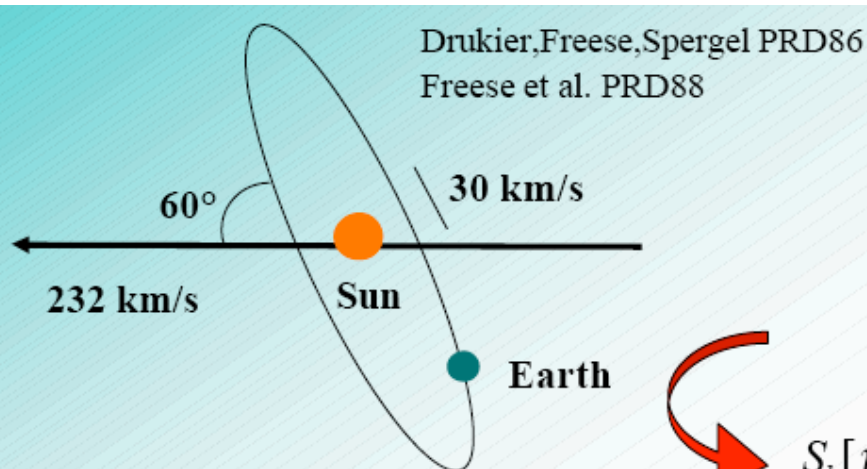


# RIVELAZIONE DIRETTA





# MODULAZIONE ANNUALE DEI CONTEGGI



- $v_{\text{sun}} = 232 \text{ km/s}$  (Sun velocity in the halo)
- $v_{\text{orb}} = 30 \text{ km/s}$  (Earth velocity around the Sun)
- $\gamma = \pi/3$
- $\omega = 2\pi/T$       $T = 1 \text{ year}$
- $t_0 = 2^{\text{nd}} \text{ June}$  (when  $v_{\oplus}$  is maximum)

$$v_{\oplus}(t) = v_{\text{sun}} + v_{\text{orb}} \cos\gamma \cos[\omega(t-t_0)]$$

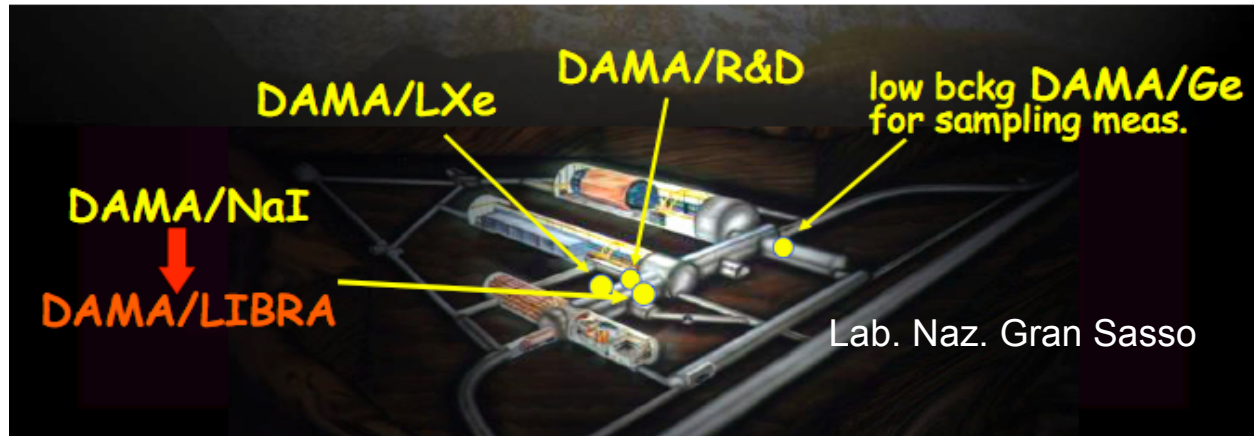
$$S_k[\eta(t)] = \int_{\Delta E_k} \frac{dR}{dE_R} dE_R \cong S_{0,k} + S_{m,k} \cos[\omega(t-t_0)]$$

Expected rate in given energy bin changes because the annual motion of the Earth around the Sun moving in the Galaxy

## *Requirements of the annual modulation*

- 1) Modulated rate according cosine
- 2) In a definite low energy range
- 3) With a proper period (1 year)
- 4) With proper phase (about 2 June)
- 5) For single hit in a multi-detector set-up
- 6) With modulated amplitude in the region of maximal sensitivity  $< 7\%$

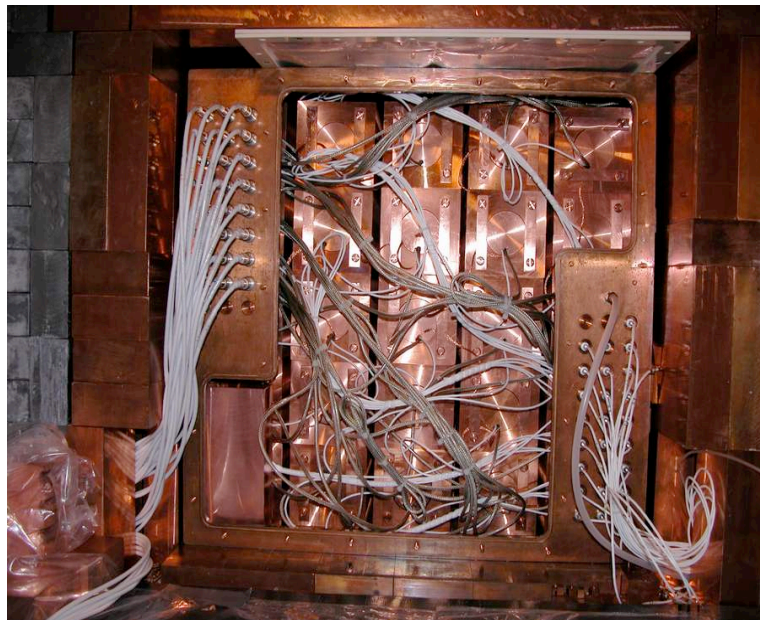
# Ricerca diretta - DAMA



- Detector a scintillazione, 100 Kg di NaI(Tl) (7 anni) + 250 Kg di NaI(Tl) (6 anni)
  - Reduced standard contaminants by material selection and growth/handling protocols.
  - Each crystal coupled - through 10cm long tetrasil-B light guides acting as optical windows - to 2 low background EMI9265B53/FL (special development) 3" diameter PMTs working in coincidence.
  - Very low radioactive shields: 10 cm of copper, 15 cm of lead + shield from neutrons: Cd foils + 10/40 cm polyethylene/paraffin + ~ 1 m concrete moderator largely surrounding the set-up
  - Walls, floor, etc. of inner installation sealed by Supronyl ( $2 \cdot 10^{-11}$  cm<sup>2</sup>/s permeability).
  - Each PMT works at single photoelectron level. Energy threshold: 2 keV (from X-ray and Compton electron calibrations in the keV range and from the features of the noise rejection and efficiencies)



# Costruzione di DAMA/Libra

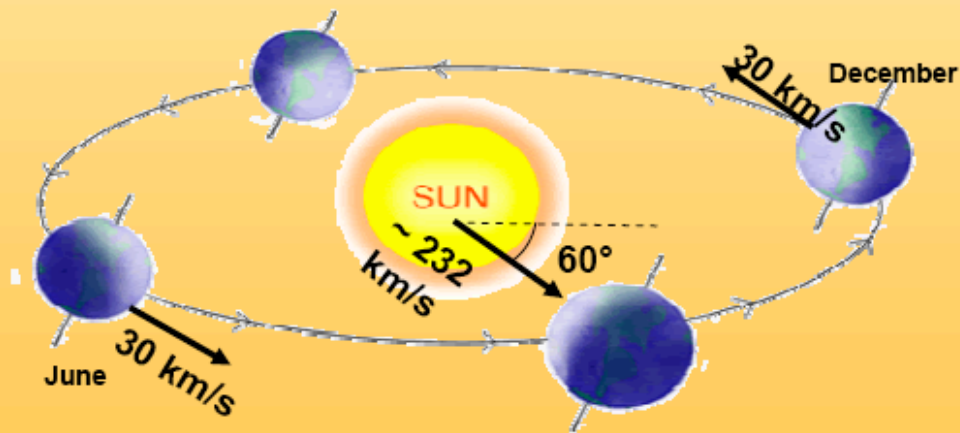


## Experimental *single-hit* residuals rate vs time and energy

- Model-independent investigation of the annual modulation signature has been carried out by exploiting the time behaviour of the residual rates of the *single-hit* events in the lowest energy regions of the DAMA/LIBRA data.
- These residual rates are calculated from the measured rate of the *single-hit* events (obviously corrections for the overall efficiency and for the acquisition dead time are already applied) after subtracting the constant part:



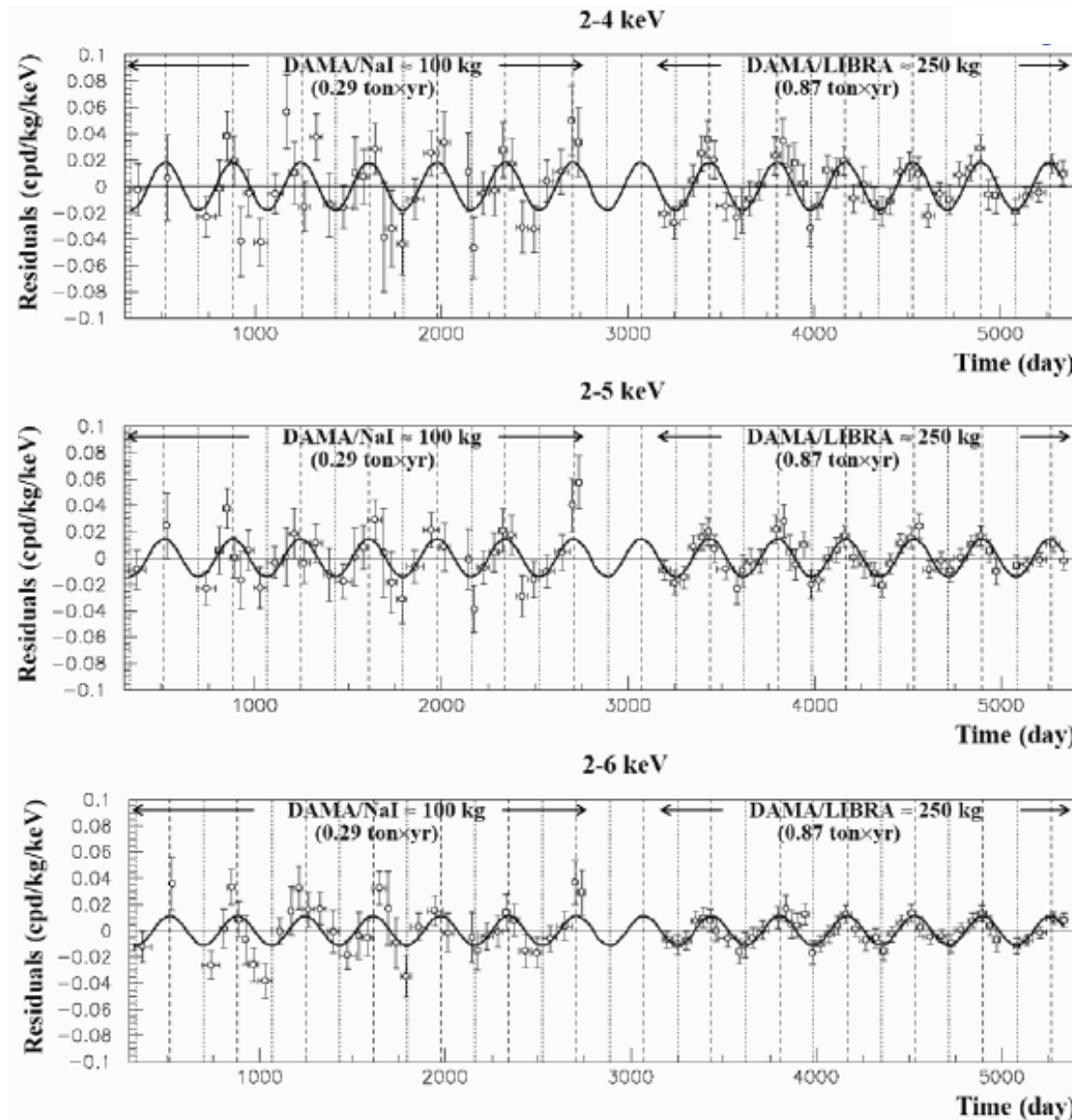
$$\langle r_{ijk} - flat_{jk} \rangle_{jk}$$



- $r_{ijk}$  is the rate in the considered  $i$ -th time interval for the  $j$ -th detector in the  $k$ -th energy bin
- $flat_{jk}$  is the rate of the  $j$ -th detector in the  $k$ -th energy bin averaged over the cycles.
- The average is made on all the detectors ( $j$  index) and on all the energy bins ( $k$  index)
- The weighted mean of the residuals must obviously be zero over one cycle.



# Modulazione annuale



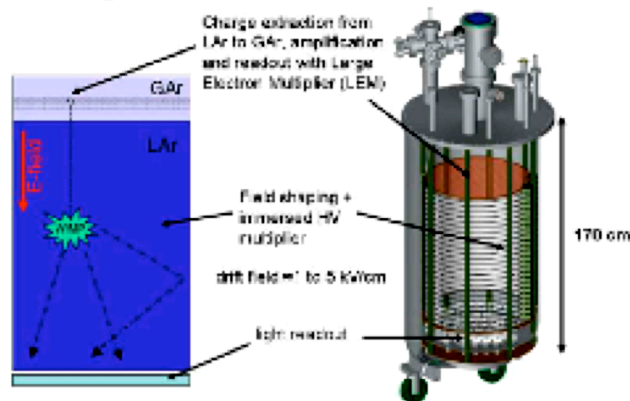
8.3  $\sigma$  CL

9.0  $\sigma$  CL

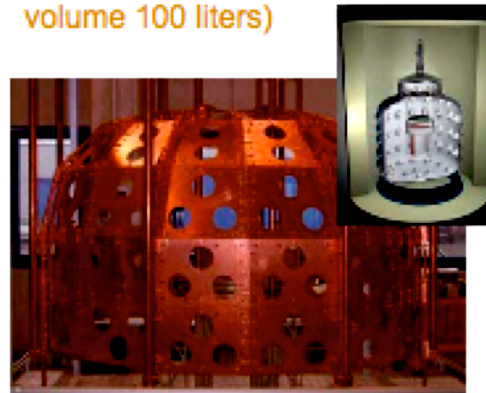
8.8  $\sigma$  CL

# Ricerca diretta - esperimenti in fase di realizzazione

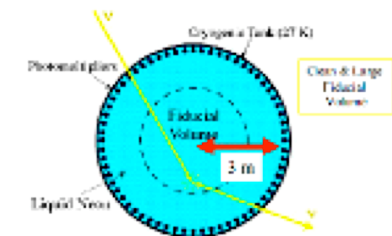
## ArDM: ton scale dual-phase Argon detector



## WARP: double phase Argon detector at LNGS (fiducial volume 100 liters)

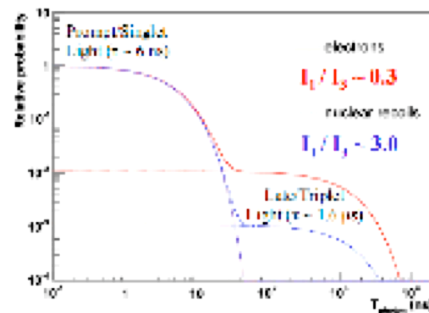


## CLEAN: Cryogenic Low Energy Astrophysics with Neon

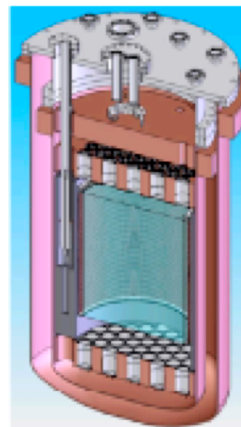


## Single phase liquid Neon detector of tens of tons

## DEAP (SNOLAB): scintillation light in LAr at 85K → PSD studying different lifetimes in singlet/ triplet states for electrons and nuclear recoil (ton scale)



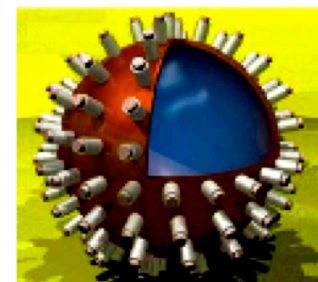
## Lux: dual phase time projection chamber with 100 kg LXe (tot: 300 kg)



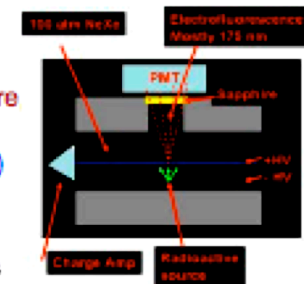
## SIGN: A High-Pressure, Room-Temperature Gaseous-Neon-Based Underground Physics Detector (100 kg @ 100 atm towards 10 tons)

### XMASS

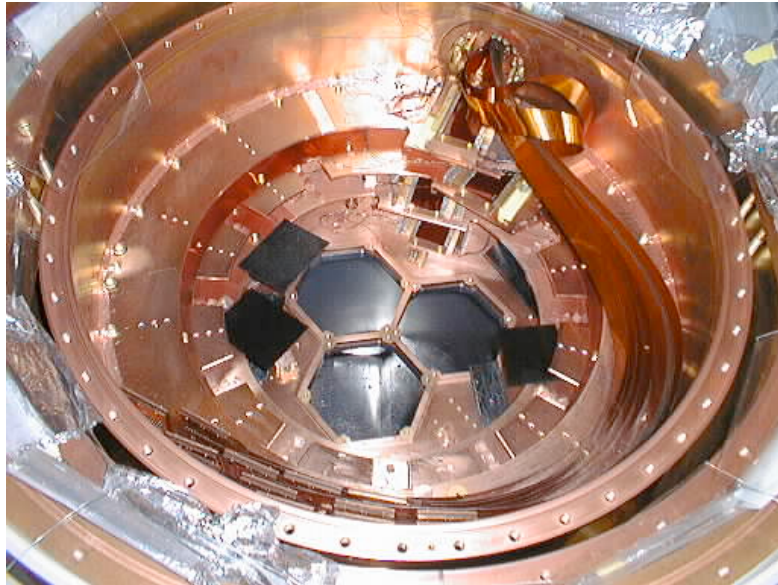
Solar  $\nu$ : Xenon **MASS**ive detector for Solar neutrinos  
 Dark M: Xenon detector for weakly interacting **MASS**ive Particles  
 $\beta\beta$ : Xenon neutrino **MASS** detector



- 10 ton liquid Xe
- 1350 3-in PMTs
- solar neutrinos by  $\nu + e \rightarrow \nu + e$
- $\sigma_{\nu\beta\beta} \sim 3.3 \times 10^{25} \text{ yr}^{-1} (\text{Syr})$   
( $\langle m_{\nu} \rangle < 0.05\text{--}0.09 \text{ eV}$ )
- 30 DM events for 100 GeV  $10^8 \text{ pb SI}$  for proton



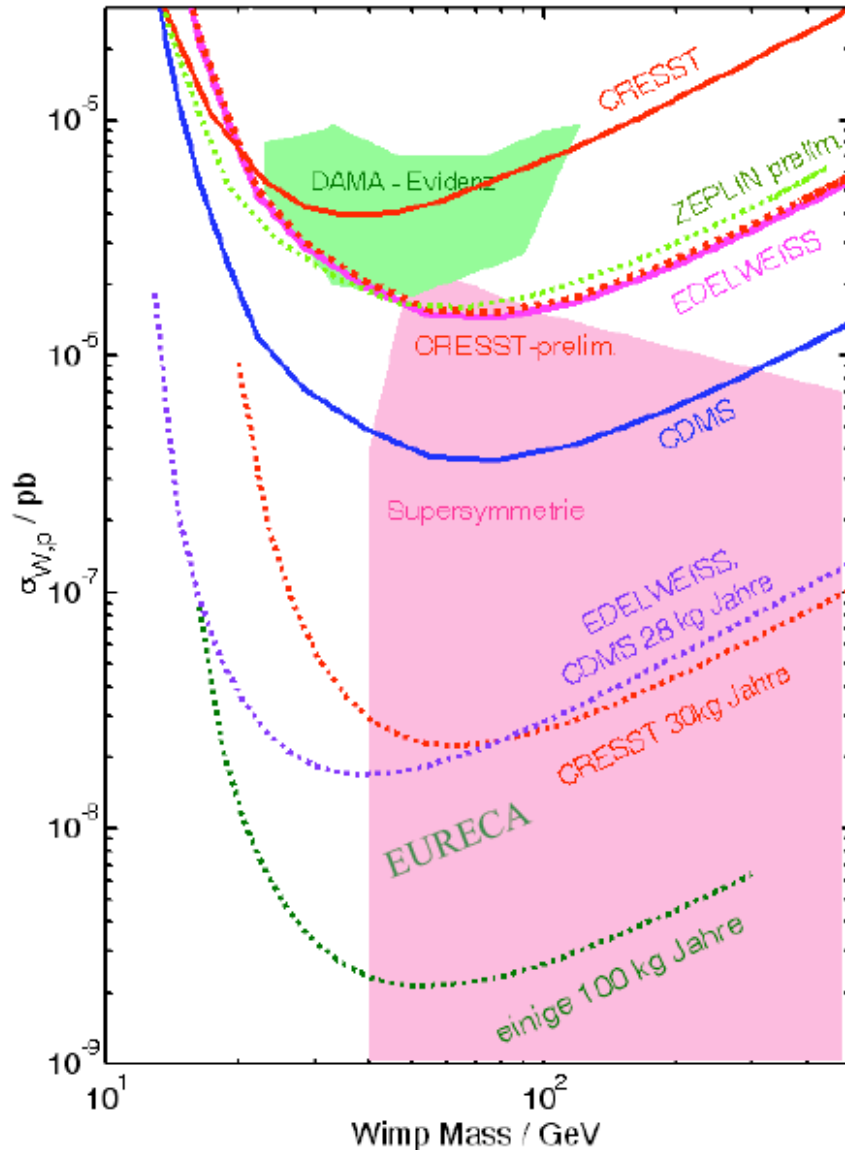
# CDMS II



\* A view of the inner layers of the cryostat. The hexagonal holes are the mounting points for the detector assembly and sits at 10 mK during operation. The surrounding layers are higher temperature stages of the cryostat. The cryostat is one-of-a-kind and was designed and built by the LBNL-UCB team. It is constructed entirely of radiopure copper to provide a low-radioactivity environment for the extremely sensitive CDMS detectors. The grey-black layer is a shield made of lead recovered from the ballast of a 18th-century French ship; the age of this lead ensures that the radioisotopes most worrying to CDMS have decayed away. In recent weeks, a polyethylene shield has been installed inside the lead layer; this new shield will attenuate the neutron flux by  $\sim 2.5$  while allowing WIMPs to pass through. The observation of a reduced event rate after installation of this new shield will prove conclusively that CDMS detectors are seeing neutrons, not WIMPs.

\* Closeup of a ZIP detector in its mount. A detector of this kind, made of Si, was operated in the 1998 run. The photolithographically-fabricated thin film on the surface is the phonon sensor and represents a significant advance over the detectors used in the 1999 run. Silicon and germanium ZIPs, weighing 100 g and 250 g respectively, will be used in future CDMS II runs at Stanford and in the Soudan mine.

# Limiti alla sezione d'urto per WIMP



- Limite alla sezione d'urto scalare WIMP-nucleone (curva blu continua). Nessun candidato in 19.4 kg · d di esposizione effettiva di Ge. Lo spazio dei parametri al di sopra della curva è escluso al 90% C.L. Il risultato è stato ottenuto da CDMS II in Soudan.
- Il risultato di DAMA è indicato dalla regione chiusa verde.
- La curva con x è il limite ottenuto da EDELWEISS
- Le curve punteggiate sono i limiti previsti per esperimenti futuri.



	DAMA/NaI	CDMS-II	Edelweiss-I	Zeplin-I	Cresst-II
Signature	annual modulation	none	none	none	none
Targets	$^{23}\text{Na}$ , $^{127}\text{I}$	$^{\text{nat}}\text{Ge}$	$^{\text{nat}}\text{Ge}$	$^{\text{nat}}\text{Xe}$	$\text{CaWO}_4$
Technique	widely known	poorly experienced	poorly experienced	liq/gas optical interface	poorly experienced
Target mass	$\approx 100$ kg	0.75 kg	0.32 kg	$\approx 3$ kg	$\approx 0.6$ kg
Exposure	$\sim(1.1 \times 10^5)$ kg $\times$ day (RivNCim 26 n1(2003)1-73)	19.4 kg $\times$ day (astro-ph/0405033)	30.5 kg $\times$ day (NDM03)	280 kg $\times$ day (Moriond03)	20.5 kg $\times$ day (astro-ph/0408006)
Expt. depth	1400 m	780 m	1700 m	1100 m	1400 m
Neutron shield	$\sim 1$ m of concrete + 10/40 cm polyethylene/paraffin 1.5 mm Cd	50 cm polyethylene	30 cm paraffin	---	none
Energy threshold	2 keVee (5.5 - 7.5 p.e./keV)	10 keVee	20 keVee	2 keVee (but: $\sigma/E=100\%$ and 1 p.e./keVee!!!; IDM02) (2.5 p.e./keVee; Moriond03)	12 keVee
Quenching factor	measured	assumed 1	assumed 1 (see also NIMA507(2003)643)	measured	assumed 1
Measured evt rate in low energy range	$\sim 1$ cpd/kg/keV	?? (claimed $\gamma >$ than CDMS-I where $\sim 60$ cpd/kg/keV, $10^5$ events)	$\sim 10^4$ events total	$\sim 100$ cpd/kg/keV (IDM02)	(??) 6 cpd/kg/keV above 35 keVee
Claimed evts after rejection procedures		0 or 1	2 (claimed taken in a noisy period!)	$\sim 20-50$ cpd/kg/keV after filtering (Moriond03, IDM02)	16
Evts satisfying the signature in DAMA/NaI	modulation amplitude integrated over the given exposure some $10^3$ evts	insensitive	insensitive	insensitive	insensitive

# Esperimenti in corso e in progetto

Name	Type	Status	Location	European Members	Others
DAMA/ LIBRA	NaI	running	LNGS	IT	China
ANAIS	NaI	construction	LSC	ES	-
KIMS	CsI	R&D	Korea	-	Korea
HDMS	Ge	running	LNGS	DE	RU
ROSEBUD	bolometer	R&D	LSC	ES, FR	-
DAMA-LXe	LXe scint	running	LNGS	IT	China
ZEPLIN-II	LXe	running	IUS	PT, UK	RU, US
ZEPLIN-III	LXe	installation	IUS	PT, UK	RU, US
XENON10	LXe	commissng	LNGS	DE, IT, PT	US
LUX	LXe	R&D	DUSEL	UK	US
XMASS	LXe	?	Kamioka	-	Japan
WARP	LAr	running	LNGS	IT	US
ArDM	LAr	construction	LSC	CH, ES, PO	-
DEAP	LAr	R&D	SNOLAB	-	Can, US
CLEAN	LNe	R&D	t.b.d.	-	US, Can
DRIFT	CS <sub>2</sub> gas TPC	R&D	IUS	UK	US
MIMAC	<sup>3</sup> He gas TPC	R&D	t.b.d.	FR	-
EDELWEISS	bolometer	running	LSM	FR, DE	RU
CRESST	bolometer	running	LNGS	DE, UK, IT,	-
CDMS	bolometer	running	Soudan	-	US
SIMPLE	Superheated droplet SHD	running + R&D	LSSB	PT, FR	US
PICASSO	SHD	running + R&D	SNOLAB	CZ	CA, RU, US
COUPP	SH liquid	R&D	t.b.d.	-	US

IUS - Boulby/UK

LNGS - Gran Sasso/Italia

LSM - Frejus/Francia

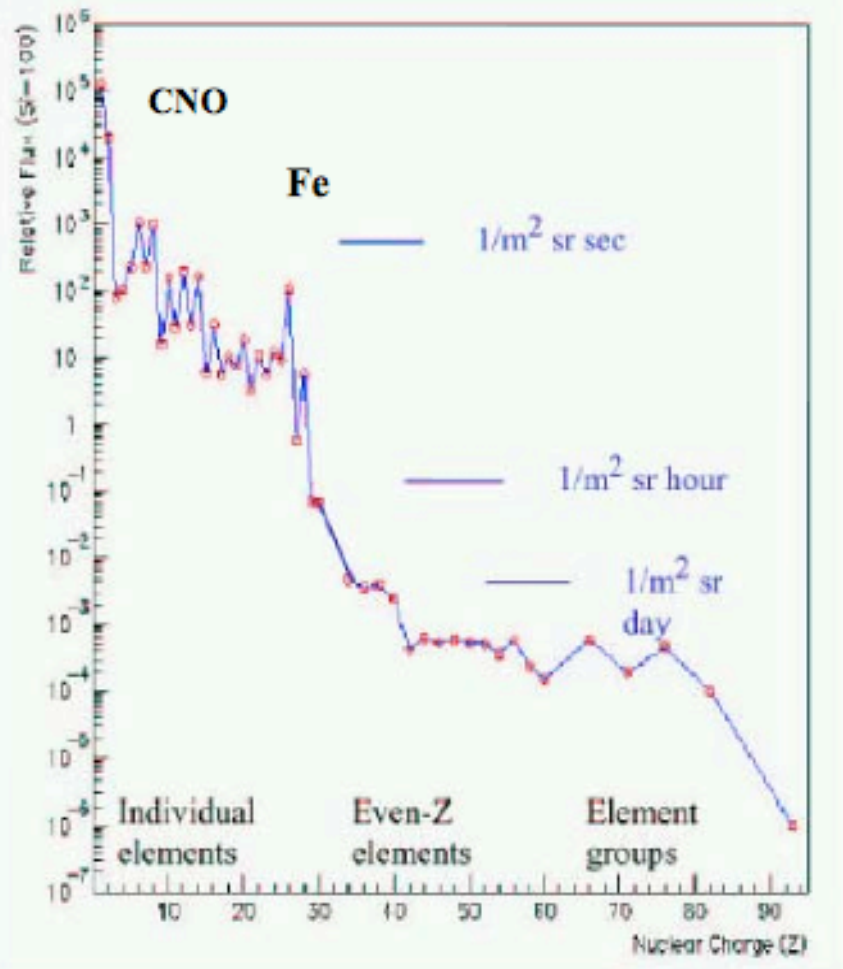
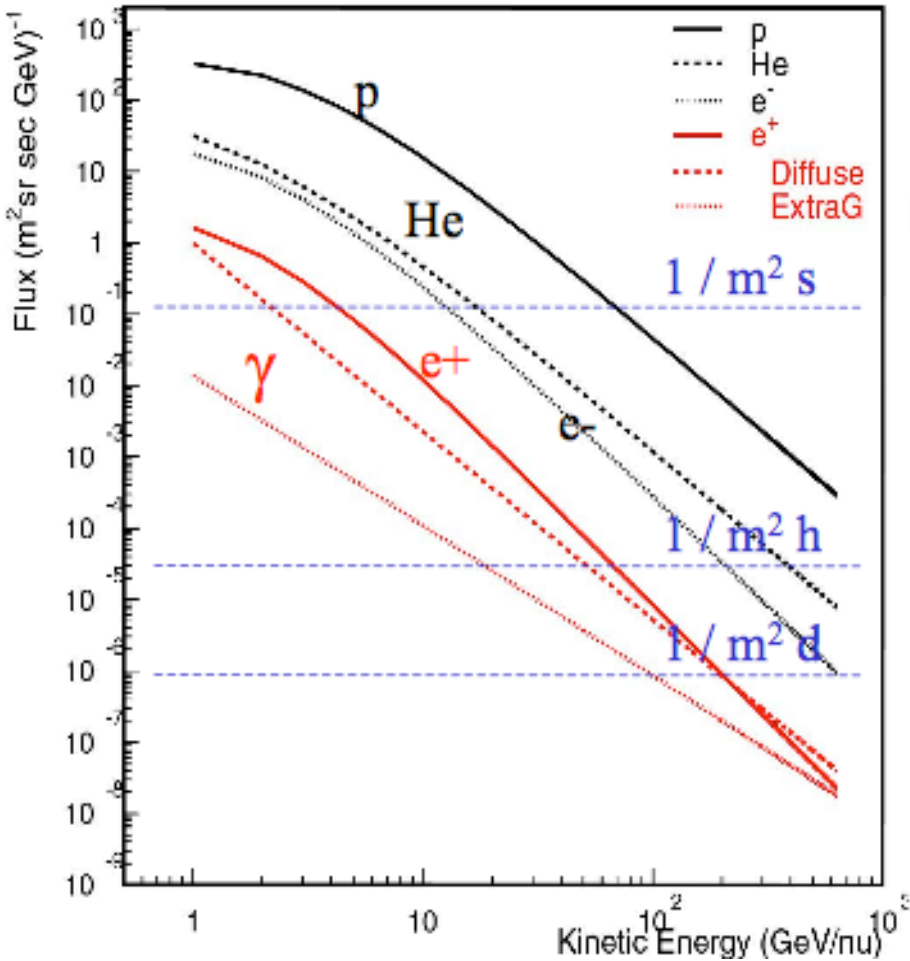
LSC - Canfranc/Spagna

LSSB - Bas Bruit/Francia



# Ricerca di Antimateria

# RC: particelle e nuclei



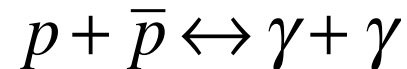
# ANTIMATERIA

L'ipotesi del Big Bang è in accordo con

- l'espansione dell'universo
- la nucleosintesi primordiale
- la radiazione cosmica di corpo nero

L'assenza di antimateria non ha un fondamento certo secondo le conoscenze attuali.

Nell'universo primitivo quando  $kT > m_{\text{adroni}}$



Barioni, antibarioni e fotoni si trovavano in equilibrio termico.

Con l'espansione e il raffreddamento, i fotoni anche nella coda dello spettro di radiazione di corpo nero non hanno energia per creare coppie di nucleoni-antinucleoni. La densità di p e anti-p è così bassa che non si annichilano più. La temperatura critica è  $kT \approx 20 \text{ MeV}$ .

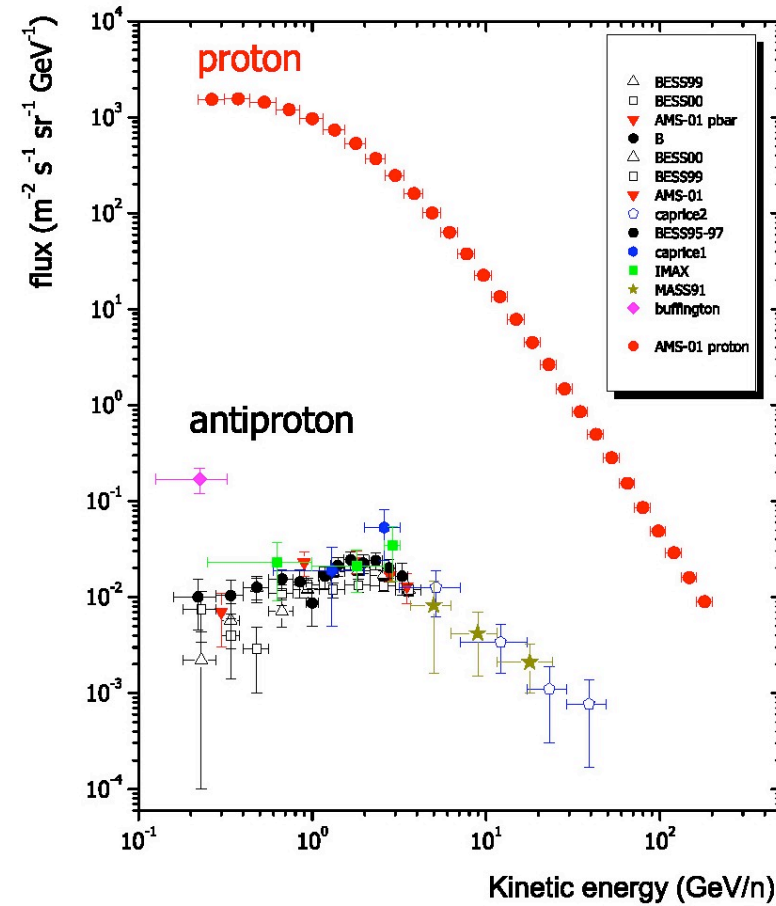
La densità di barioni e antibarioni susseguente, rispetto alla densità di fotoni, si mantiene costante e si calcola

$$\frac{N_B}{N_\gamma} = \frac{N_{\bar{B}}}{N_\gamma} \approx 10^{-18}$$

# ANTIMATERIA?

Al contrario i rapporti sperimentali sono

$$\frac{N_B}{N_\gamma} \approx 10^{-9}; \quad \frac{N_{\bar{B}}}{N_B} < 10^{-4}$$



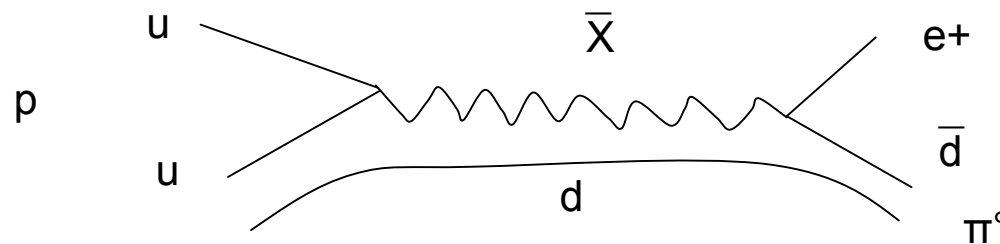
$$\frac{\Phi_{\bar{p}}}{\Phi_p} \sim 10^{-4} - 10^{-5}$$

# BARIOGENESI

Le condizioni per ottenere asimmetria materia/antimateria (Sakharov 1967), sono:

- violazione del numero barionico; *limite vita media del  $p > 10^{33}$  anni*
- deviazione dall'equilibrio termico nel plasma primordiale; possibile e favorevole se  $T \approx m$
- violazione di C e CP; *misurata nel decadimento del K e del B.*

GUT (Grand Unified Theories), ad esempio SUSY, forniscono un meccanismo diretto per la violazione di B tramite lo scambio di un bosone supersimmetrico X:



# BARIOGENESI - GUT

- E' permessa la violazione del numero barionico B e del numero leptonico L in modo tale che la carica totale sia conservata,  $(B-L) = \text{cost}$
- I bosoni supersimmetrici X e Y presenti alla scala temporale  $t = 10^{-40}$  s decadono in due ipotetici canali con barioni  $B_1$  e  $B_2$ .
- Siano  $x$  e  $\bar{x}$  i rapporti di decadimento di X e  $\bar{X}$  in  $B_1$
- Si ha
 

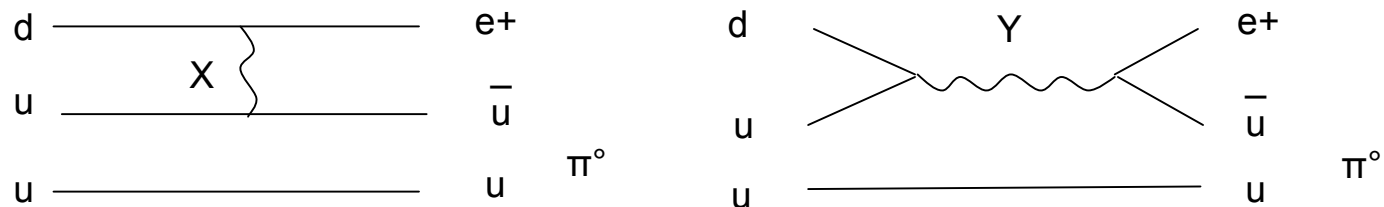
$X \rightarrow xB_1$	$X \rightarrow (1-x)B_2$
$\bar{X} \rightarrow \bar{x}B_1$	$\bar{X} \rightarrow (1-\bar{x})B_2$
- L'asimmetria barionica sar  quindi

$$A = xB_1 - \bar{x}B_1 + (1-x)B_2 - (1-\bar{x})B_2 = (x - \bar{x})(B_1 - B_2)$$

- La violazione di B assicura  $B_1 \neq B_2$
- La violazione di CP assicura  $\bar{x} \neq x$

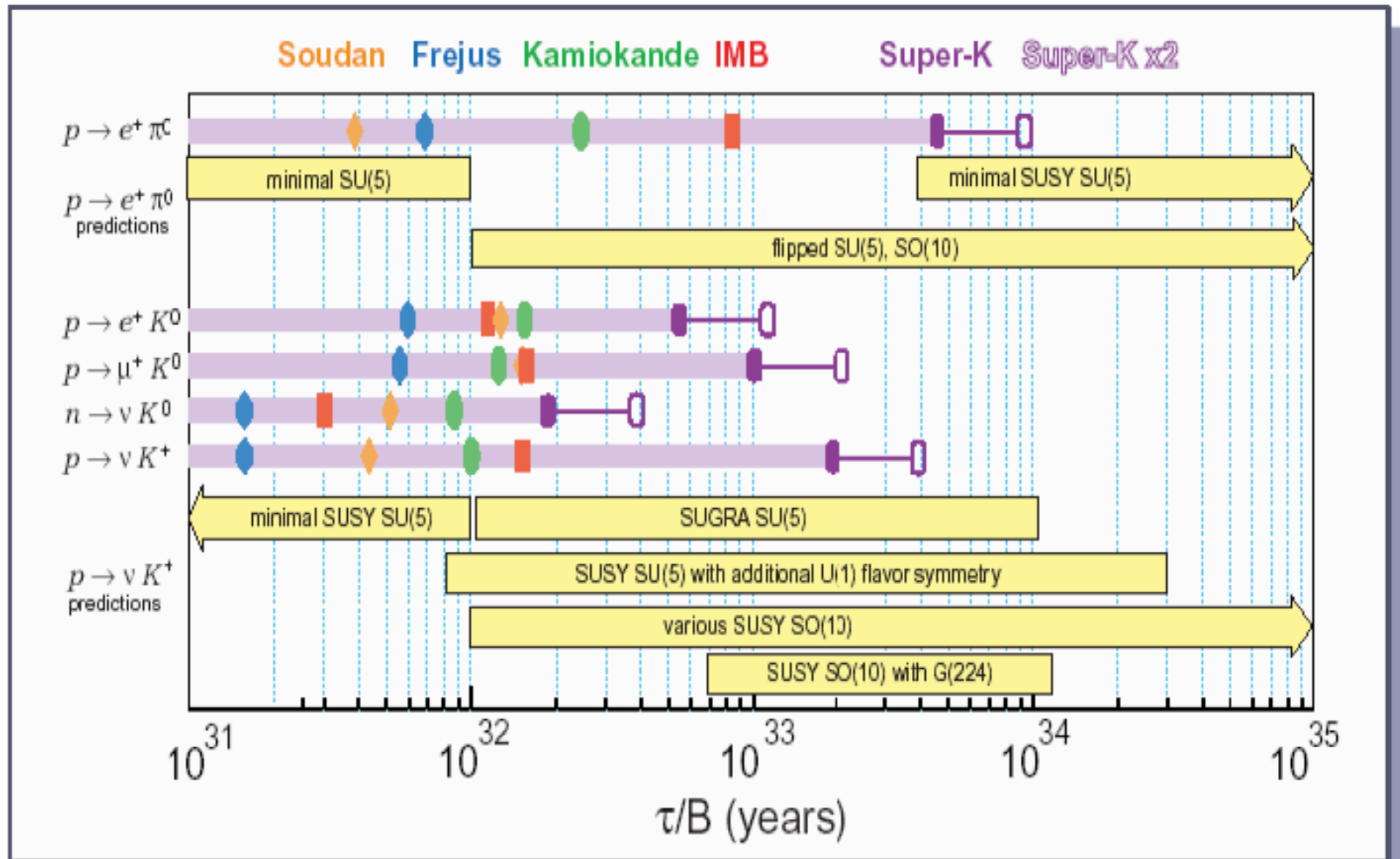
# Decadimento del protone

- Nelle teorie Grandi Unificate, SU(5), SUSY, è possibile il decadimento del protone, dovuto al raggruppamento dei quark e leptoni in una simmetria più ampia.
- In SU(5) i quark e leptoni possono trasformarsi gli uni negli altri per mezzo dello scambio di *leptoquark*, bosoni pesanti X e Y.



- Poiché il tempo di decadimento scala approssimativamente con  $\tau \approx M^4/m_p$ , dove M è la massa del leptoquark alla scala di Planck, SU(5) suggerisce una vita media di  $10^{31} - 10^{33}$  anni.
- Modelli basati sulle supersimmetrie predicono vite medie inferiori ma anche dell'ordine di  $10^{35}$  anni.

# Decadimento del protone





# Violazione di CP nel mesone B

**Belle experiment observes a difference in direct CP-asymmetry between charged and neutral B meson decays**

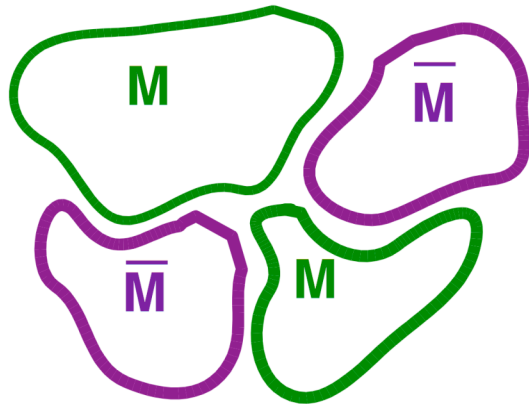
The Belle collaboration, an international research group working at the KEKB accelerator of High Energy Accelerator Research Organization (KEK) in Japan, observed a difference between direct charge-parity (CP) asymmetries for charged and neutral B meson decays into a kaon and a pion. Although it is susceptible to strong interaction effects, this difference could be an indication of a new source of CP violation that is needed to explain the matter-dominated Universe. The Belle result has been accepted for publication by Nature.

Equal amounts of matter and antimatter were expected to be produced after the Big Bang, but our Universe is clearly matter-dominated. One of the prerequisites to explain the absence of antimatter is the violation of CP symmetry, a difference in the elementary properties of matter and antimatter. So far CP violation has been established only in the  $K^0$  and  $B^0$  meson systems, with larger effects in the latter. However, experimental results are still consistent with the mechanism proposed by Kobayashi and Masakawa, which has a unique source of CP violation that is known to be too small to explain the elimination of antimatter.

Since the effect of CP violation is very small, large quantities of data are needed to search for CP violation. In the early 21st century two experiments were dedicated to this purpose: the Belle experiment at KEK and the BaBar experiment at the Stanford Linear Accelerator Center in the USA.

Quanta antimateria esiste nell'”universo”?  
Modelli di “antibariogenesi” ?

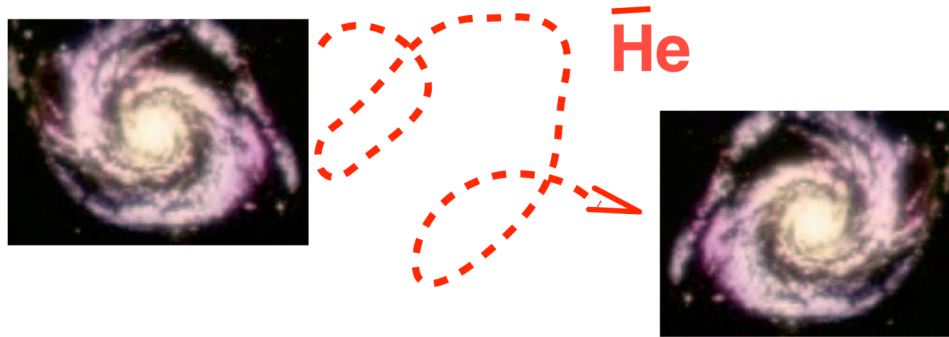
L'universo è simmetrico in materia-antimateria?



L'assenza di radiazione di  
annichilazione  $p + \bar{p} \rightarrow \gamma + \gamma$   
nei cluster di galassie di dimensioni  
tipiche  $d \approx 20$  Mpc  
indica che i cluster sono gli oggetti di  
dimensioni più grandi che non  
possono contenere quantità  
significative di antimateria

# Trasporto antimateria

Il campo magnetico intergalattico e gli effetti del vento magnetico introducono incertezze sul calcolo della propagazione di antimateria.

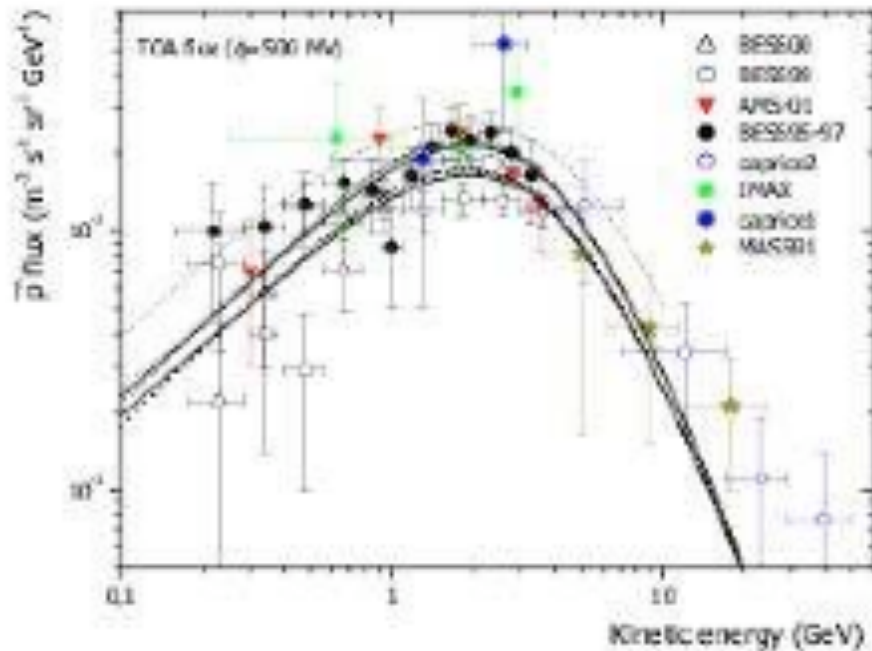


rigidità:  $R = p_{\perp}/Ze$

raggio di curvatura  
 $r = p_{\perp}/ZeB = R/B$

L'osservazione di antinuclei con grande *rigidità* è più promettente, perché ci potrebbe essere un cut-off magnetico.

# CALCOLO DEL FONDO



Antinuclei sono prodotti nelle interazioni dei RC con la materia interstellare.

Calcolo antiprotoni: Duperray et al. (astro-ph/0503544)

Gli antiprotoni non sono un buon segnale della presenza di antimateria primordiale.

Nel caso di antielio il rapporto è

$$(\bar{\text{He}}/\text{He})_{\text{fondo}} < 10^{-12}$$

# Come rivelare l'antimateria

apparato sperimentale:

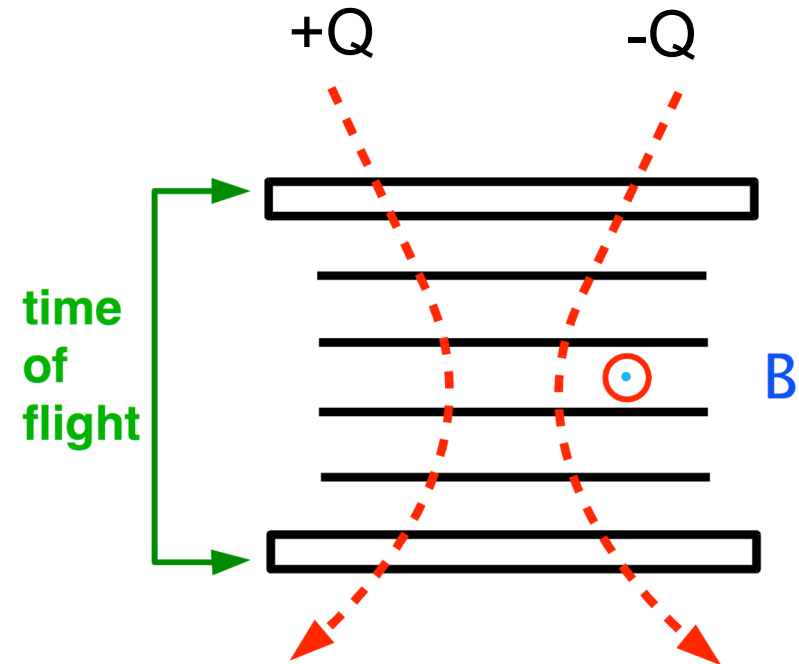
1. campo magnetico B
2. tracciatore
3. tempo di volo

$p = m\gamma v$  dal raggio di curvatura

$v = d/\Delta t$  dal tempo di volo

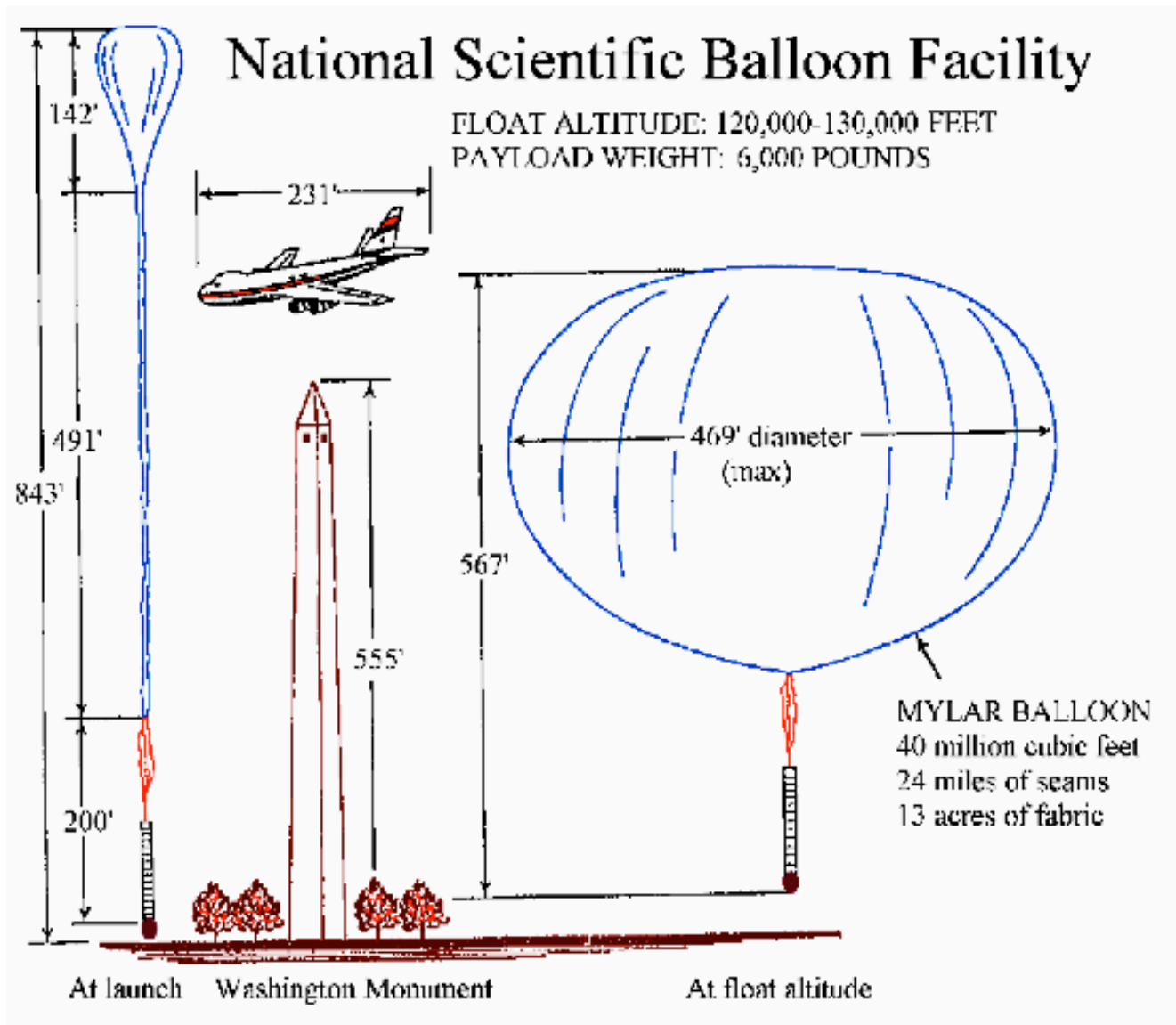
$Q$  da  $dE/dx$ , ionizzazione

$\pm Q$  da direzione della curvatura



$m \pm Q$  identificano particella  
o antiparticella

# ESPERIMENTI SU PALLONE







# BESS



BESS-Polar, is similar in design to previous BESS instruments, but is completely new with an ultra-thin magnet developed at the High Energy Accelerator Research Organization (KEK) and configured to minimize the amount of material in the cosmic ray beam, so as to allow the lowest energy measurements of antiprotons.

BESS-Polar has the largest geometry factor of any balloon-borne magnet spectrometer currently flying, and is ideally suited to statistics-limited studies of  $Z=1$  and  $Z=2$  components - identifying antiprotons, and searching for antihelium nuclei in the cosmic radiation. BESS-Polar has a geometrical acceptance of  $0.3 \text{ m}^2\text{-sr}$ , an aerogel Cherenkov counter with index of refraction  $n=1.02$  and a time-of-flight system with  $150 \text{ ps}$  resolution, capable of identifying antiprotons over the energy range from  $100 \text{ MeV}$  to  $4.2 \text{ GeV}$ .



# BESS

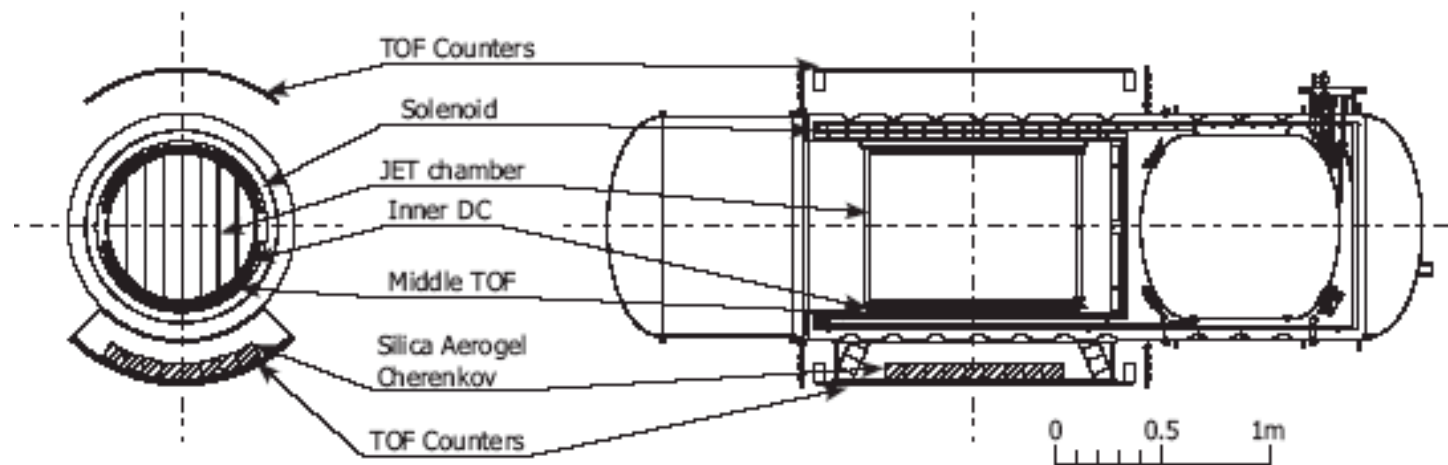
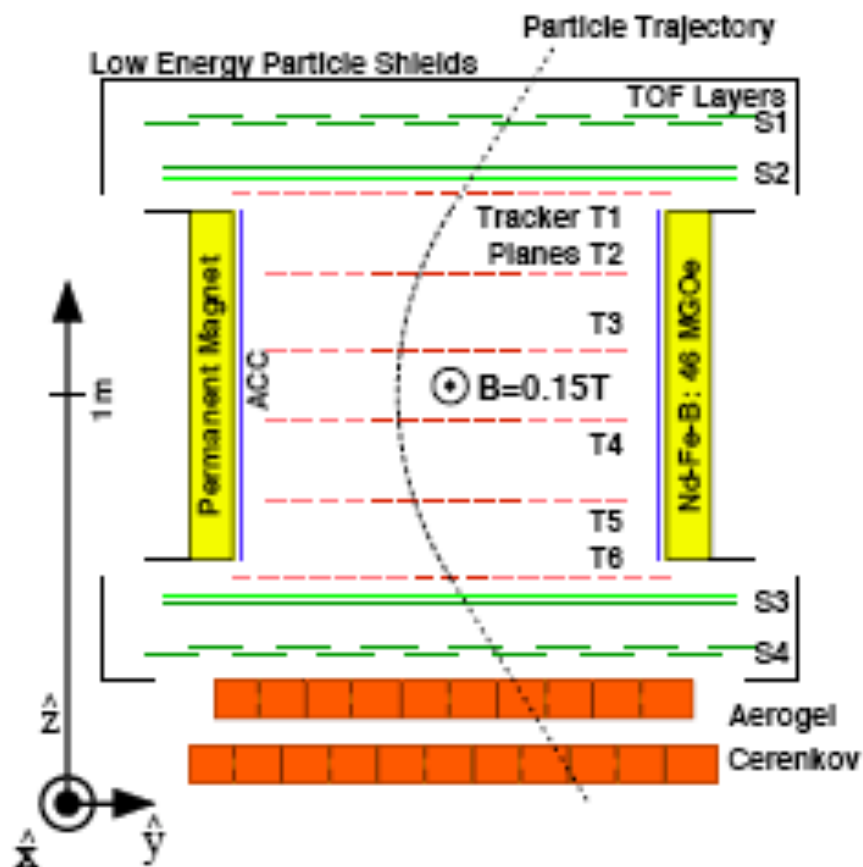


Fig. 1. Cross-sectional views of the BESS-Polar spectrometer

Table I. BESS-Polar spectrometer design parameters.

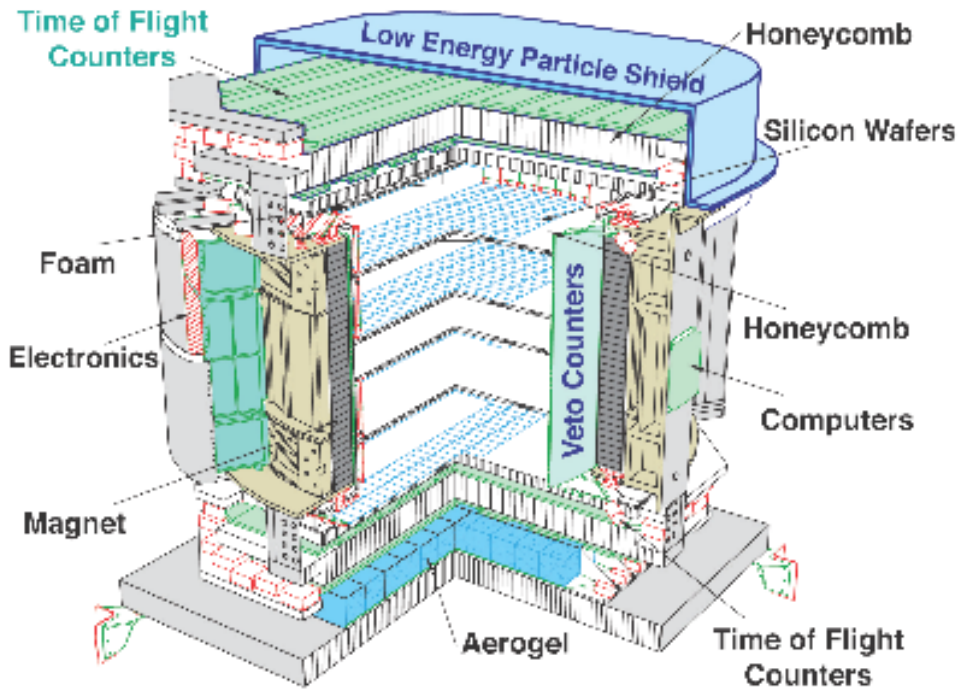
Geometrical acceptance	0.3 m <sup>2</sup> sr
Flight duration	10 ~ 20 days
Energy range for p-bar (@TOA)	0.1 ~ 4.2 GeV
Magnetic field	0.8(~ 1) T
Distance between TOF counters	1.47 m
Diameter of Central tracker (JET/IDC)	0.75 m
Maximum detectable rigidity	150 GV
Power consumption	600 W
Material in upper-half detector wall	4.5 g/cm <sup>2</sup>
Over-all payload size ( $x/y/z$ )	1.5/1.5/4 m
Weight	1.5 ton

# AMS-01



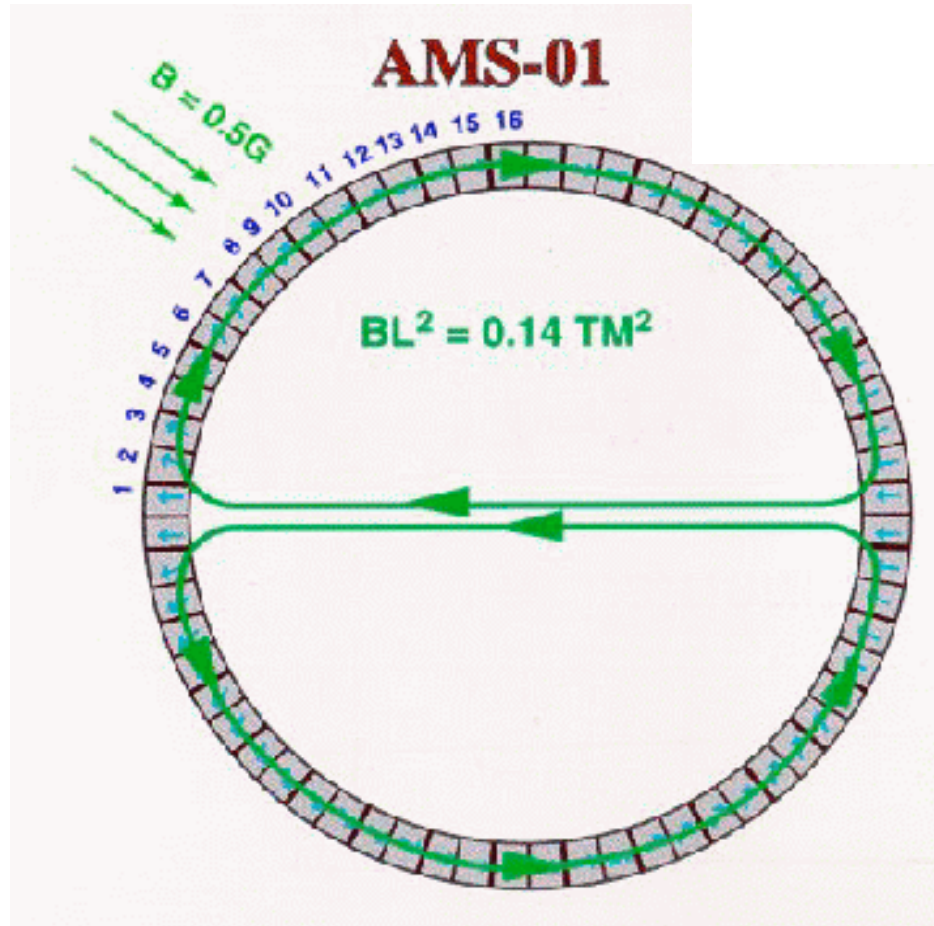
- STS91 2-11 June 1998  
Shuttle Discovery
- Mean altitude 370 km
- 90 min orbit inclined at  $51.7^\circ$
- Trigger-rate 100-700 Hz
- Recorded  $10^8$  events in 100 h

# AMS-01



- magnete permanente,  $BL^2 = 0.14 \text{ Tm}^2$
- tracciatore  $\mu$ strip silicio,  $\Delta x \approx 10 \mu\text{m}$   
 $p/Ze, dE/dx, \pm Q$
- 4 piani scintillatori tempo di volo,  $\Delta t \approx 100 \text{ ps}$   
 $v, Q$
- Cerenkov aerogel  
 $v/c$

# AMS-01: Magnete permanente



diametro  $d = 1\text{ m}$

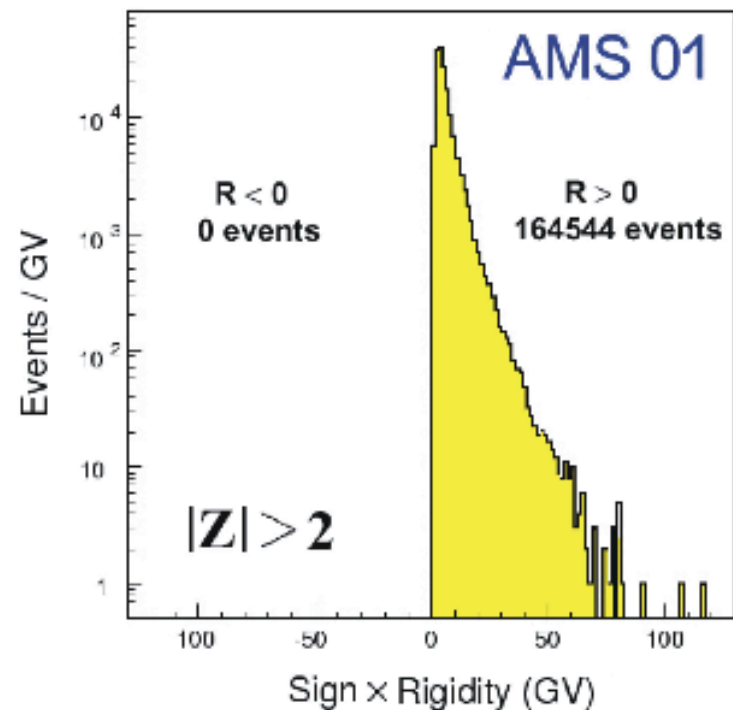
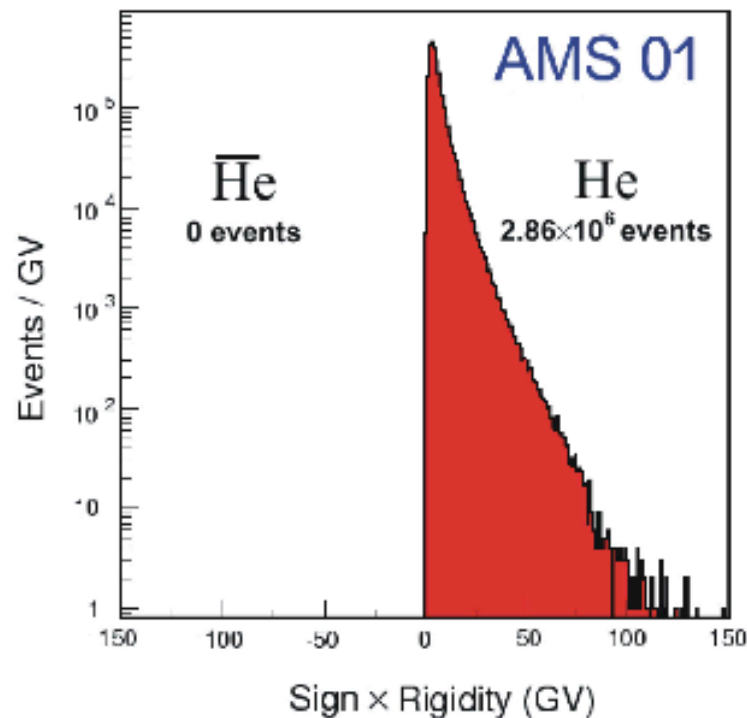
$h \approx 1\text{ m}$

momento di dipolo  $\approx 0$

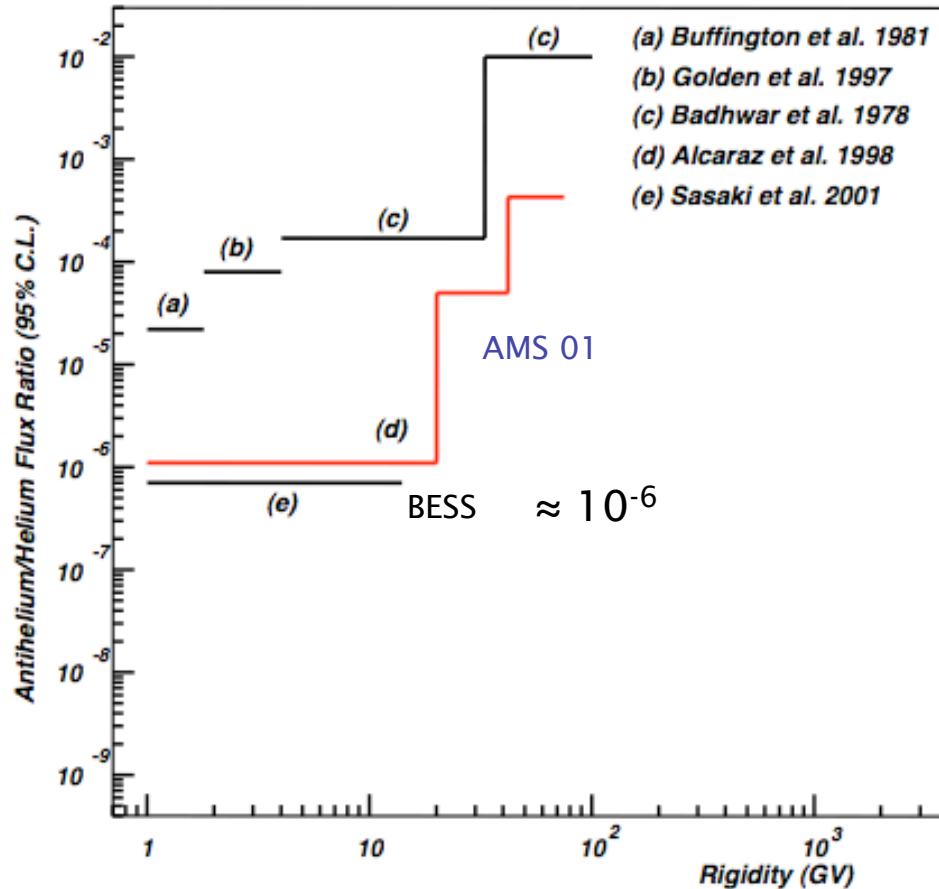
campo disperso  $< 60\text{ G}$

# Search for Antimatter

## AMS-01 10 day precursor flight



# Limiti attuali



Sakharov (2001) predice  
 $n(\bar{\text{He}})/n(\text{He}) \approx 10^{-6} - 10^{-8}$

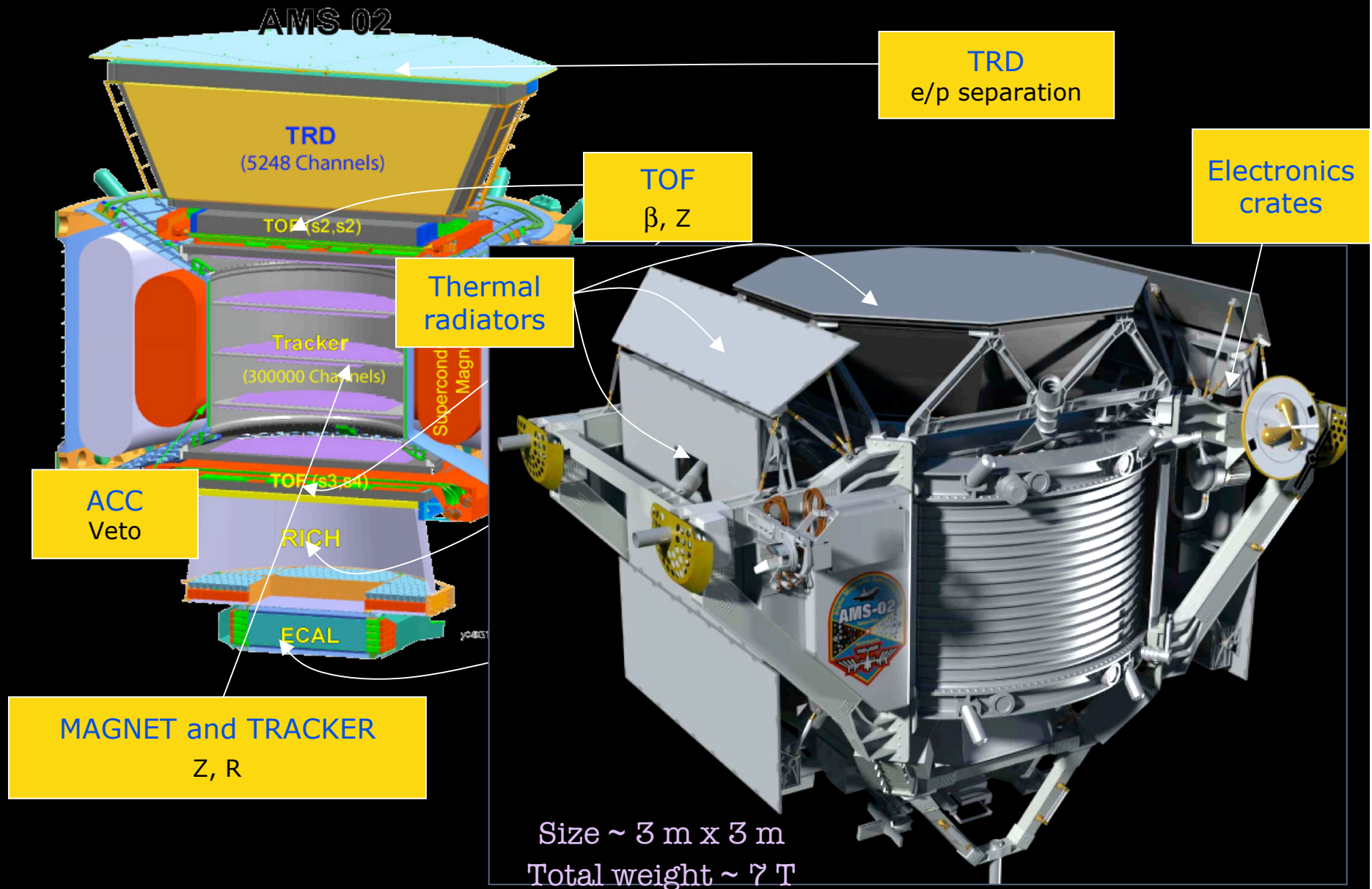
$$\Rightarrow \boxed{\pm Q \quad m}$$

apparato sperimentale  
ideale

- grande  $BL^2$
- direzione “alto-basso”
- rivelatori con spessori minimi
- tracce con punti ridondanti



# The AMS-02 detector



# Signatures

	$e^-$	P	He, Li, Be, ..., Fe	$\gamma$	$e^+$	P, D	He, C
TRD							
TOF							
Tracker							
RICH							
ECAL							
Physics example	Cosmic Ray Physics Strangelets			Dark matter			Antimatter



# AMS History and Schedule



## AMS approval: Apr 1995

- AMS-01 assembled at ETH-Zürich: Dec 1997
- AMS-01 flight: Jun 1998

## Integration of AMS-02

- Subdetectors integration + 1st integration at CERN without magnet: 12 months in 2007/2008
- 1st de-integration: 1 month in 2008
- 2nd integration with SC magnet: 1 month in 2009

## Final AMS-02 integration

- 2nd de-integration: May 2010
- 3rd integration with Permanent magnet: Jun – Jul 2010

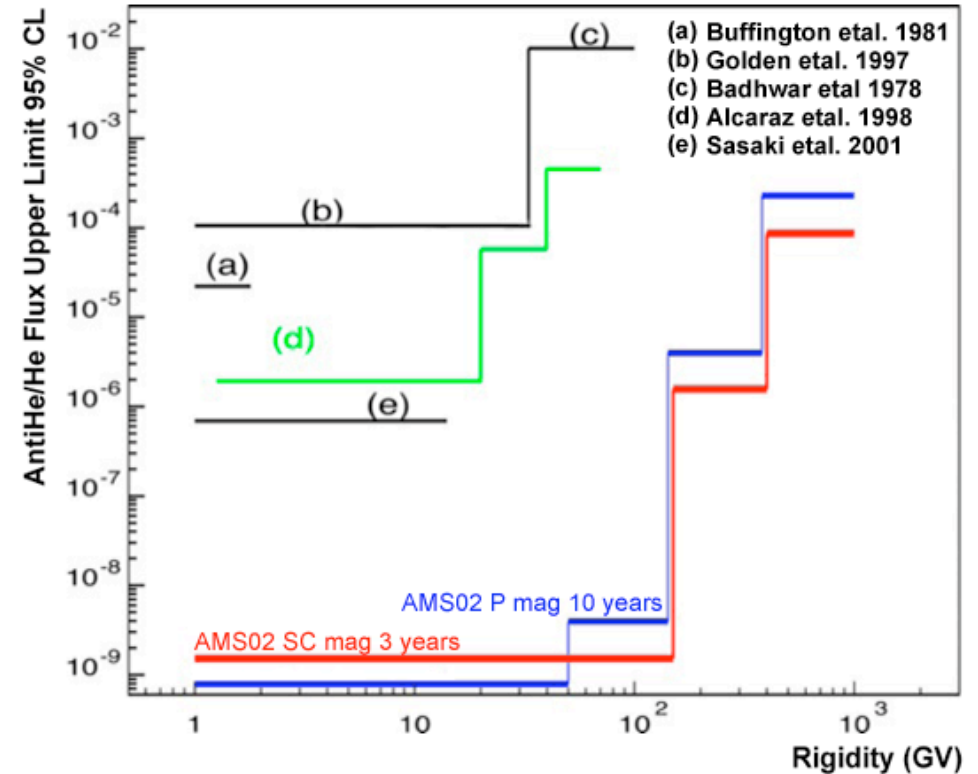
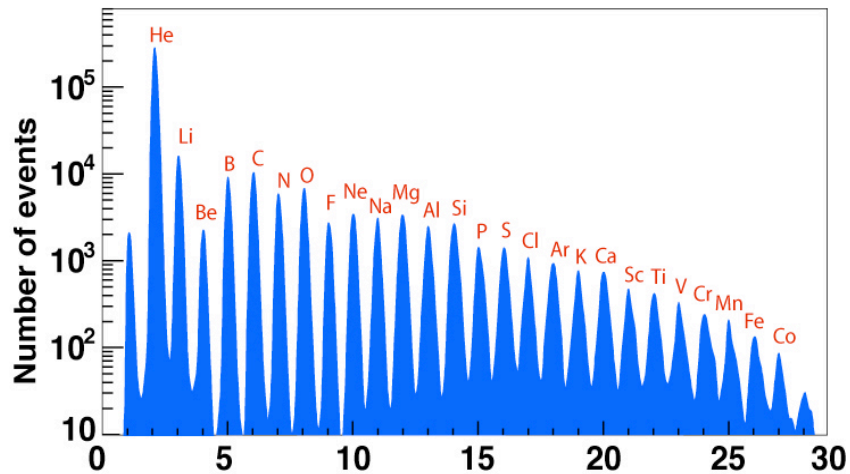
The detector will be shipped from CERN to Kennedy Space Center with a C5 Galaxy no later than **Sep 1, 2010**

**AMS is scheduled to fly to the ISS on board of the STS-134 Endeavour not earlier than Nov 2010**

# Expected limits on Antihelium

AMS will collect  $>10^9$  nuclei with energies up to 2 TeV

Charge sensitivity up to anti-Iron, magnet-independent



The  $\overline{\text{He}}$  limit put by precursor flight AMS-01 will be increased of a factor  $10^3$

Loss of sensitivity at higher energies due to lower acceptance