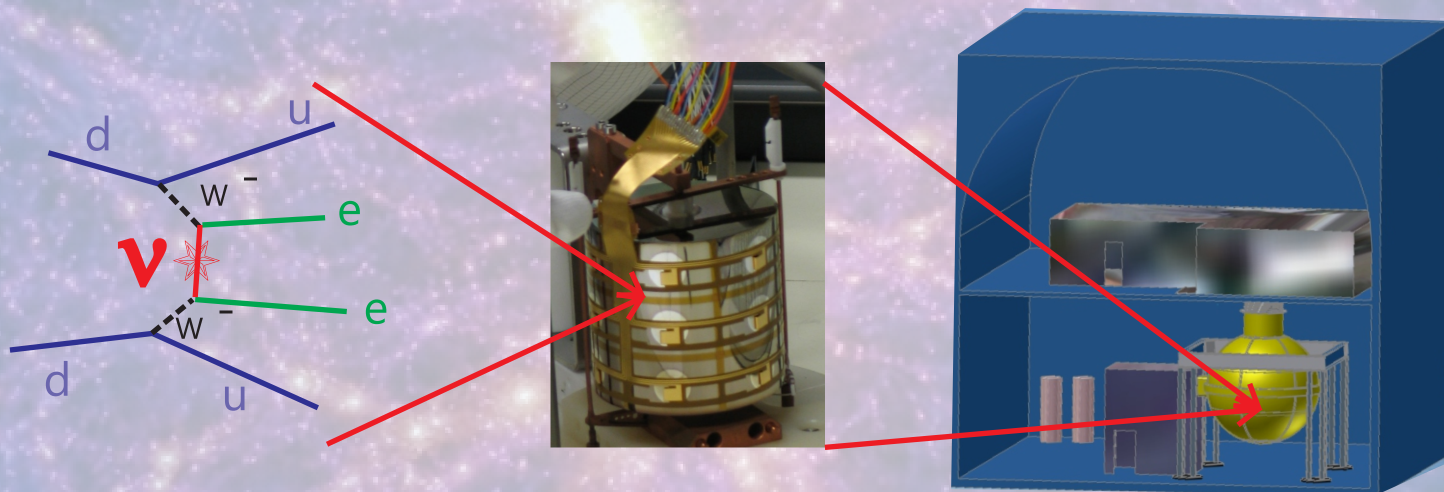
The 1 ton Challenge

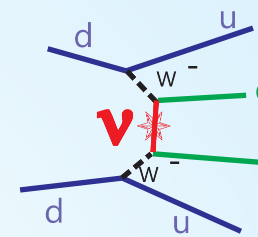


GDT Symposium 2013

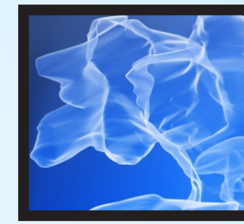
I.Abt, MPI für Physik

Content

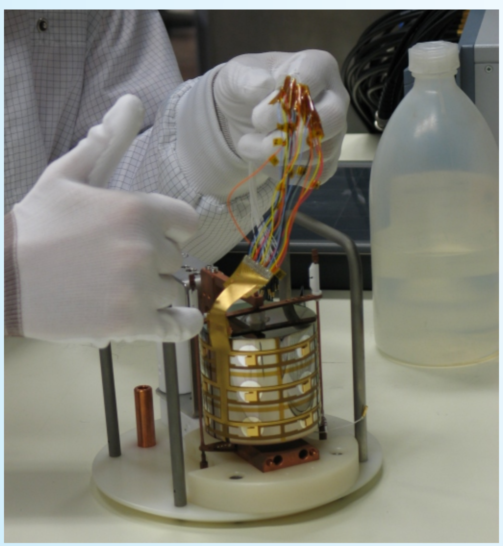
Germanium Detectors as tools to search for neutrinoless double beta decay and dark matter.



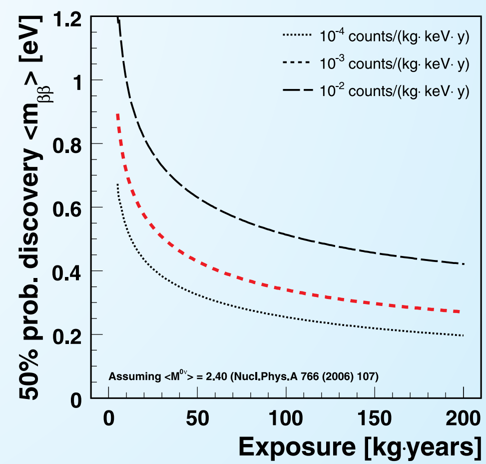
(Majorana) Mass



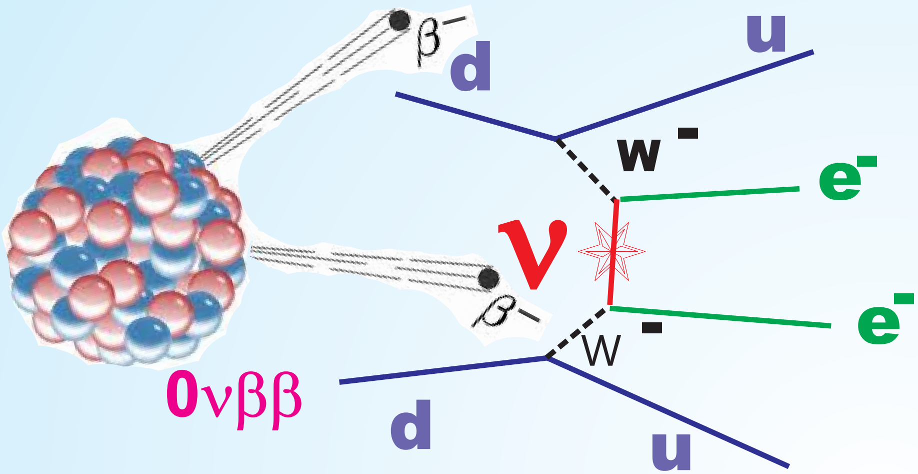
Physics goals, large experiments, costs.

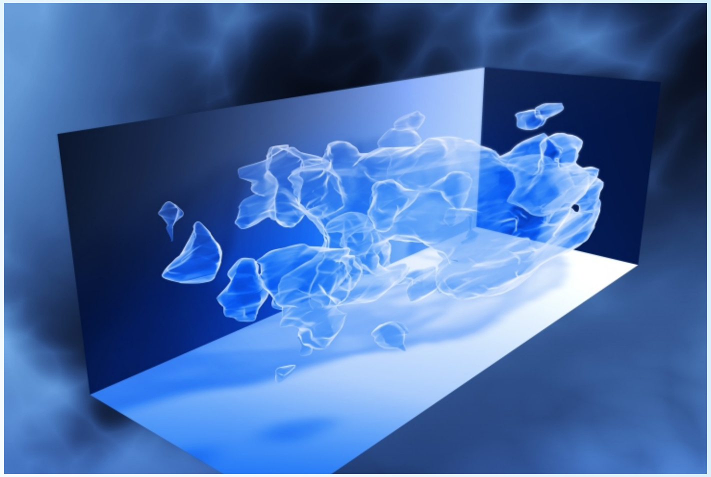


- **Experimental Reach**
- **Background**
- **Detector Technology**



Neutrino-Nature and Dark Matter





We know a lot about neutrinos, but we still do not know whether they are of **Dirac or Majorana nature**.

We assume normally they are either or.

The universe is full of something we cannot see!

And we have no clue what it is.

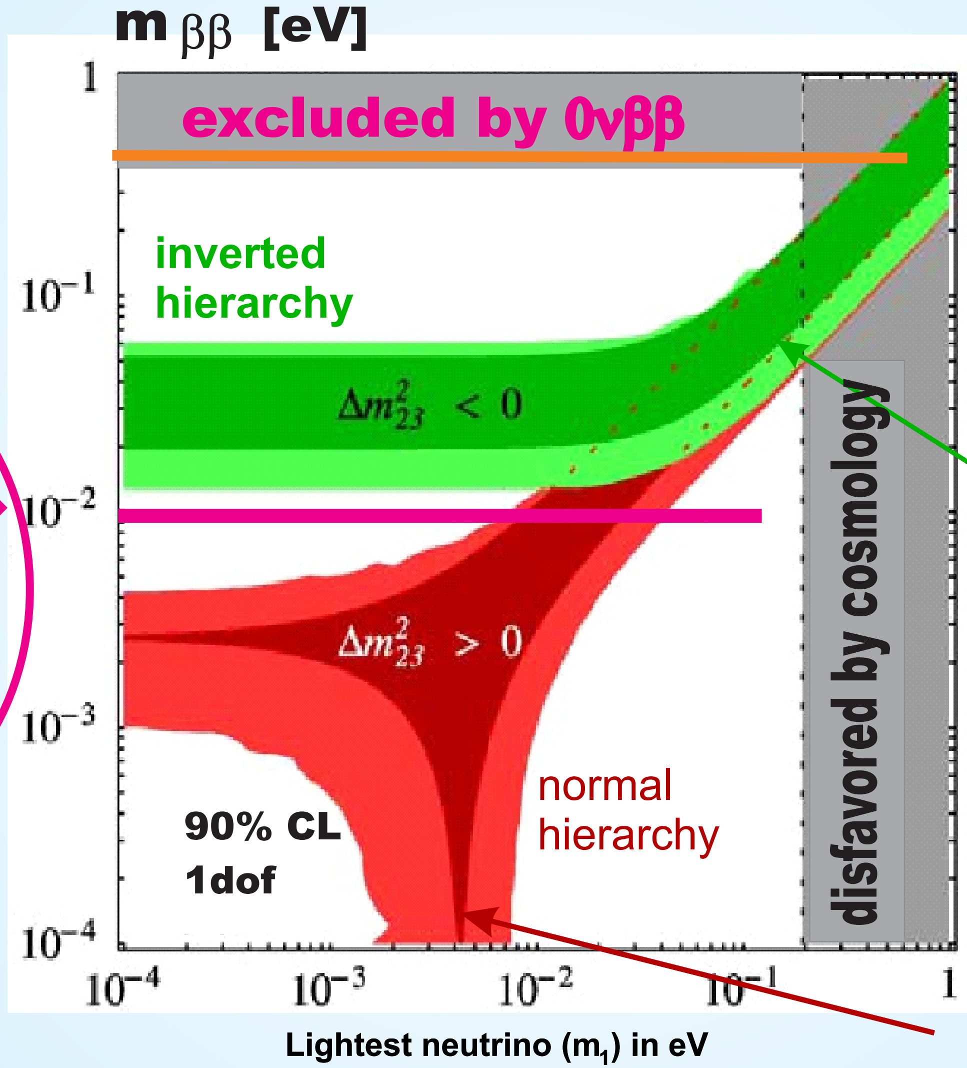
We assume it interacts weakly.

Set a goal for Neutrino Reach

CLAIM

10 meV

good goal



Feruglio
Strumia
Vissani
NPB 637

"Evidence for 0νββ"
$1.2 \cdot 10^{25}$
(0.69-4.18 3σ)
H.V.Klapdor - Kleingrothaus et al
Phys. Lett. B 586 (2004)

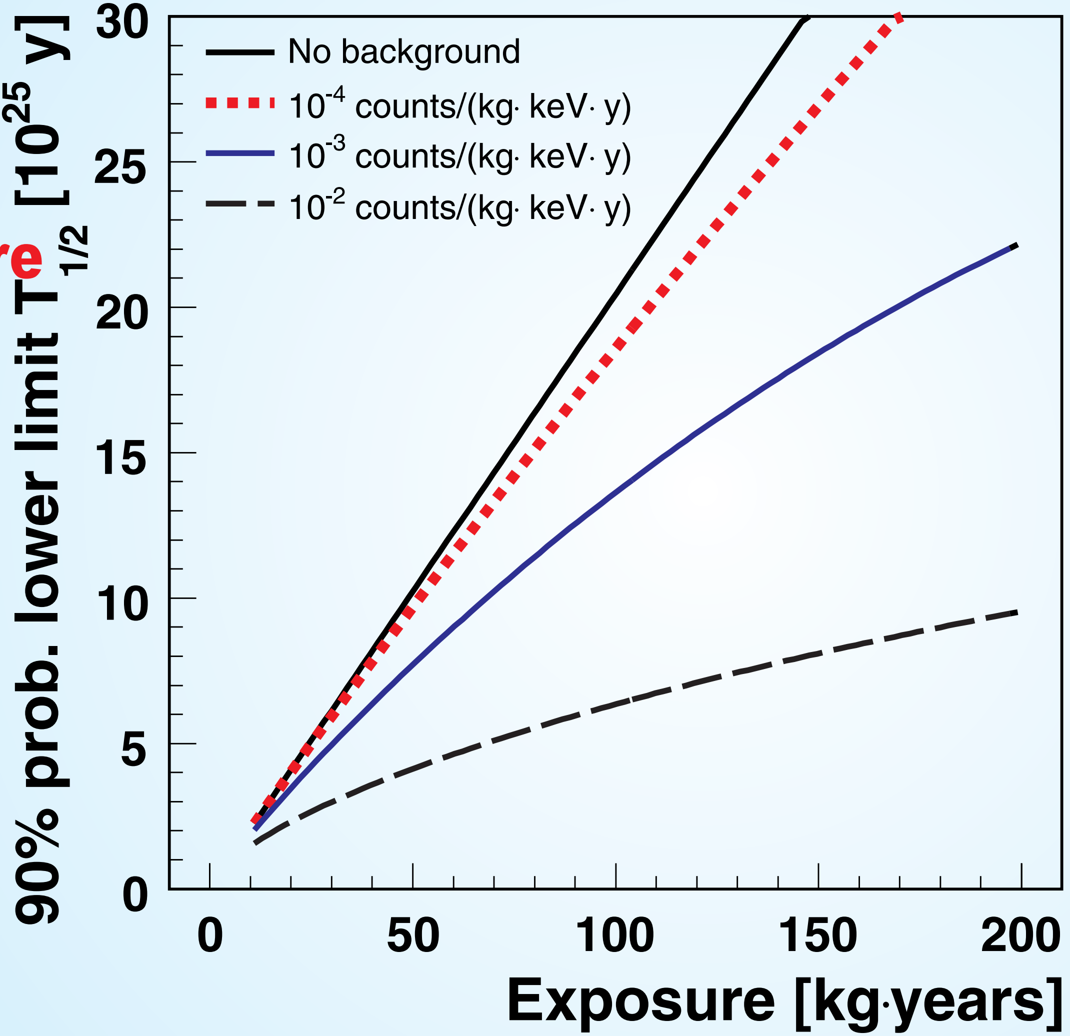
uncertainty from Majorana CP phases

This assumes that the neutrino is purely Majorana.

Conspiracy of Majorana phases

It is all in the Background

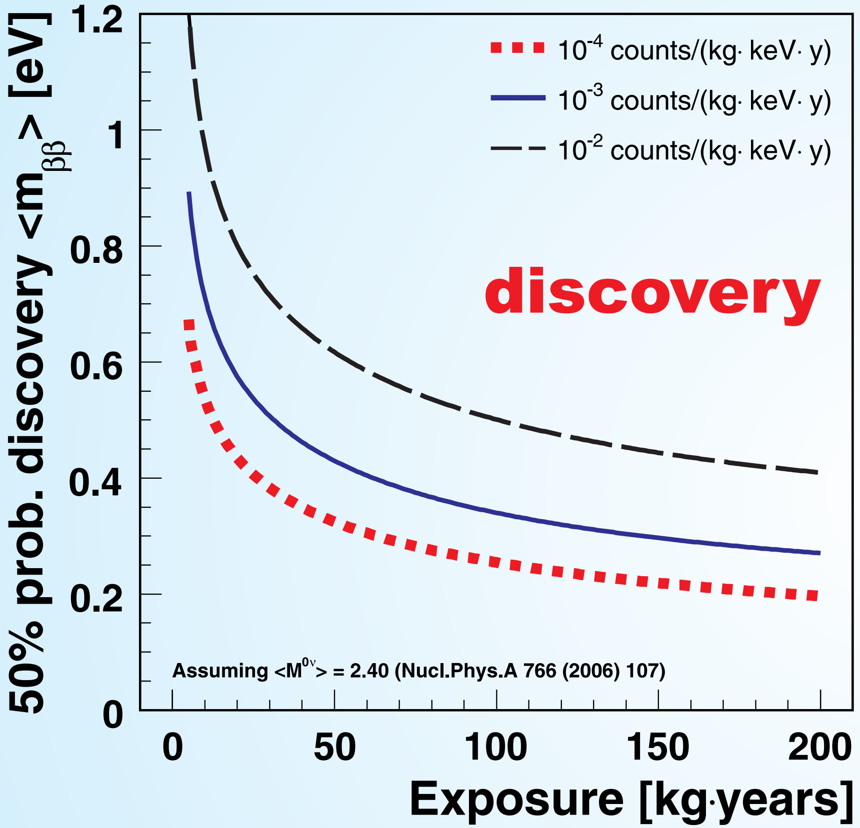
We measure halflife not mass.

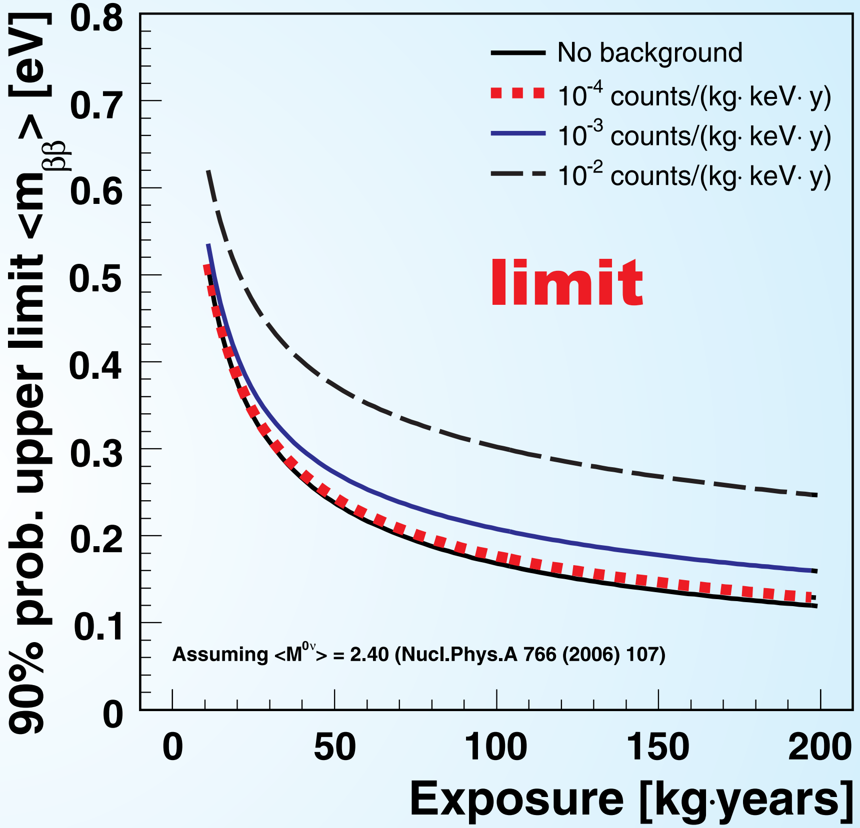


Exposure larger than 100 kg year is wasted for background of 10^{-3} /(kg keV y) .

To guarantee that we need to understand and simulate the truly rare event.

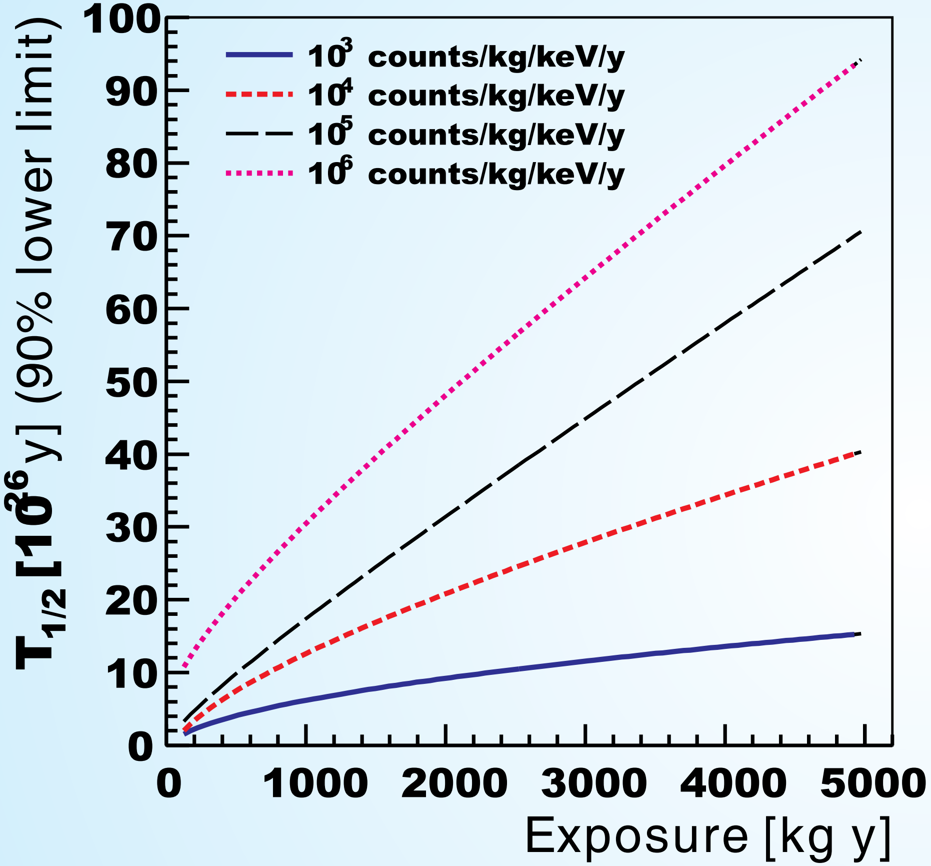
Importance of Background

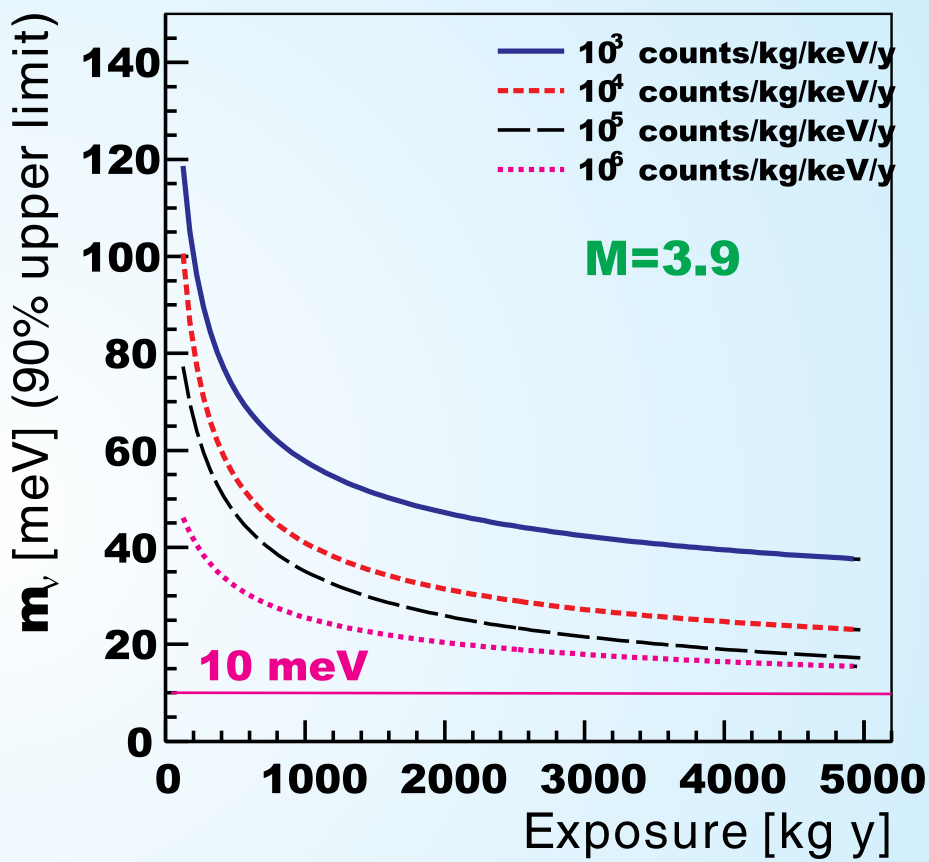




Is 10^{-4} good enough to reach 10meV to exclude inverted hierarchy ?

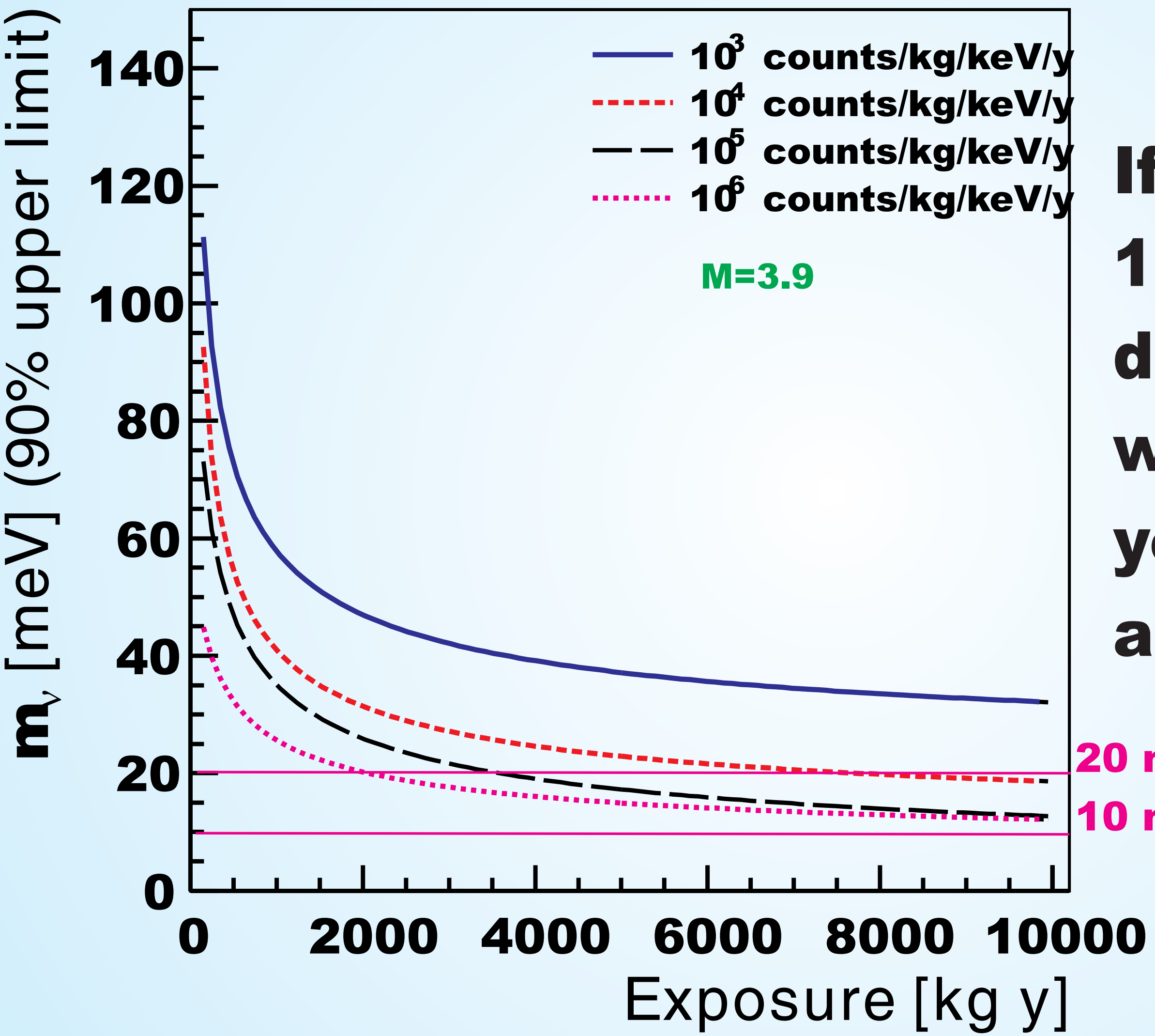
Importance of Background





Even 10 $^{-6}$ is not good enough to reach 10 meV with 5000 kg y .

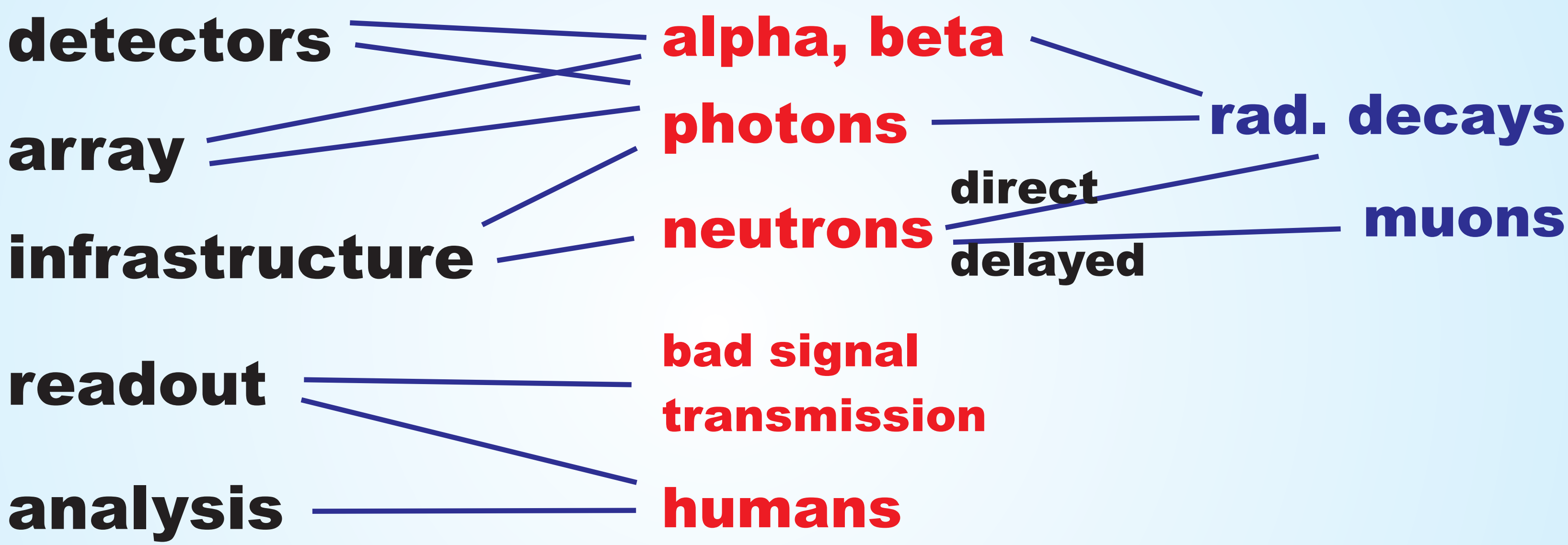
Importance of Background



If you measure 10 years, 10^{-6} does not help; with $10^{-5/-4}$ you can reach about 13/20 meV.

Reality of Background

Unwanted events have many sources:

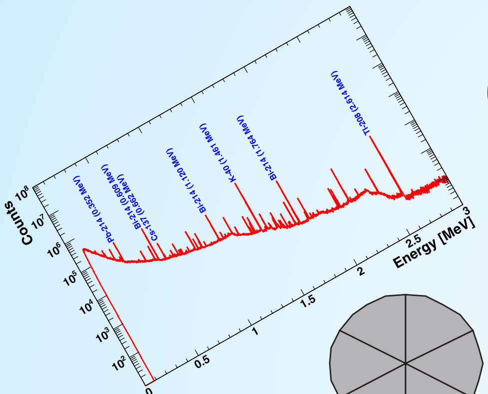


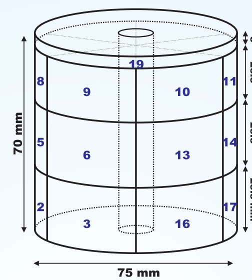
All this needs to be understood and prevented at levels of less than one event in a million.

Almost infinite simulation and screening needed.

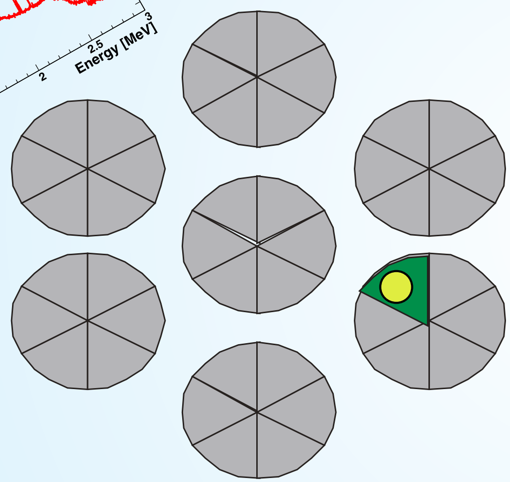
Handle on Background

Beyond energy resolution: Segmentation

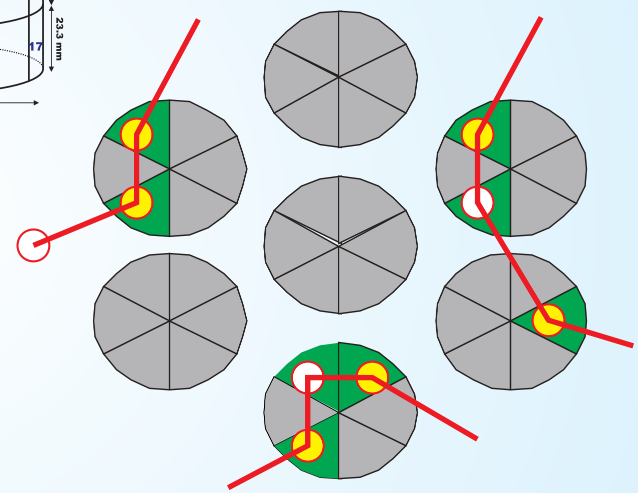




0νββ



γ or 2γ

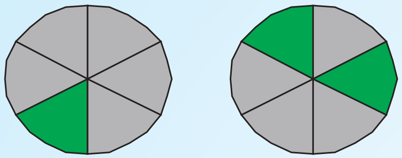


localized deposit
single-site event

several deposits
multi-site event

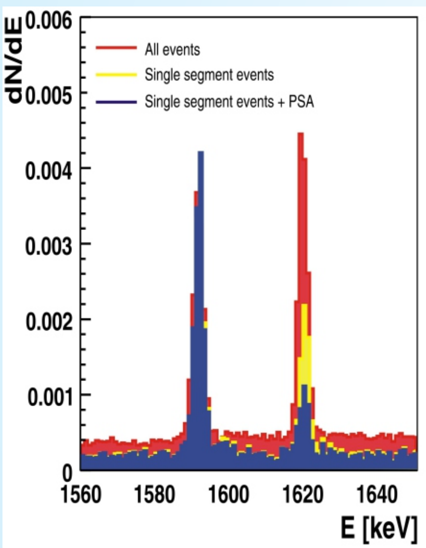
Almost all background sources are multi-site

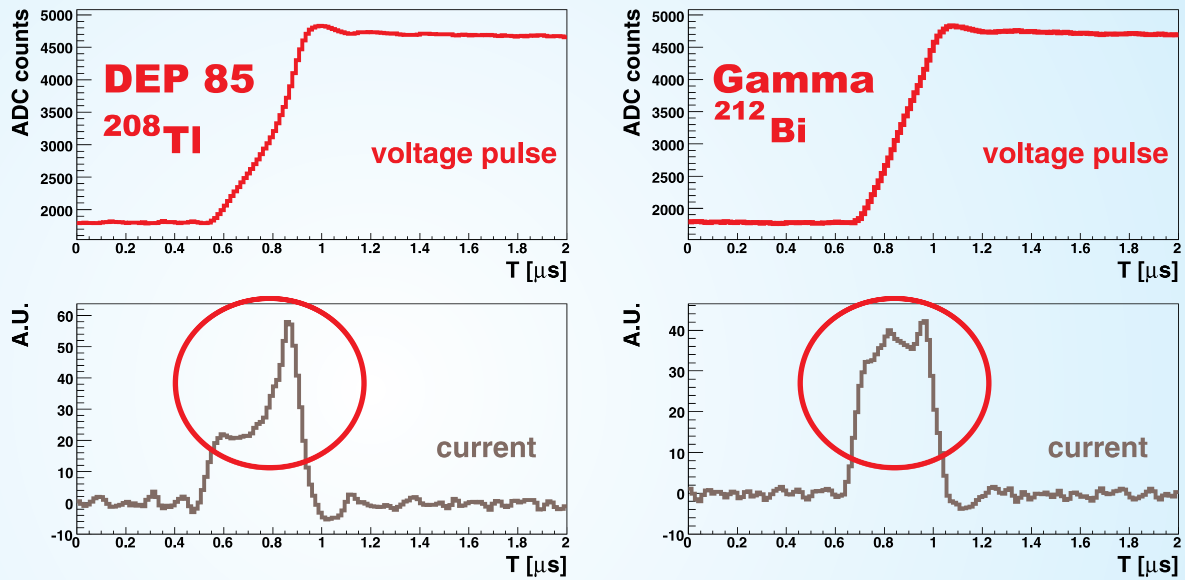
Pulse Shape Analysis



factor ≈ 10

Background suppression from counting segments is easy and robust.





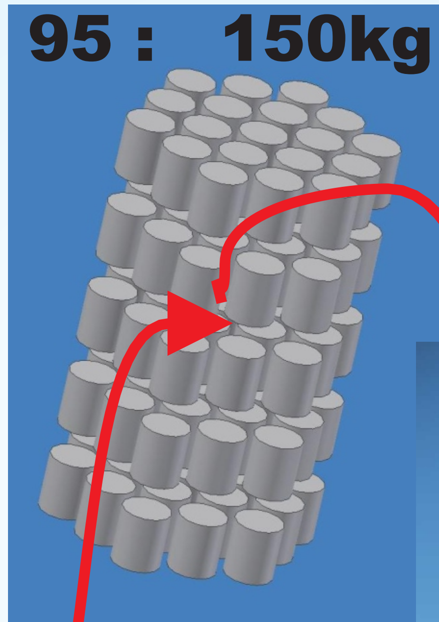
Pulse shape analysis gets you an extra factor of 1.4 for single segment events.

Should we use current sensitive devices ?

Can we afford the more/better cables ?

Array

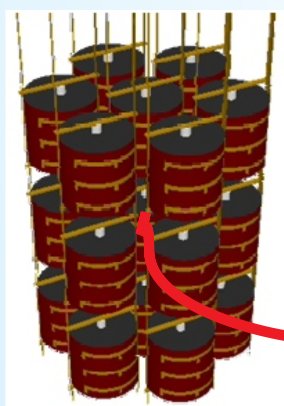
1.6 kg Ge
31 g Cu
8 g Teflon



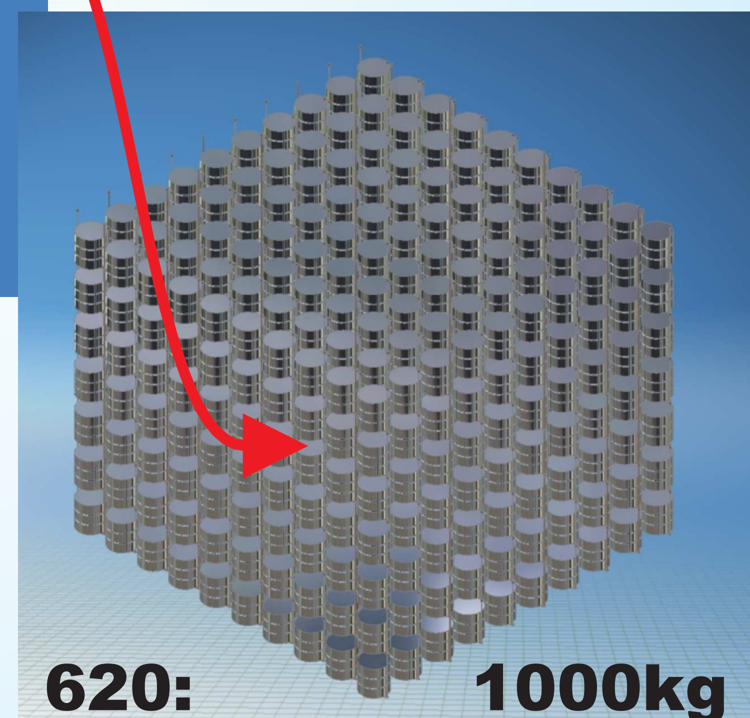
This is technically possible.

This is not

21:
34kg

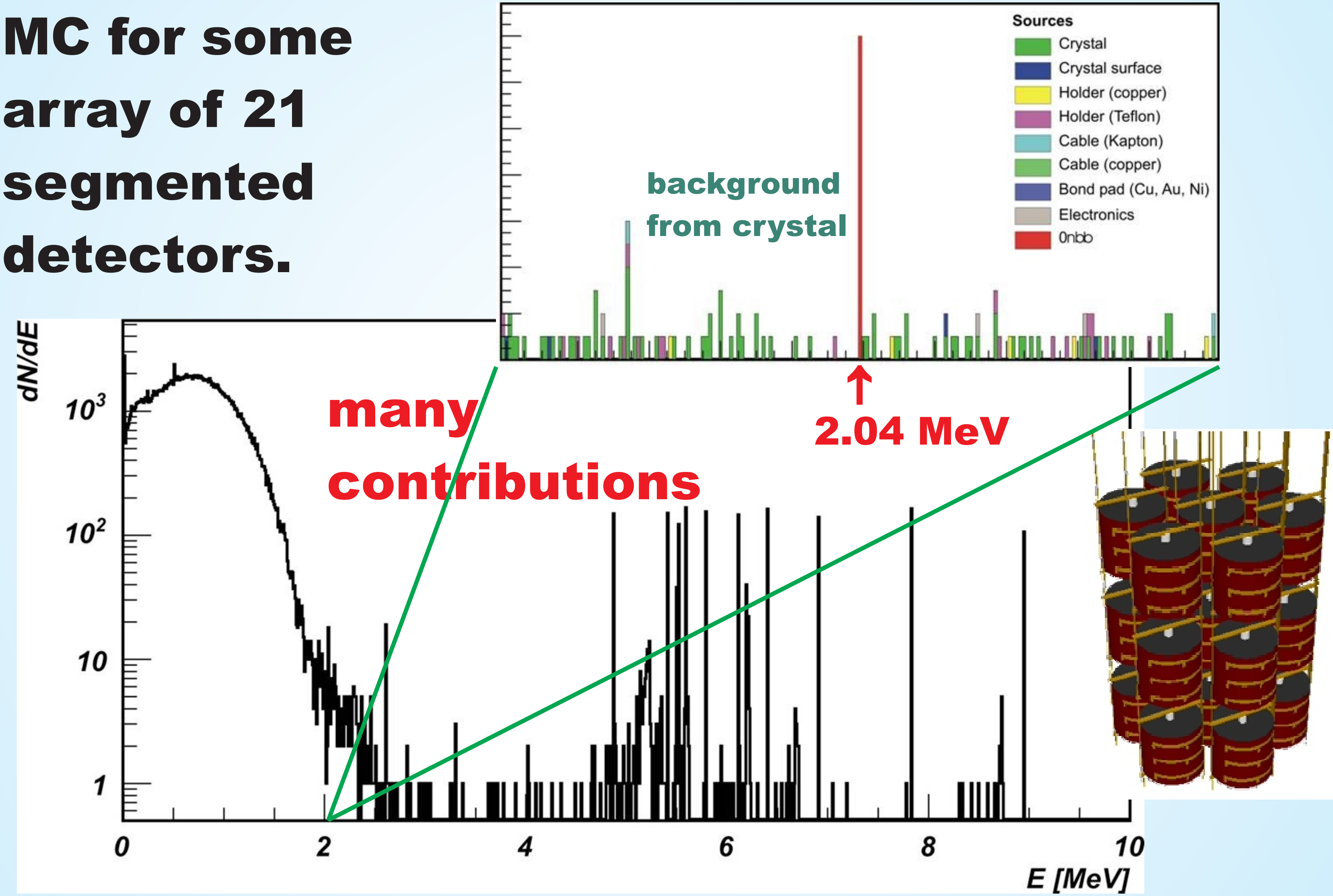


Screen every piece used.
But, HOW?



MC Example

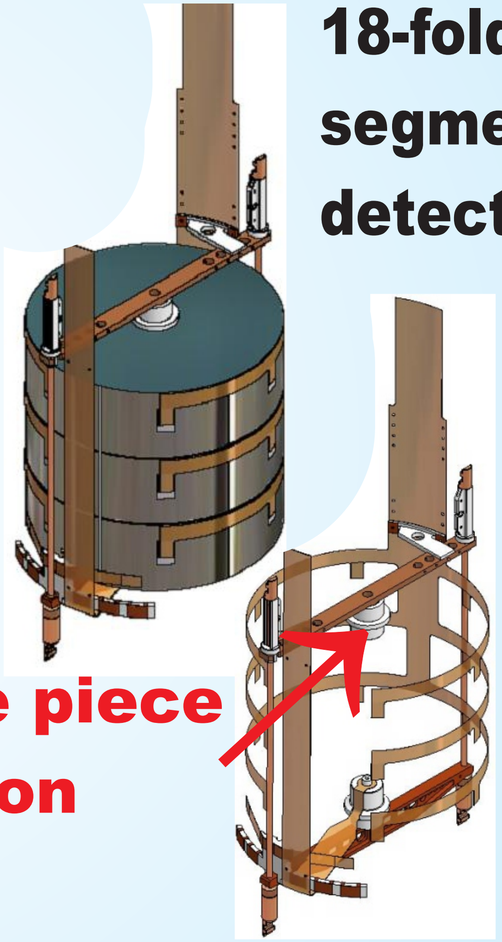
MC for some array of 21 segmented detectors.



Need to focus

Part	Background index [10^{-4} counts/(kg·keV·y)]
Crystal	5
Holder (copper)	4
Holder (Teflon)	8
Cabling	6

18-fold segmented detectors

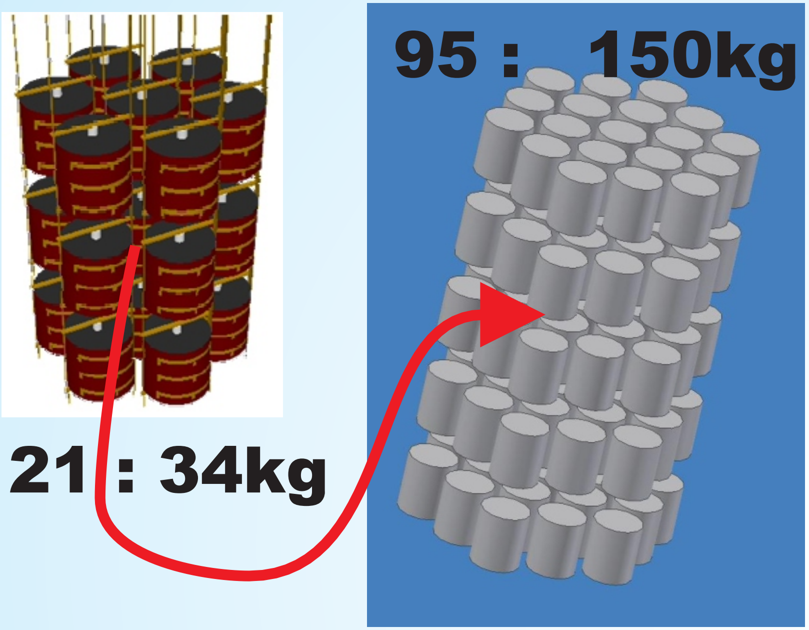


Something will have to touch and hold.

a little piece of teflon

We need to focus on key elements of any system.

Just the Insulator



Assume scaling:
The inner part of the large array should behave like the center crystal of the small array.

Simulate Thorium chain for the insulators that touch.

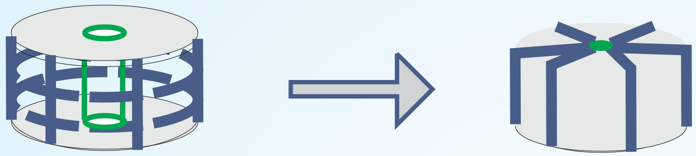
21 Million decays: survical prob. 0.0002 ± 8%.
A 1t array requires 625 detectors ⇒ 625 M decays.

Assume 1g insulator / detector ⇒ 50μBq/kg for 10^{-5}
without segmentation ⇒ 10μBq/kg

And the outer detectors can only be worse....

Array of the Future

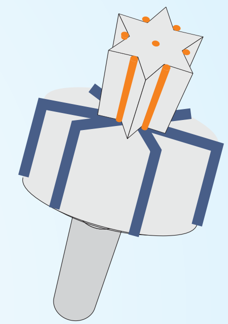
Path to 1 ton is not clear at all. Need < 10^{-4} bgr.



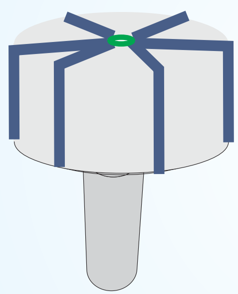
6 x 3 true coax

6

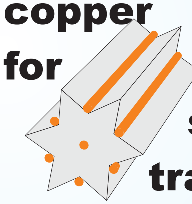
Point contact segmented detectors



Support out of "Optical" germanium crystals



Laminate copper for signal transfer



We need new technology!

We need MC to guide new technology. We need to simulate every configuration with a lot of statistics and with correct tails of distributions.

And we need the perfect germanium detector.

Detectors

Germanium Enrichment ~50 M€ — Easy, but for cos-mogenic activation

Crystal Growing ~?0 M€ — Alchemie
Many problems
plus cosm. activ.

Detector Manu-facturing ~100 M€ — Very few sources!

Detector Testing — 1000 x 3 months = 250 years

All this can probably be solved by spending money.

System Integration/Infrastructure will require thinking!

Total cost will be around 400 M€.

The egg-laying woolly Ge milk-pig

= one size/technology fits all

threshhold of 20 eV

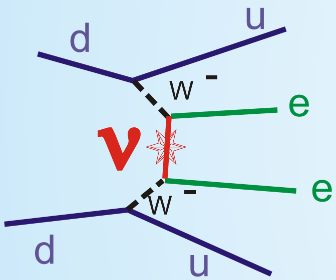
perfect separation of multi/single-site

position resolution 1mm

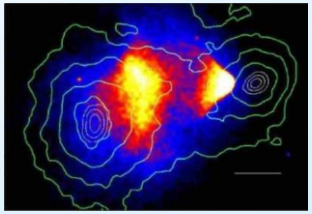
energy resolution 1keV at 1MeV

no contamination: bulk and surface

separation of gamma and neutron

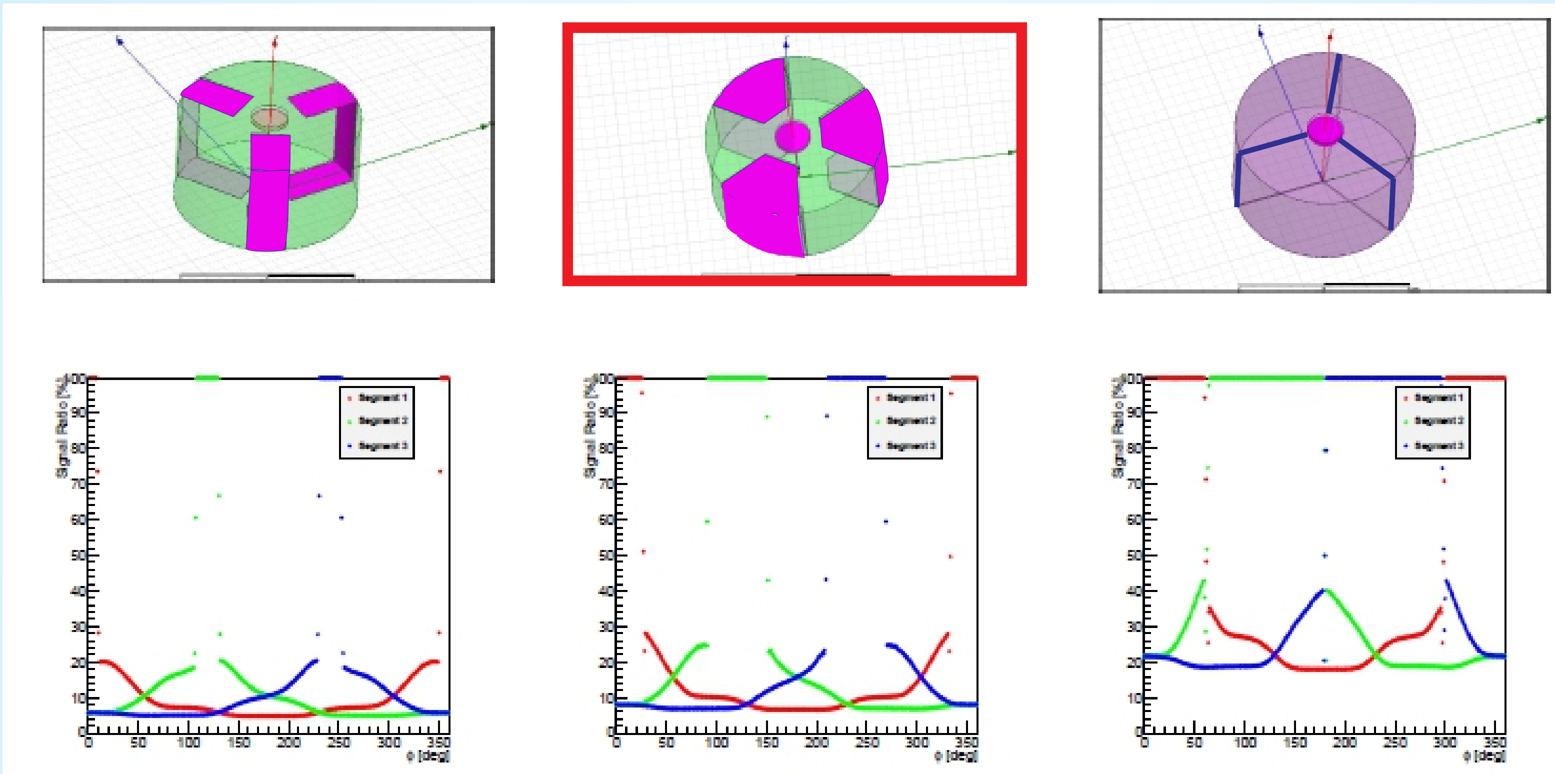


It needs to be perfect for more than one application to justify the cost.



Detector of the Future

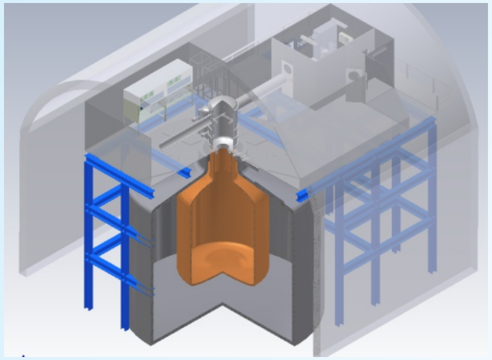
studied a multitude of designs: z=40mm r=75mm



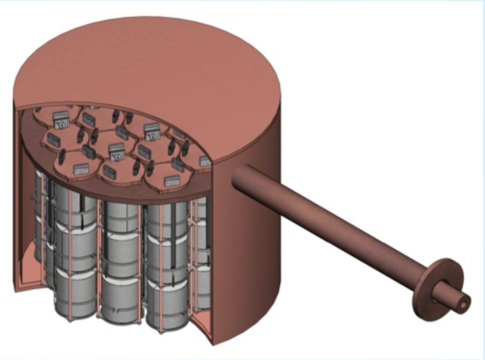
Phi dependence of the signals at r=25mm, z=20mm

Choose detector with best grip on topology.

Infrastructure of the Future



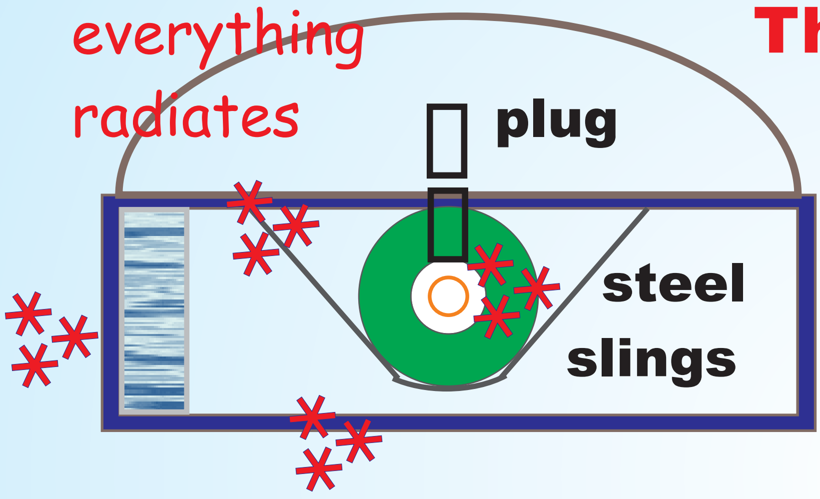
Gerda
or
Majorana
or .....
CDEX



Cryogenic Shield	Copper Shield
homogenous	compact
longer signal path	cracks
~~submerged detectors~~	high Z material

Is one of them THE choice ? Probably not .....

Infrastructure of the Future



The hall has to be large!

water shielding

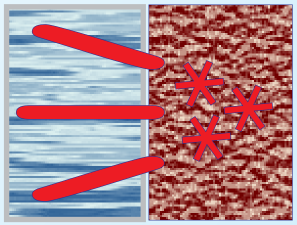
LAr/Ln/Xe shielding

Copper vessel with vacuum holds array

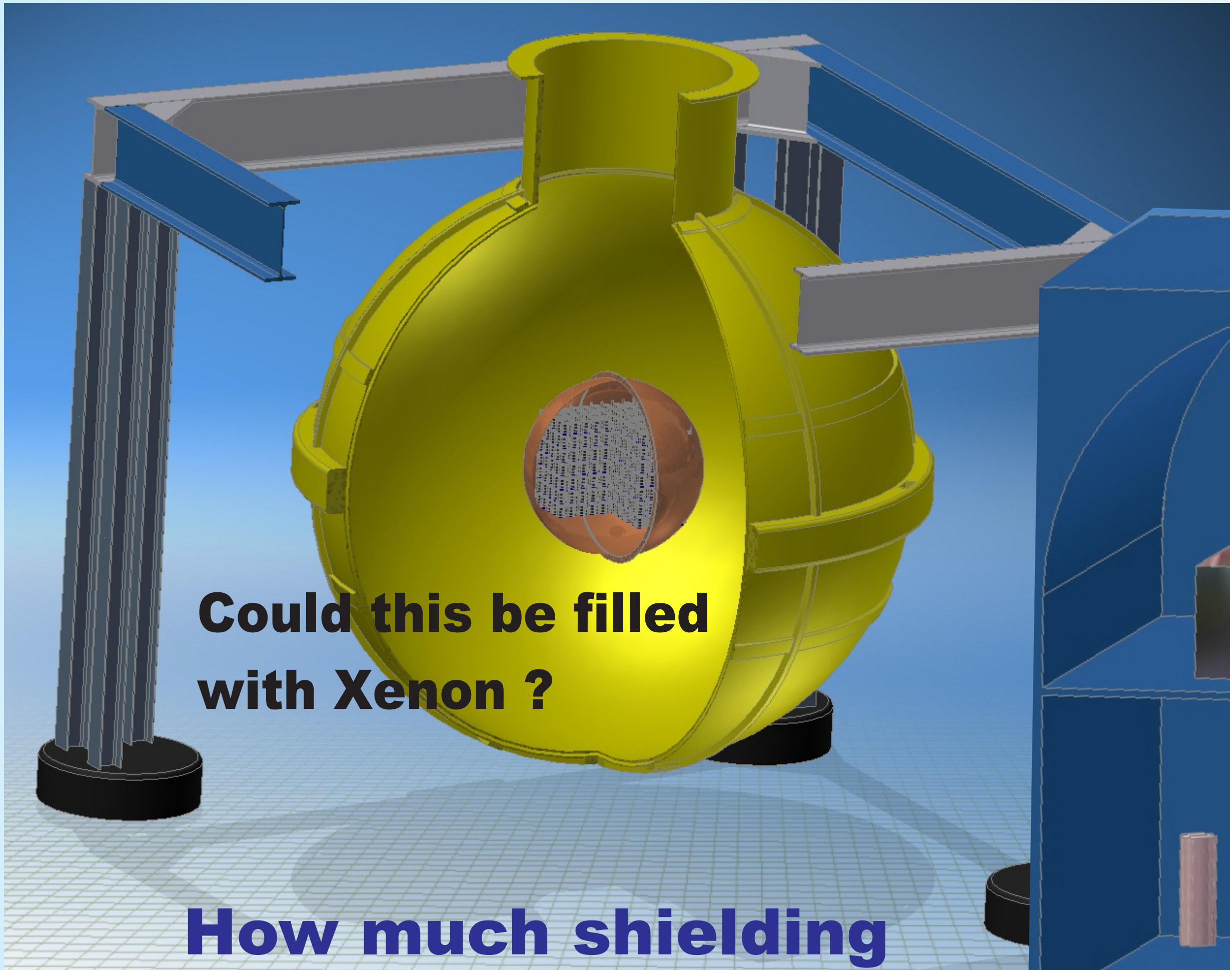
NO compromises!

It will be necessary to use some intelligence to simulate large infrastructure and it has to be done before digging starts.

We need MC benchmarks for "little" things and for large structures.



Infrastructure of the Future

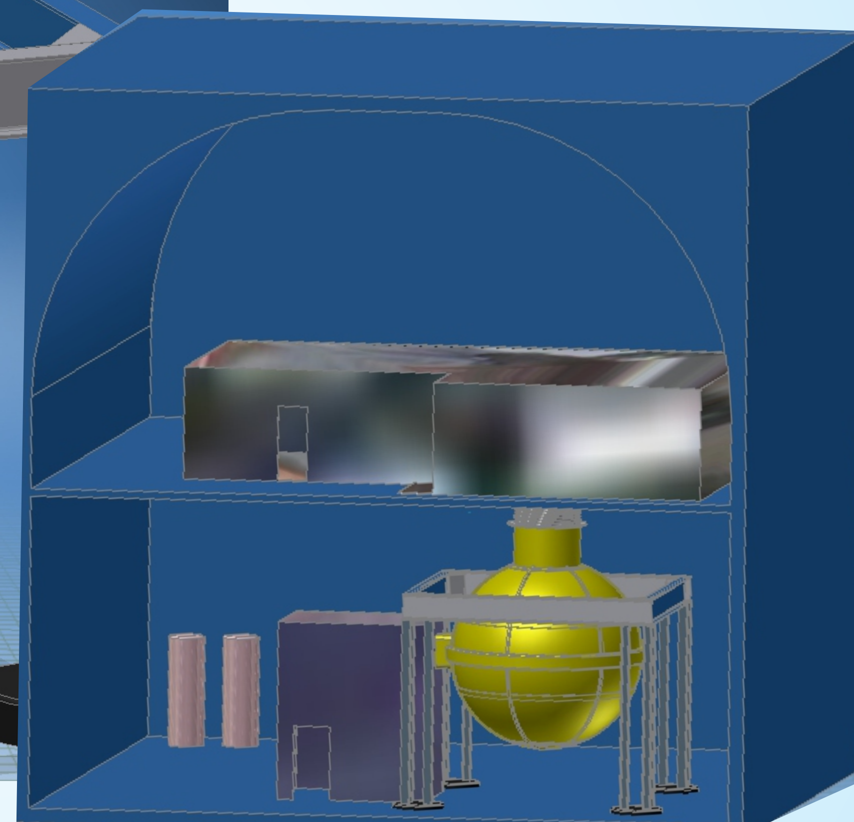


Could this be filled with Xenon ?

How much shielding do the walls need?

MC is being tackled.

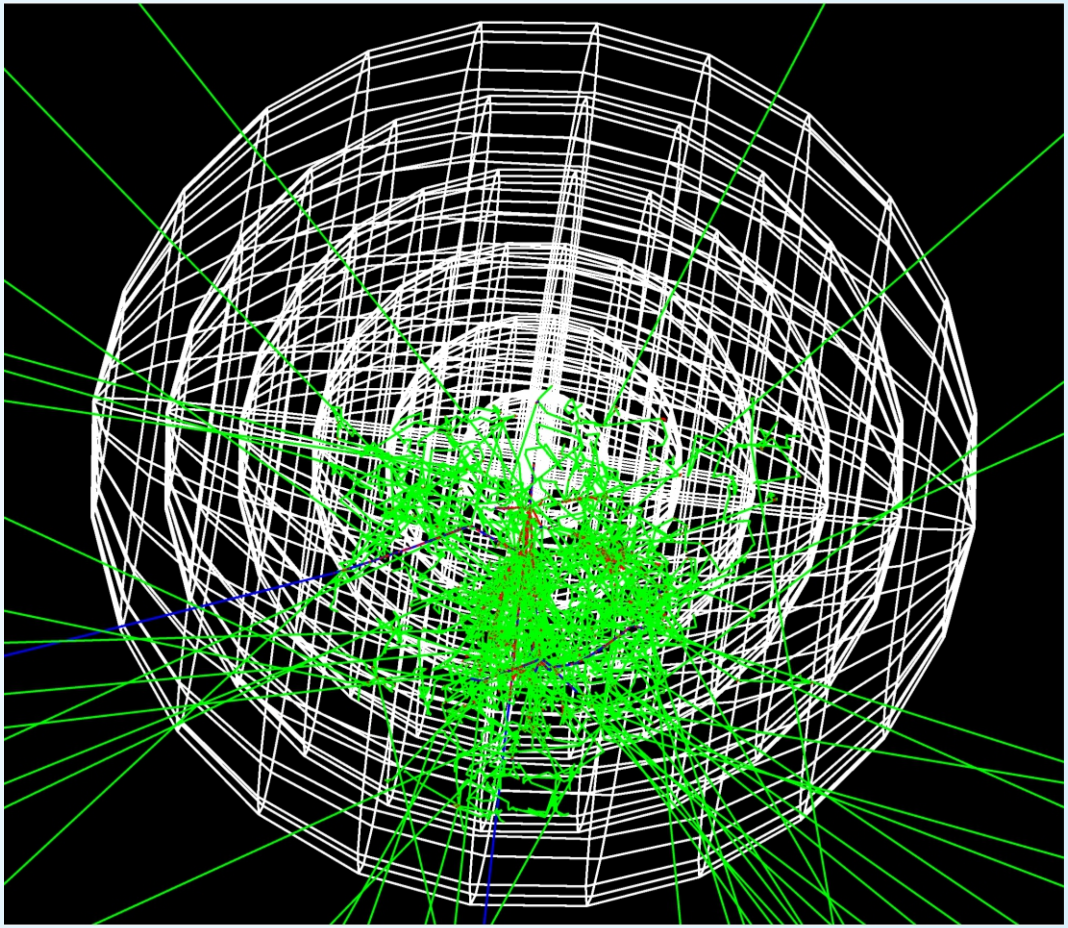
Some bad dreams.



multiply the lower hall

MC on Showers in Rock

What has the wall to do?



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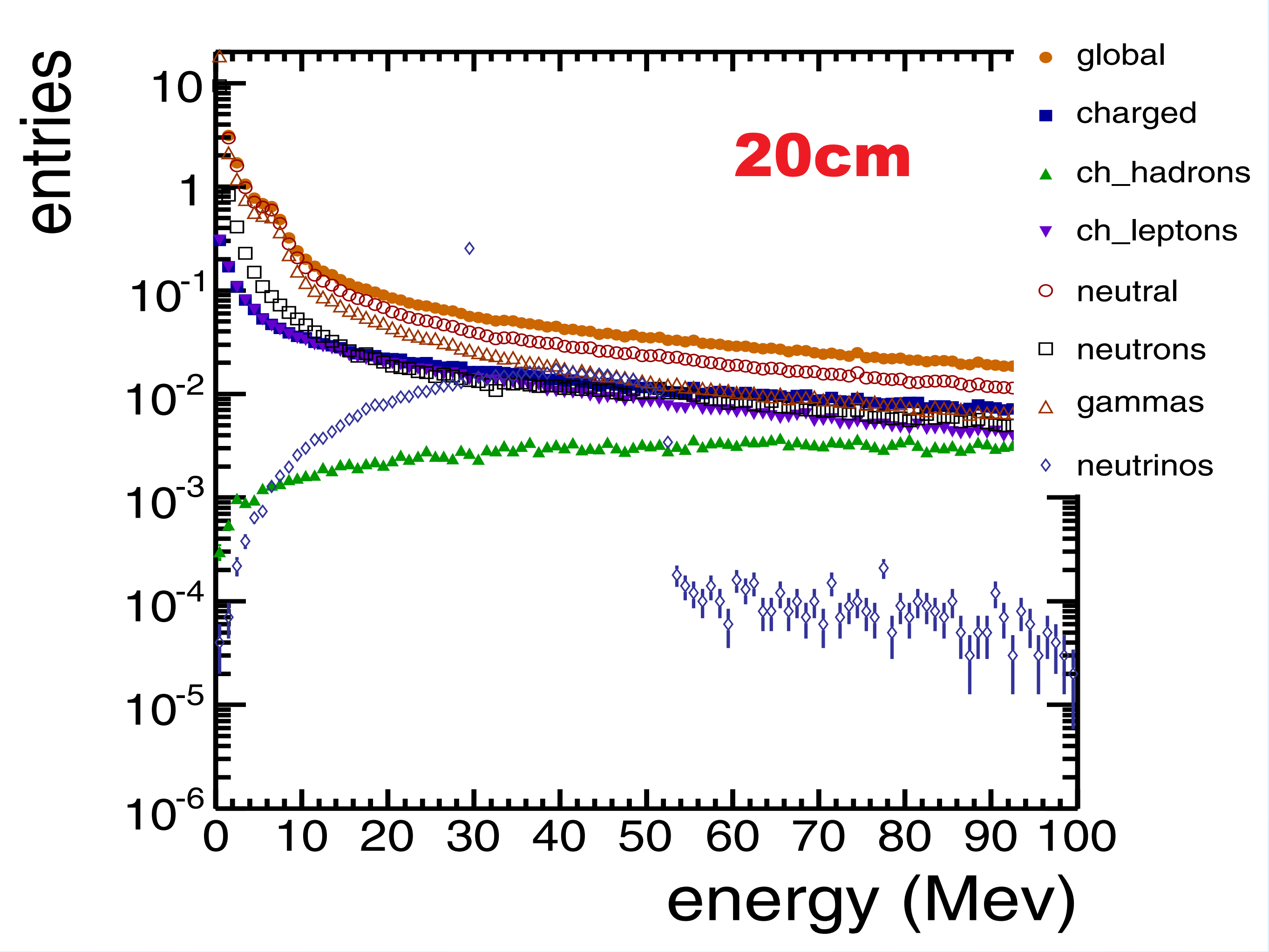

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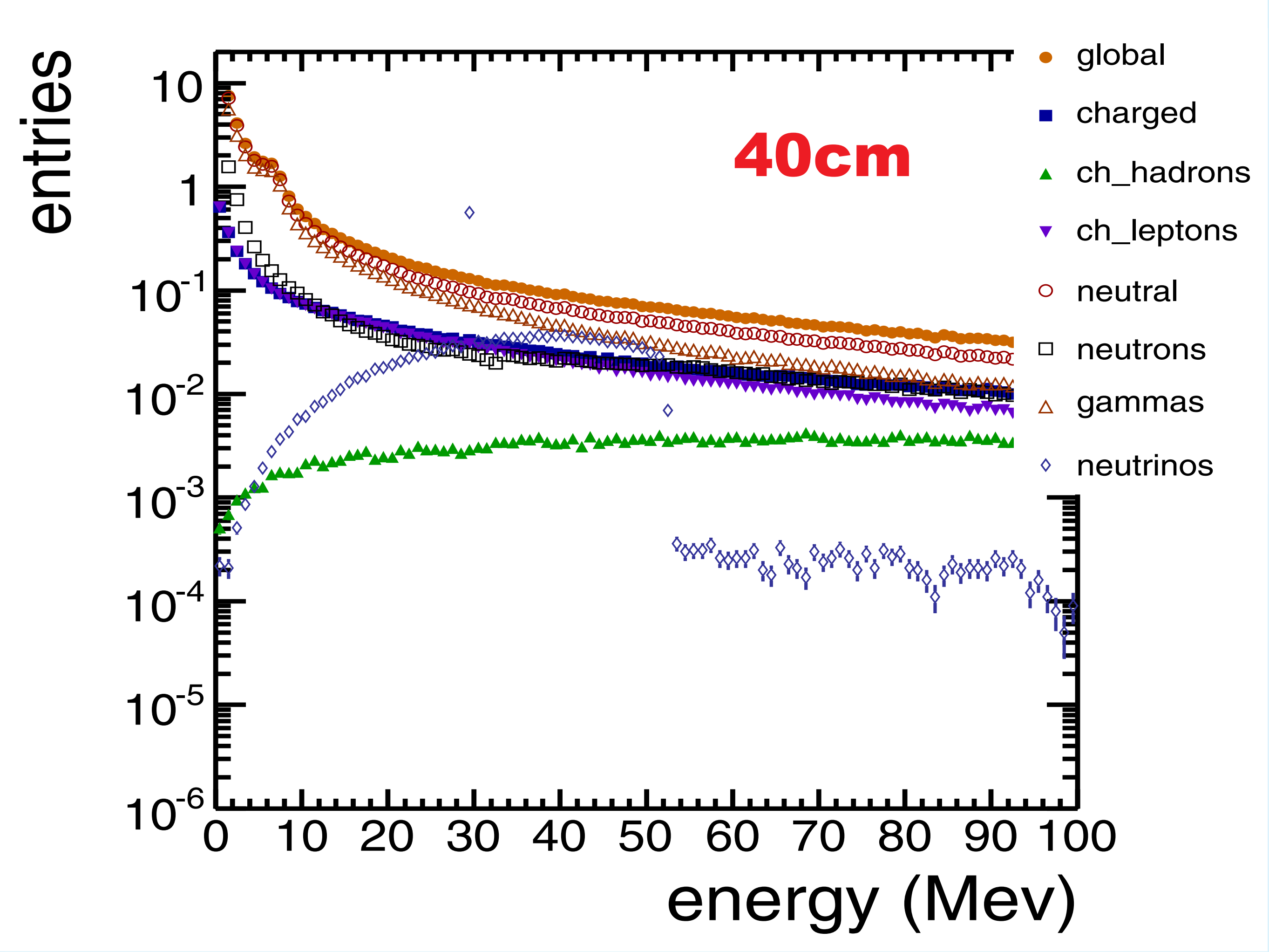

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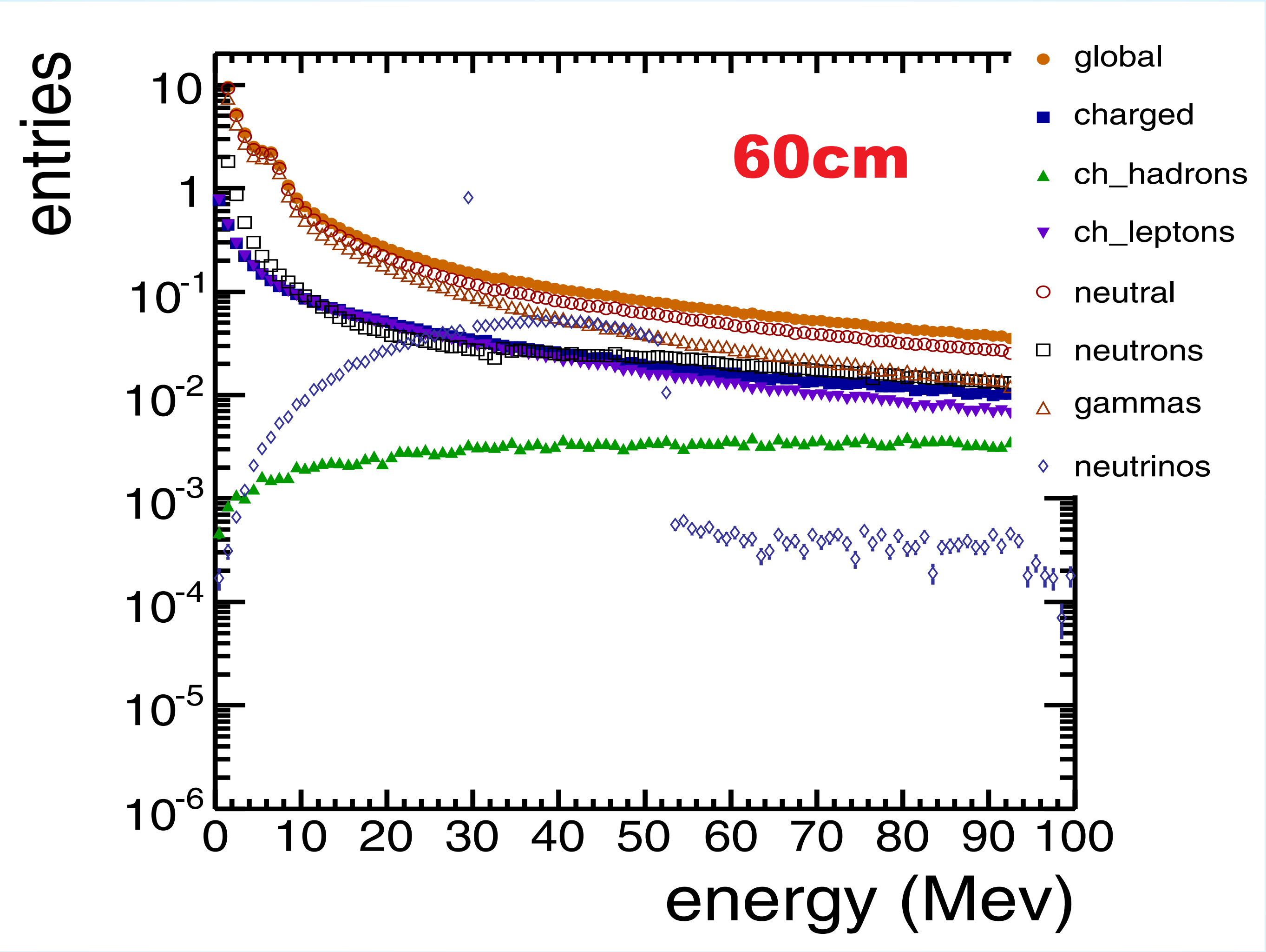

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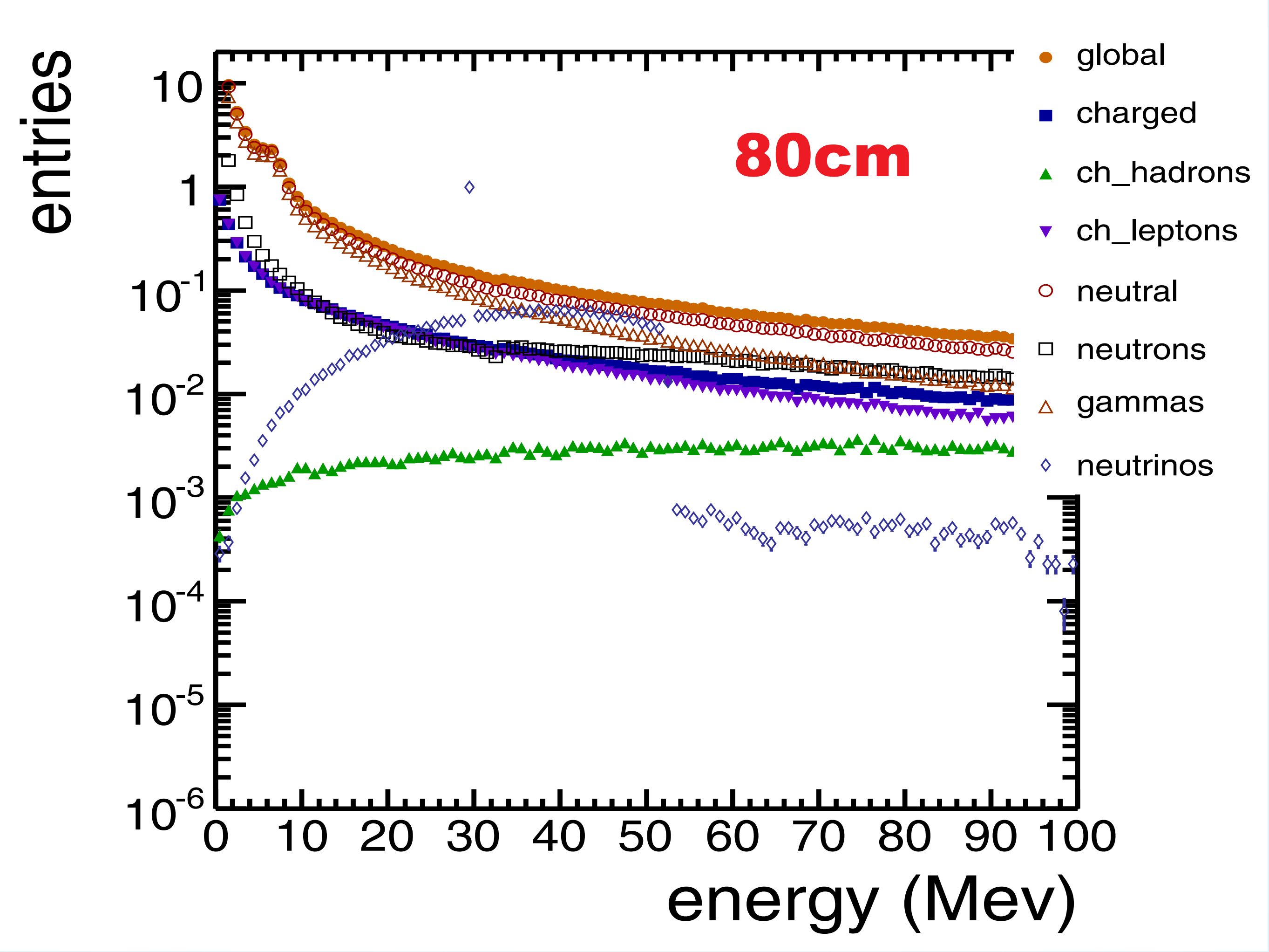

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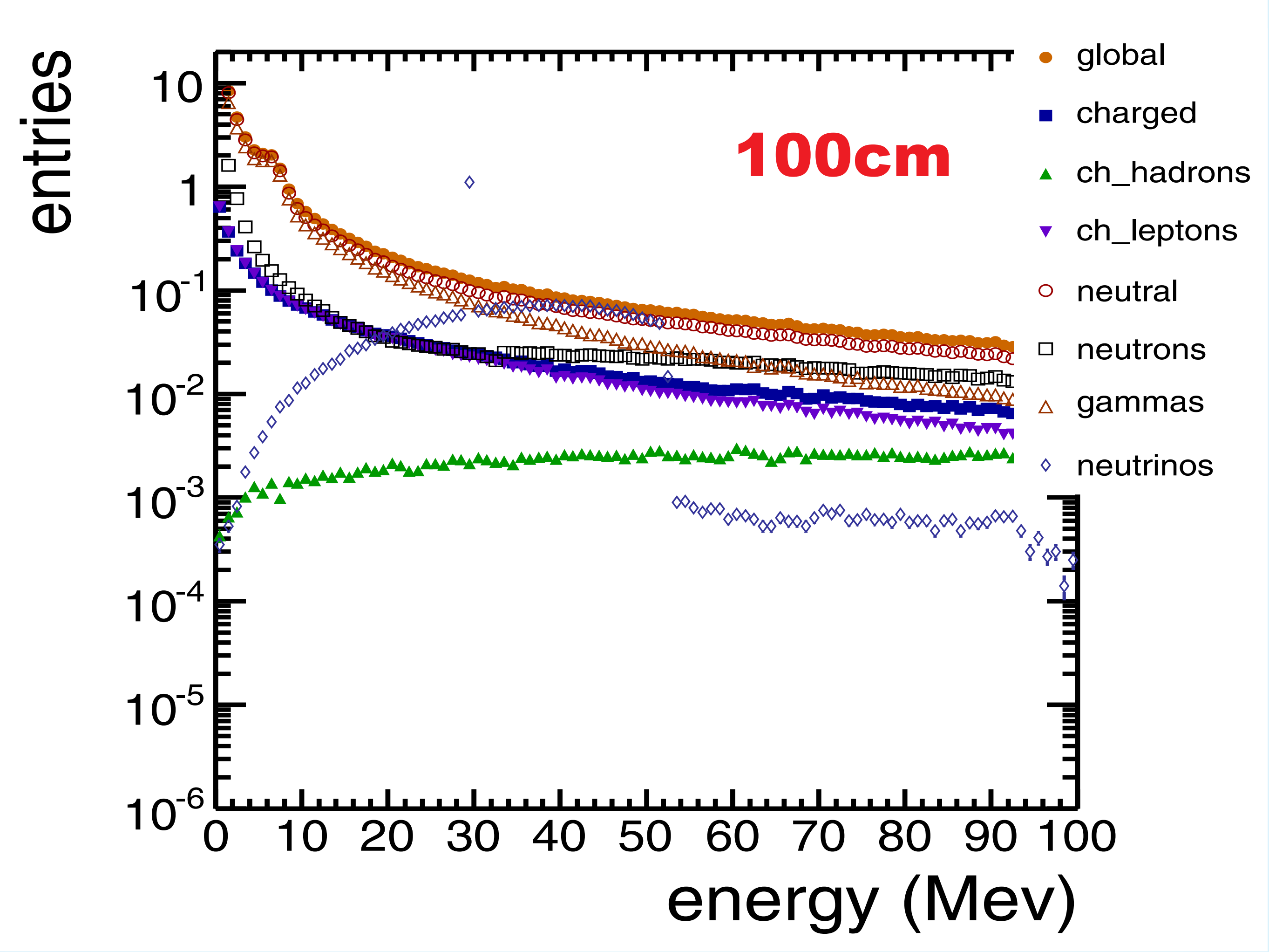

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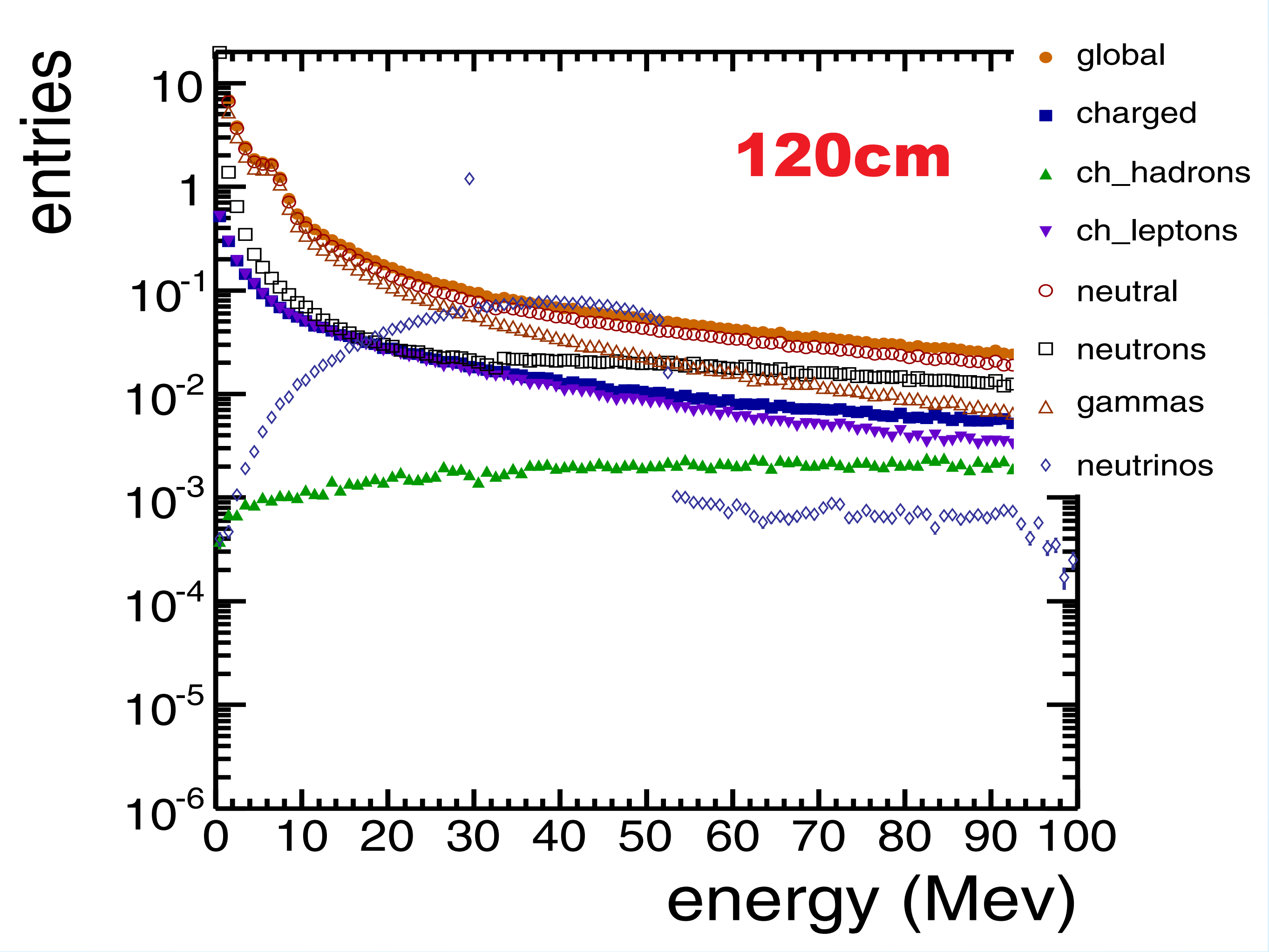

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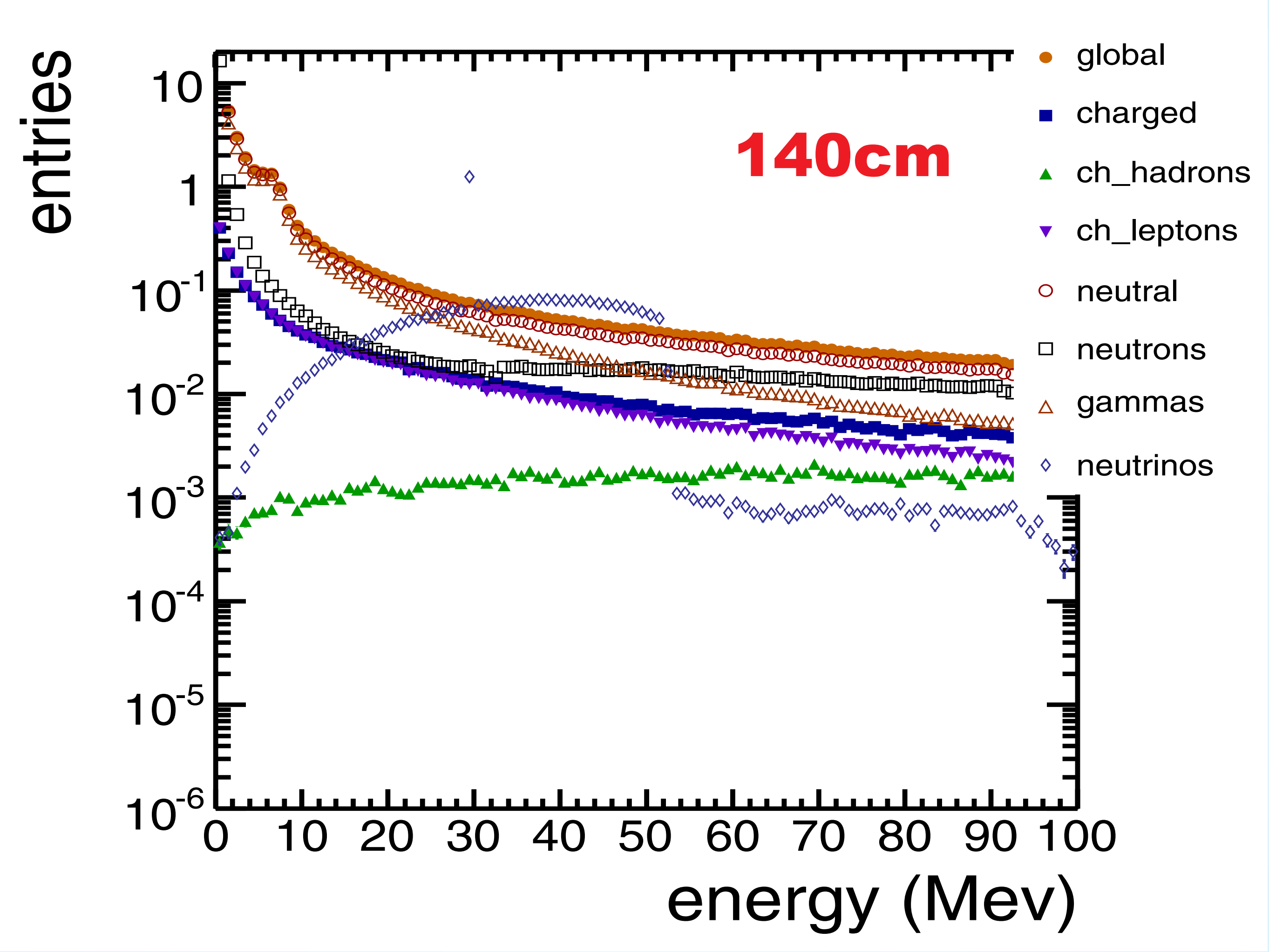

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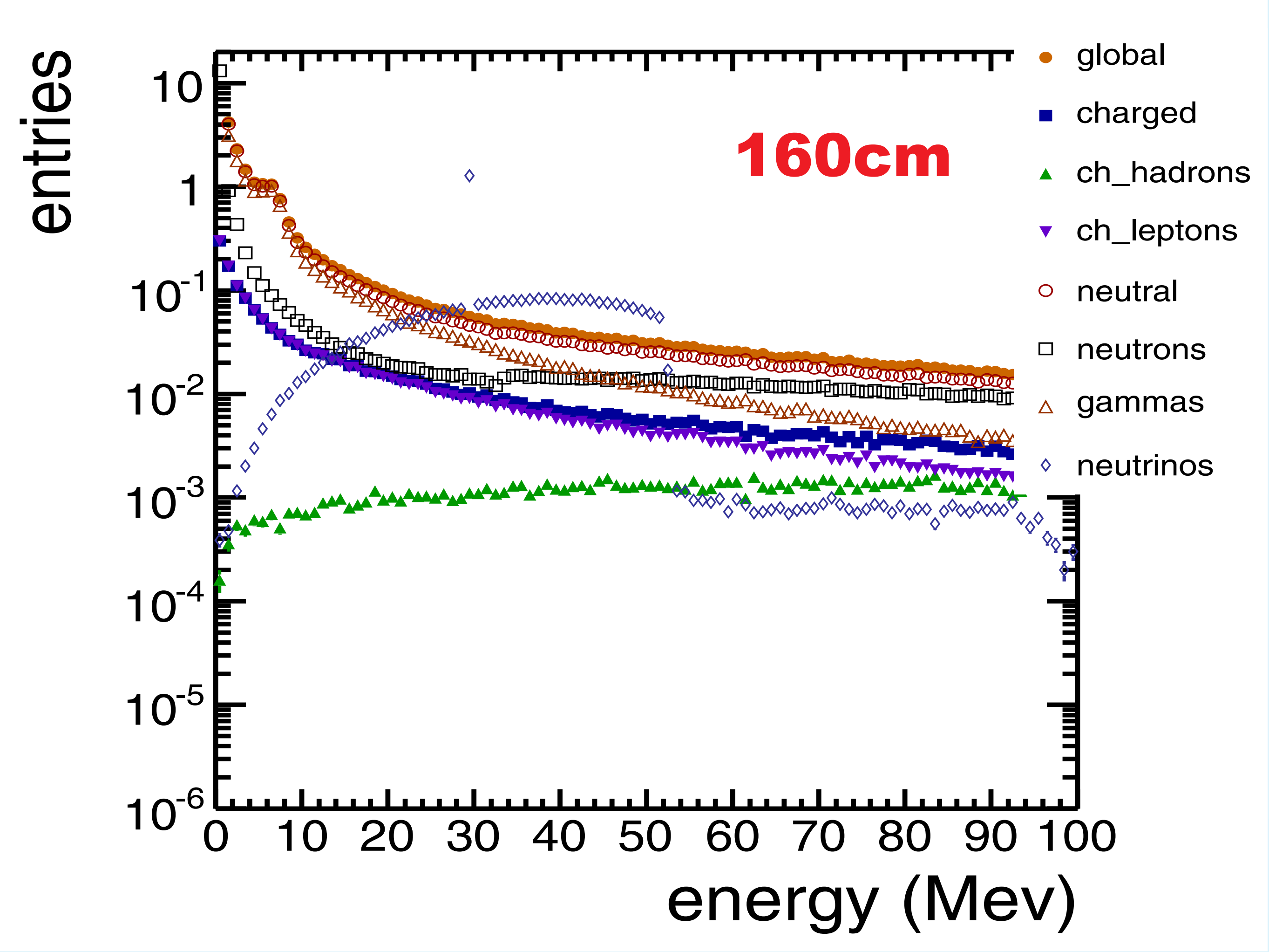

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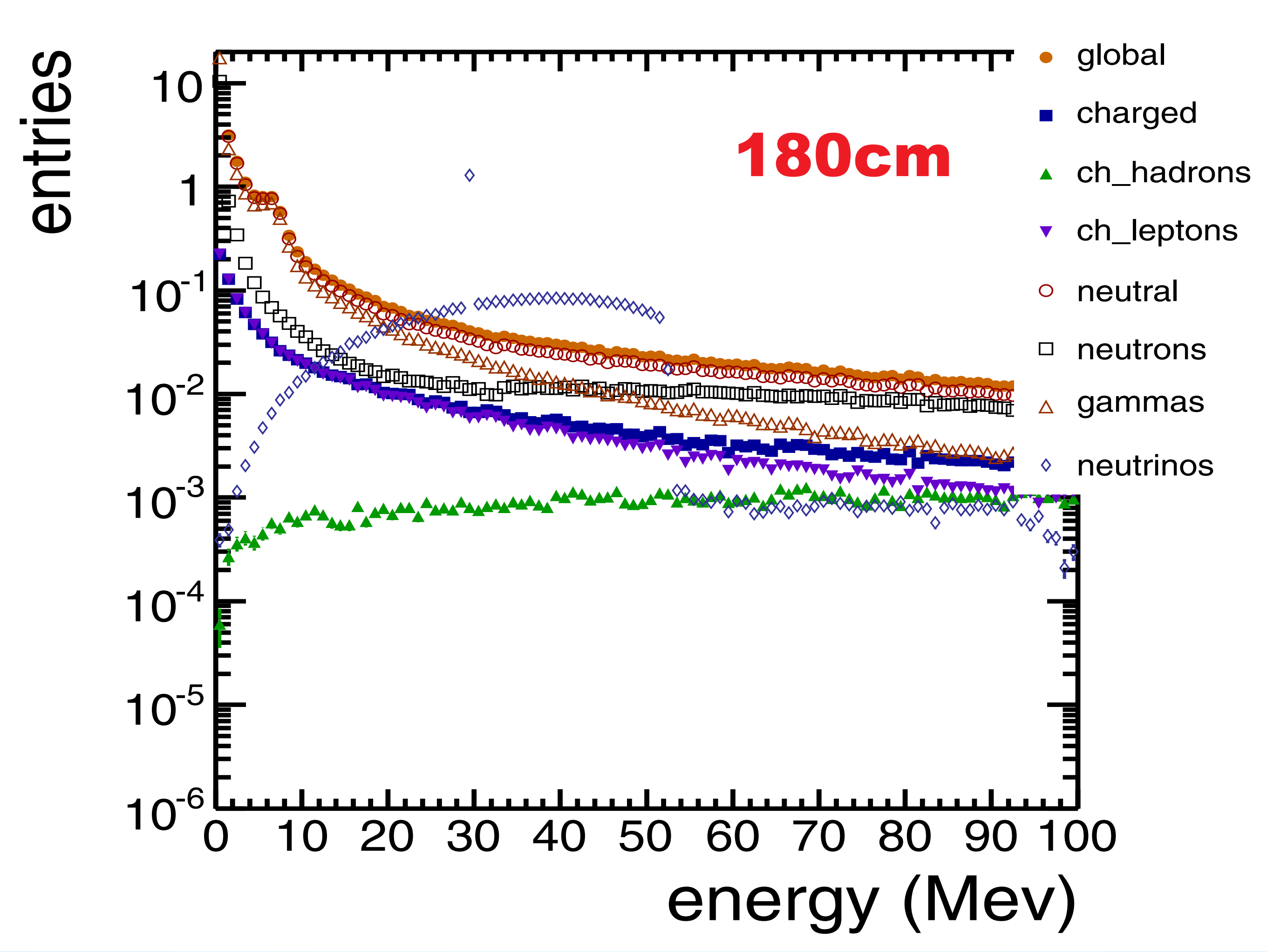

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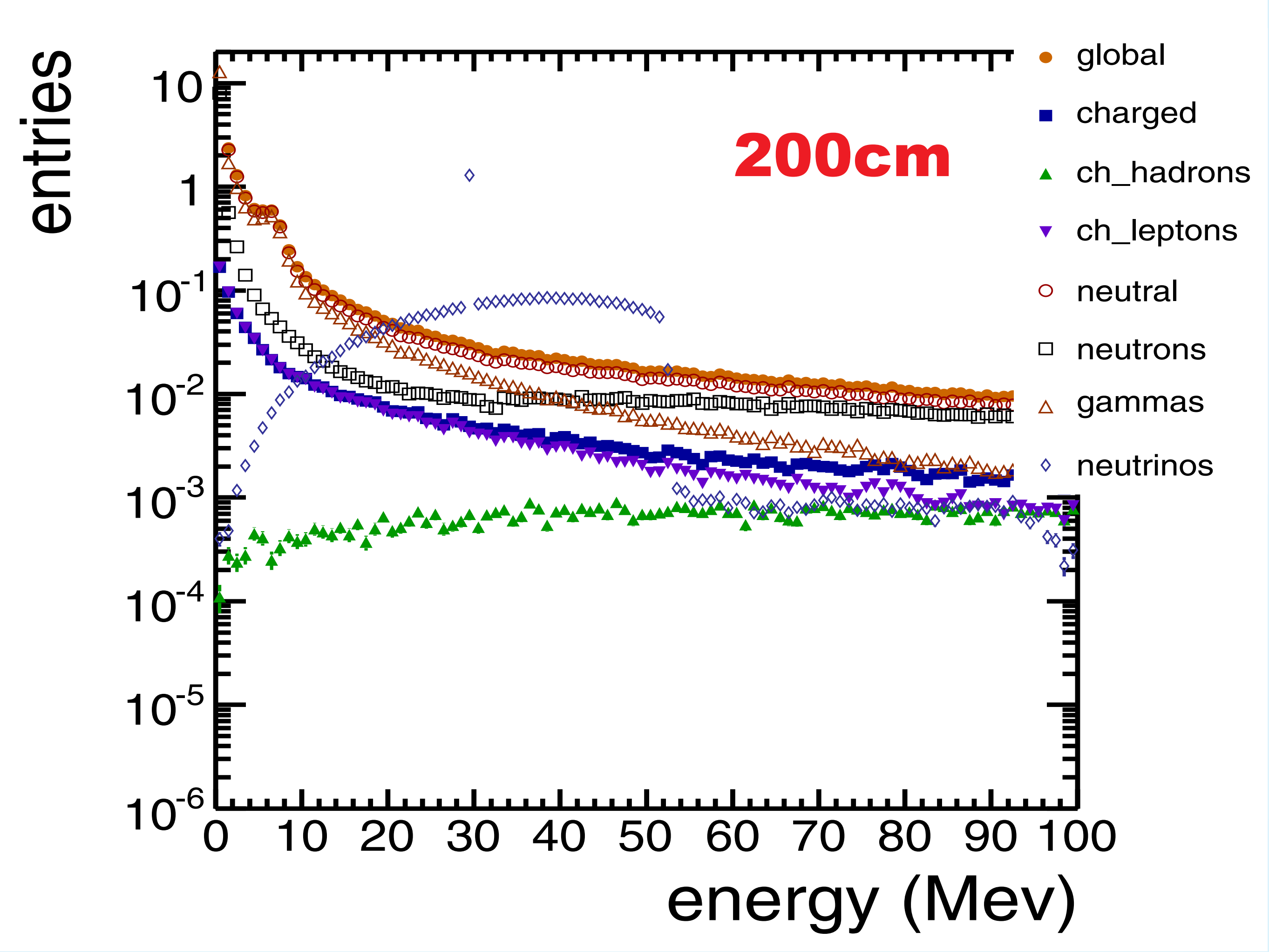

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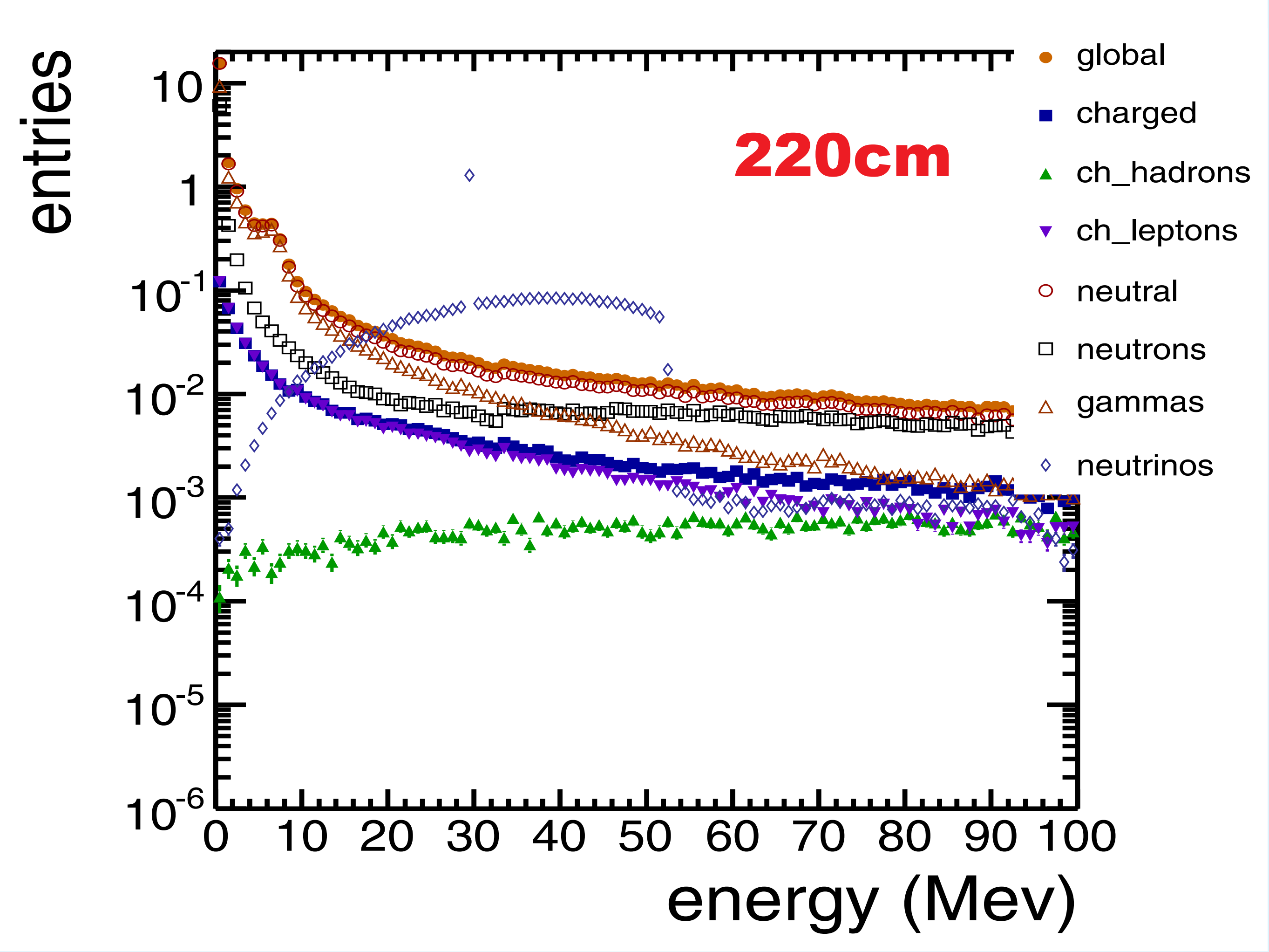

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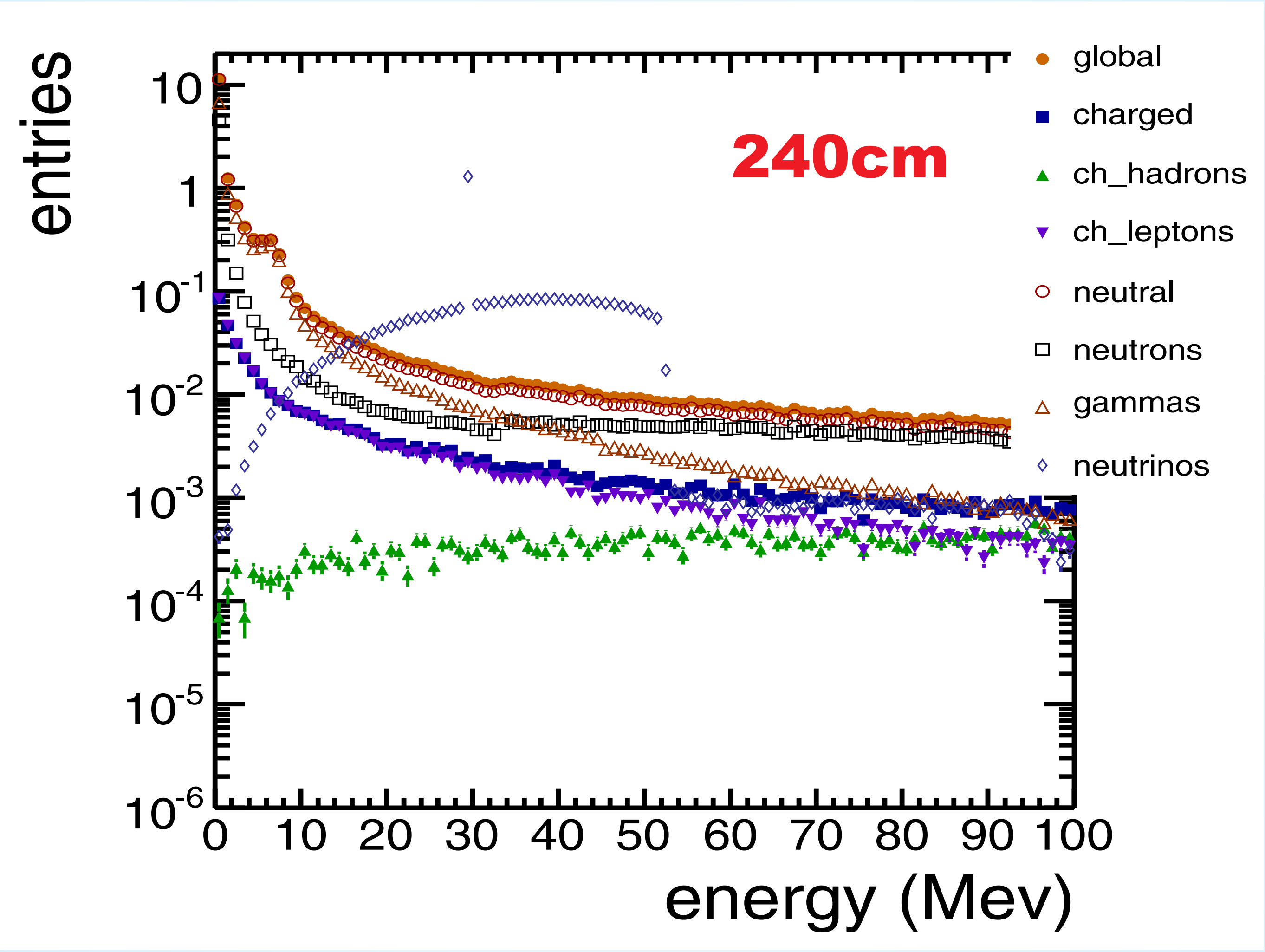

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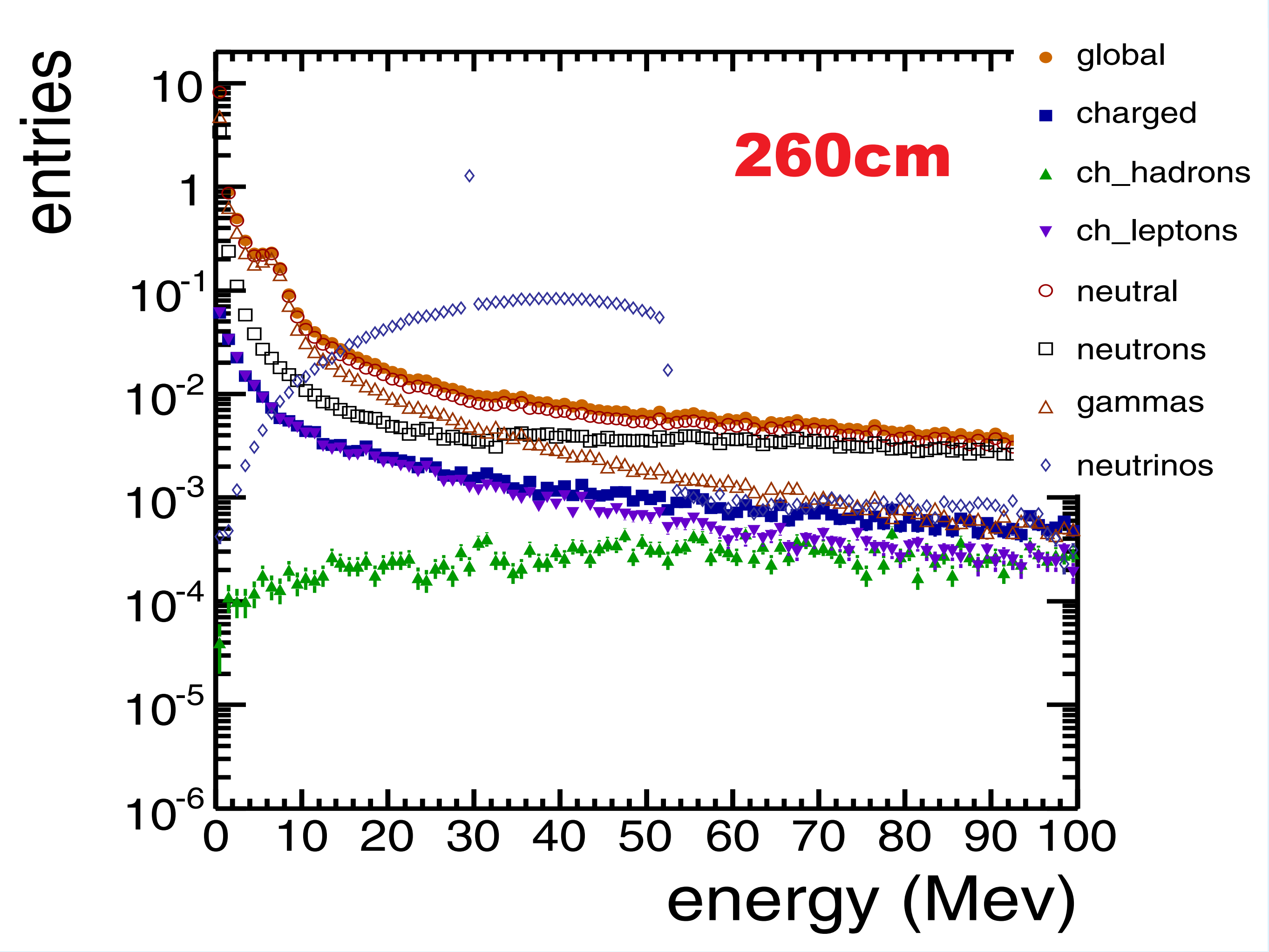

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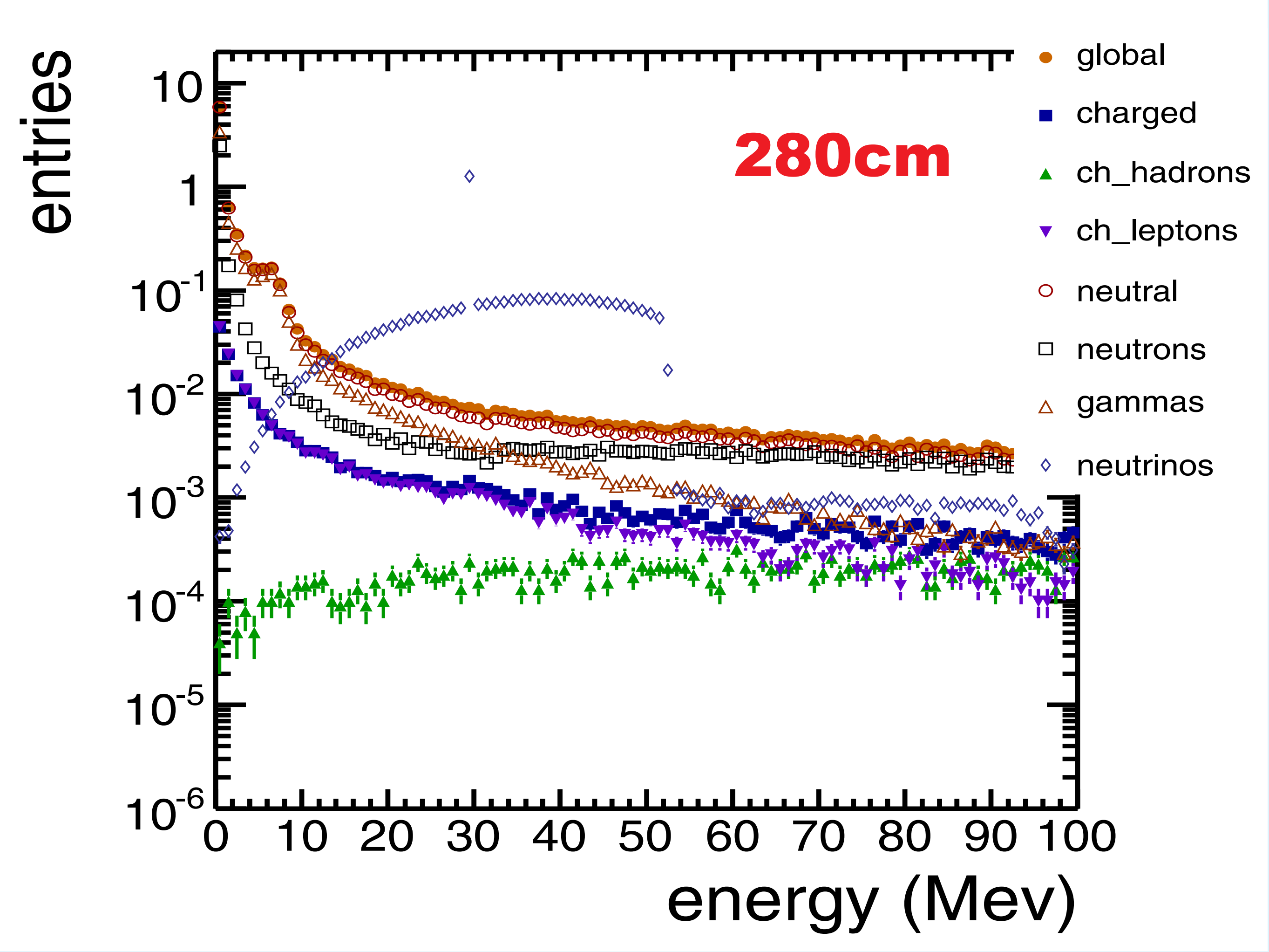

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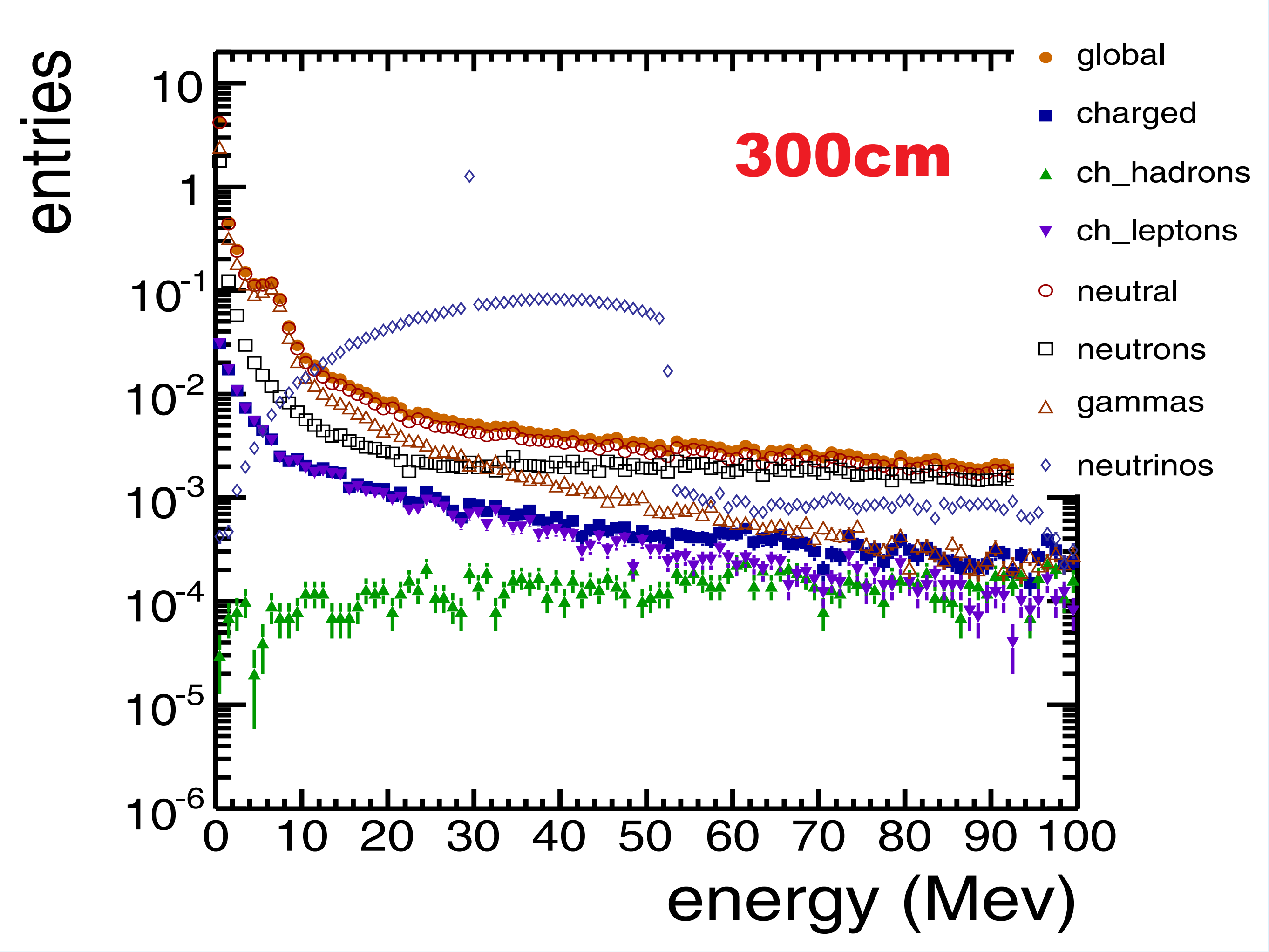

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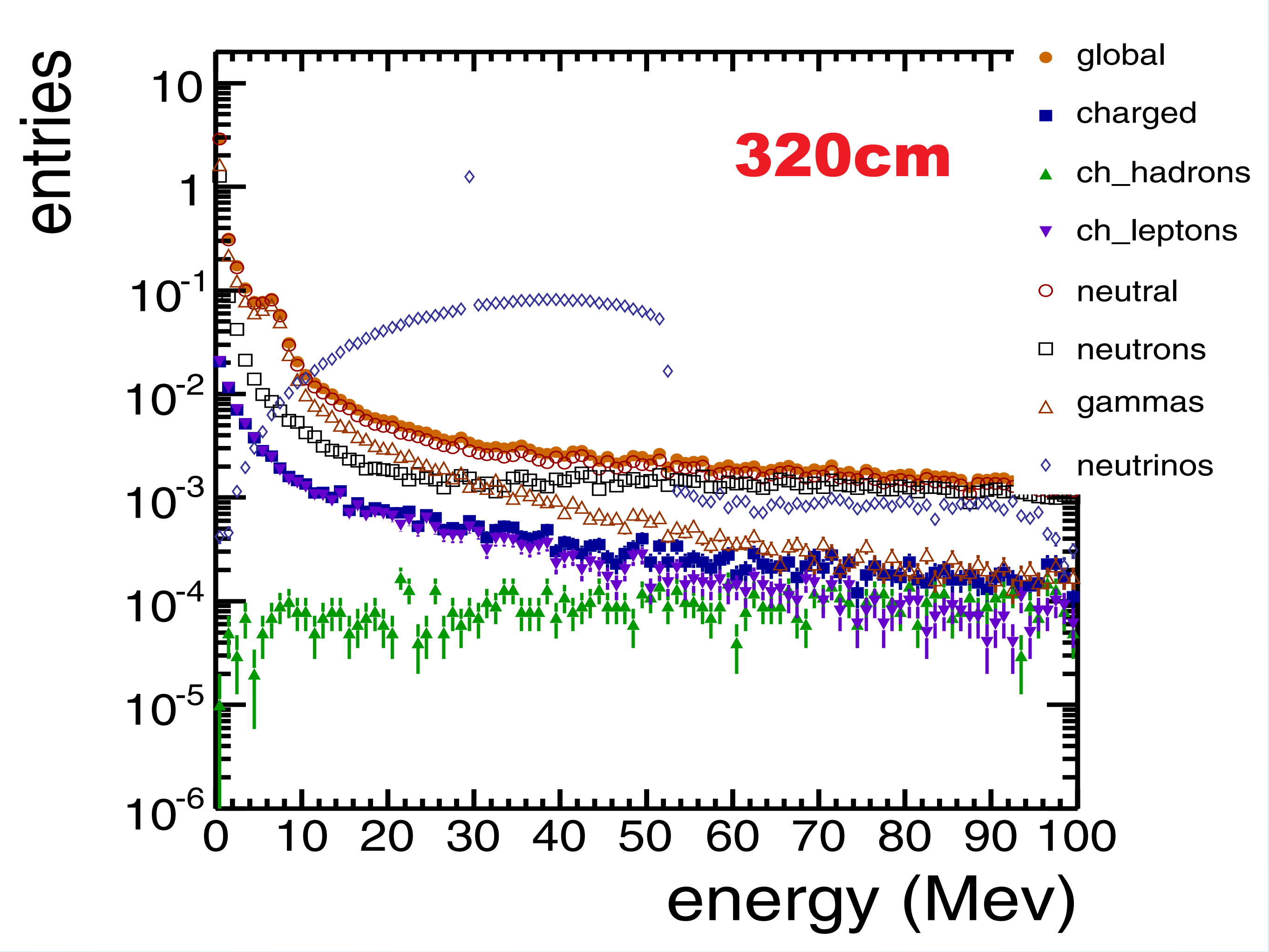

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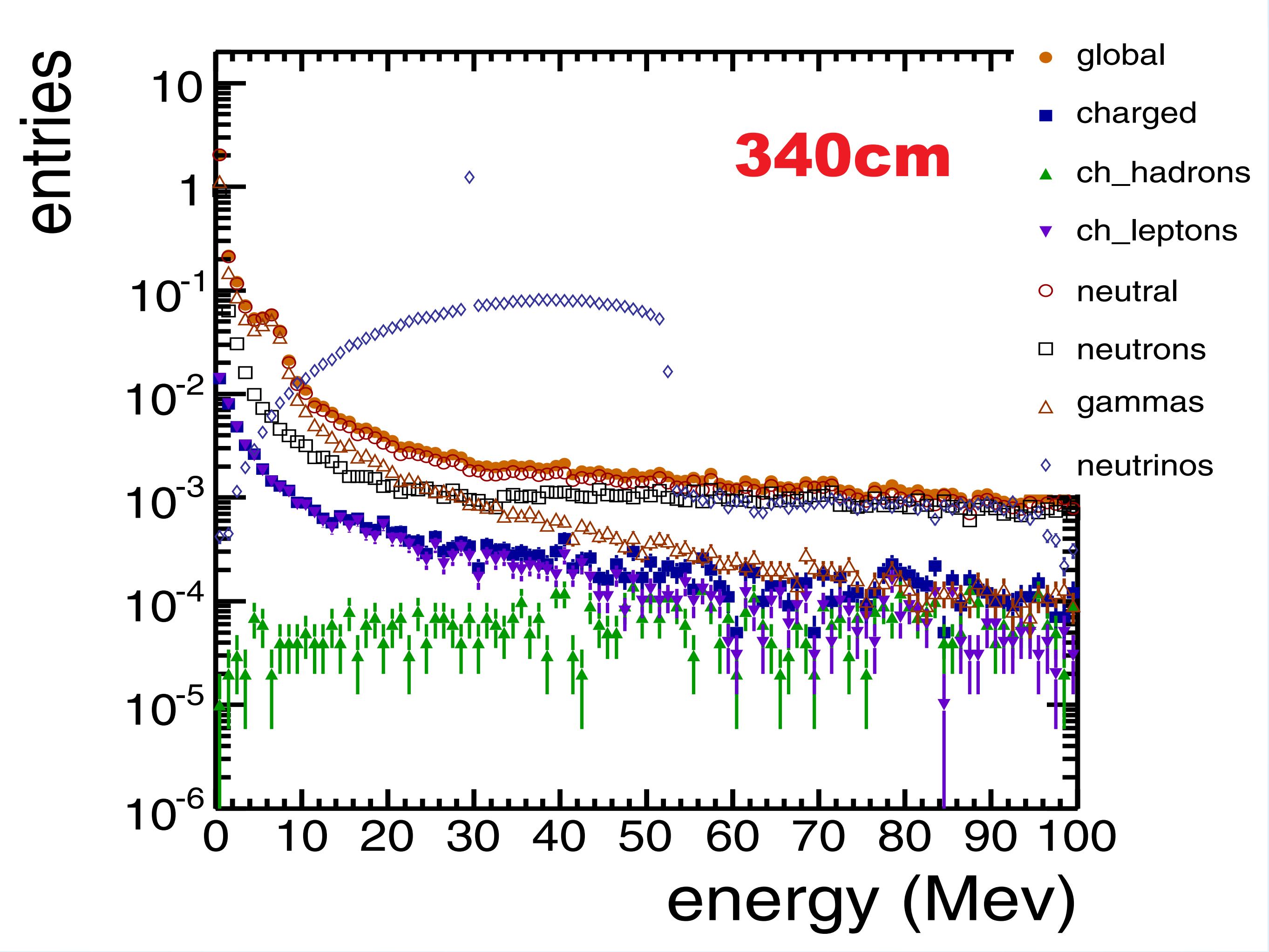

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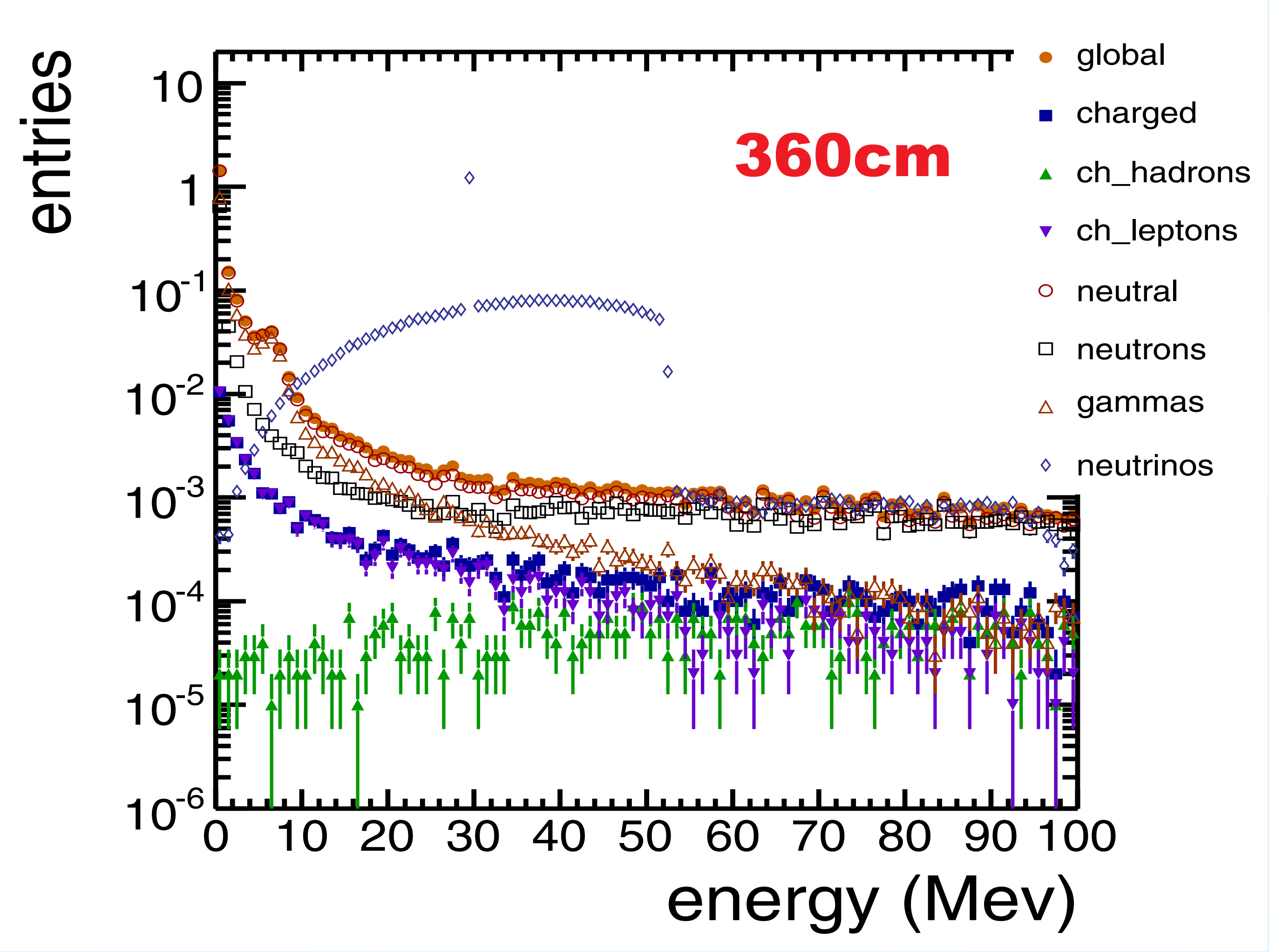

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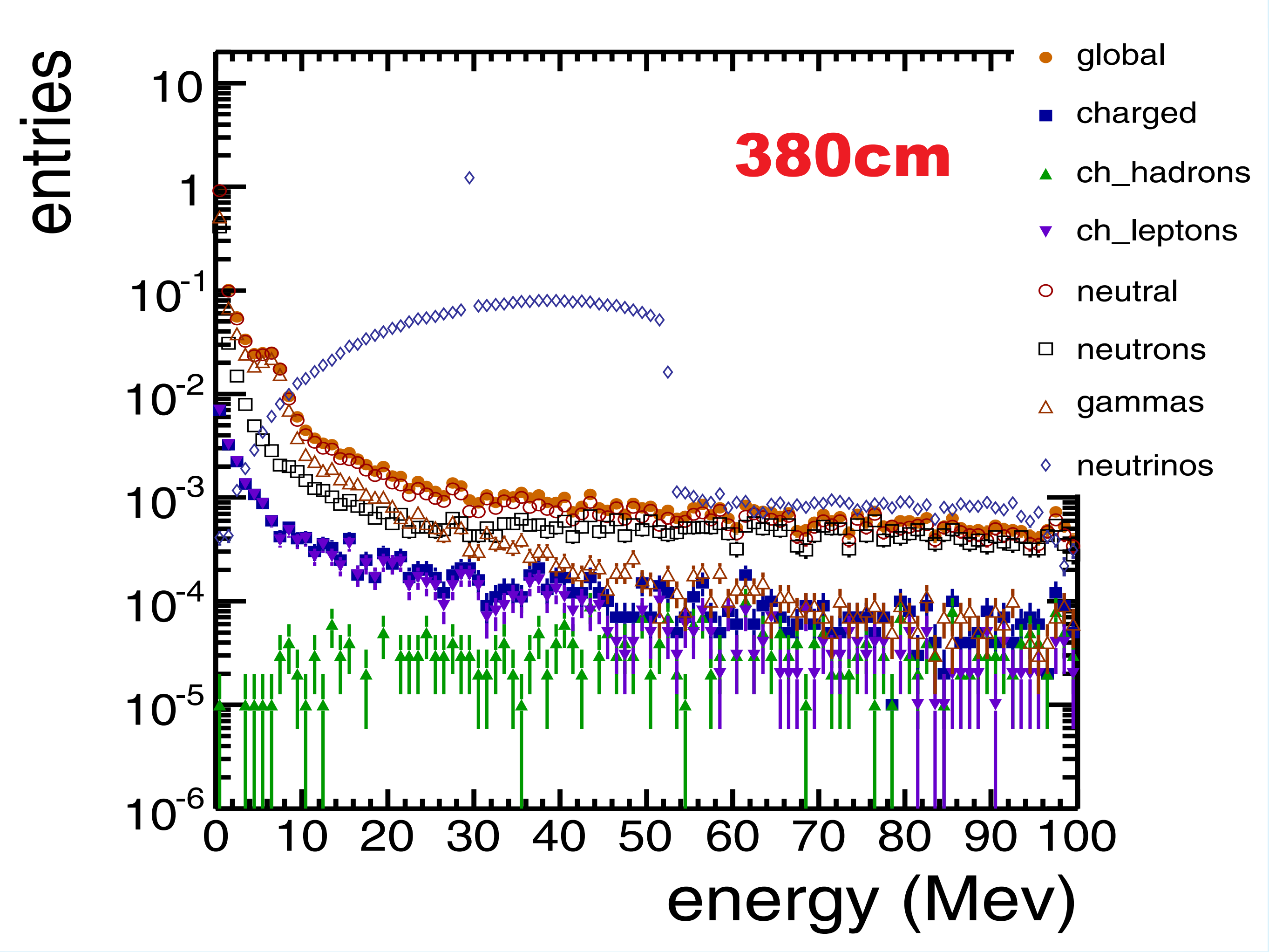

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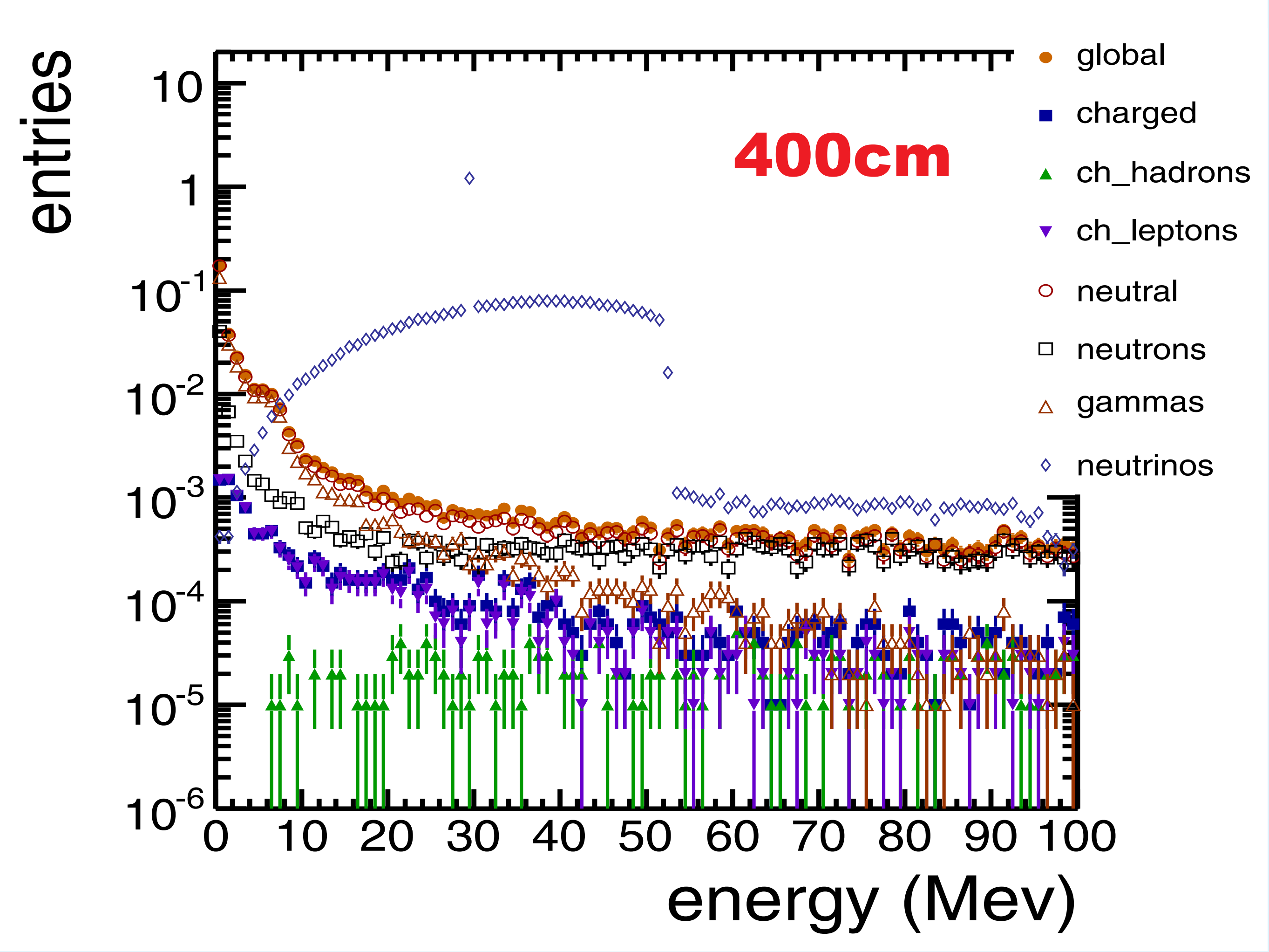
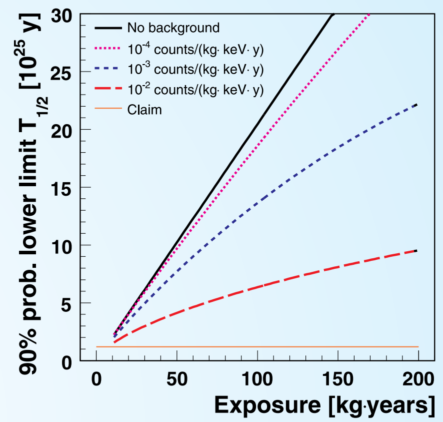


[In]Famous Last Words

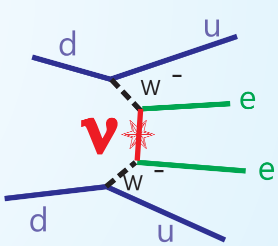
A 1t experiment will be all about background.

I am absolutely not convinced that 1 ton Ge experiment makes sense.



New technology will be needed together with a gigantic amount of simulation and screening.

Germanium probably only makes sense, if it addresses more than physics question.



Possibilities to combine technologies should be investigated, also to use the infrastructure optimally.

Absolutely no compromises !

There might be better places to waste time.