New neutron long-counter on the Lohengrin spectrometer

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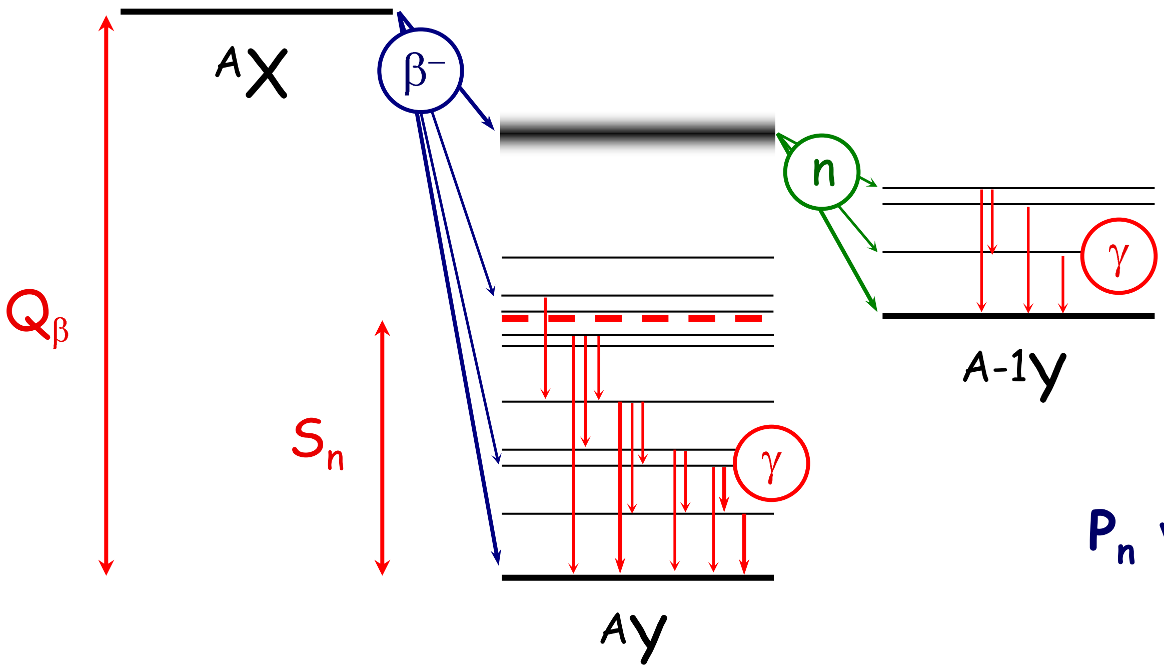
Presentation



P_n = ratio of (β^-,n) decay over total β^- decay

P_n value is a **nuclear data**
Independant of the fissionning system

Requierement: $Q_\beta > S_n$

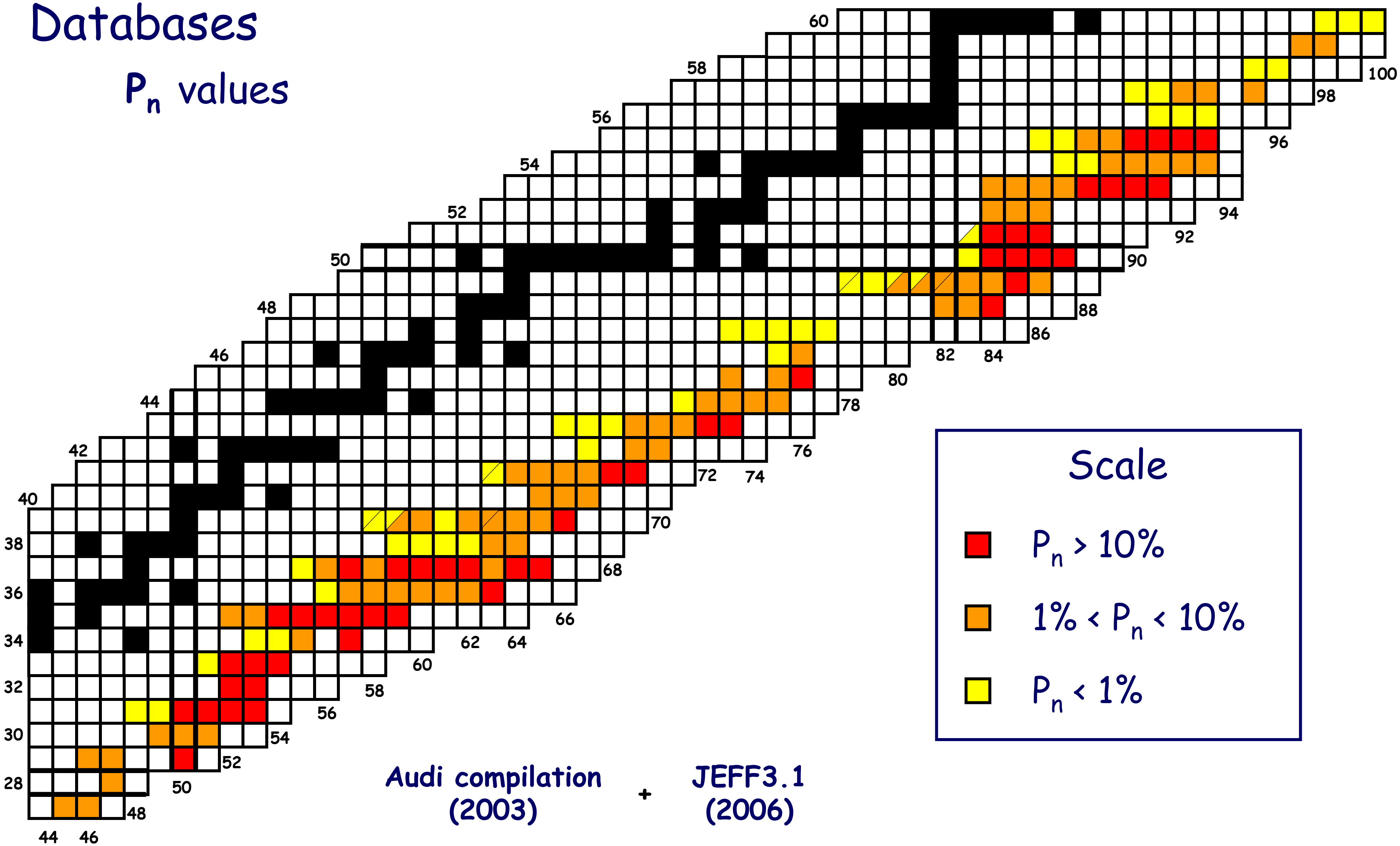
S_n low and **Q_β high** for neutron-rich nuclei

➡ P_n value increases far from stability

I- P_n and ΔP_n

Databases

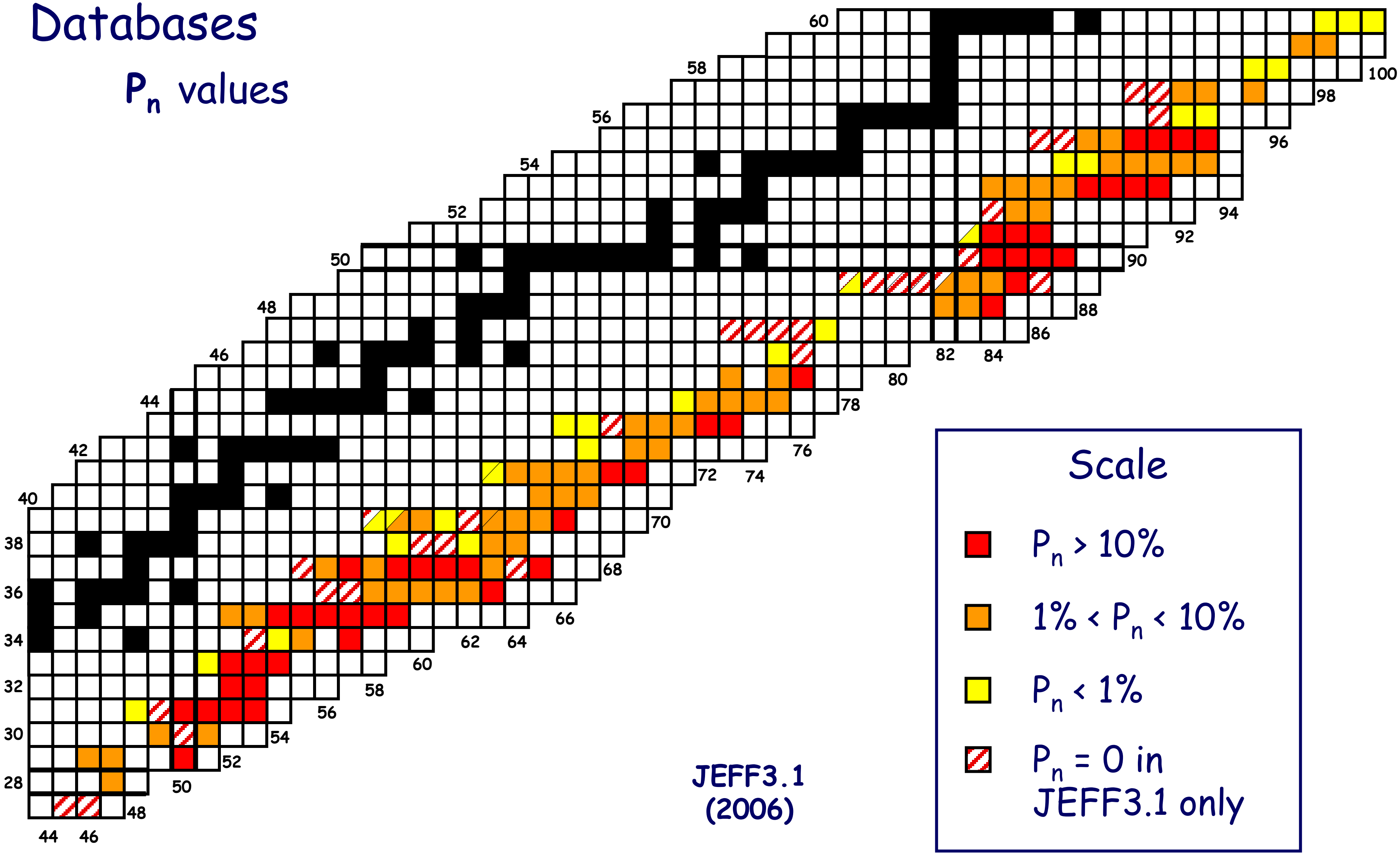
P_n values



Audi compilation (2003) + JEFF3.1 (2006)

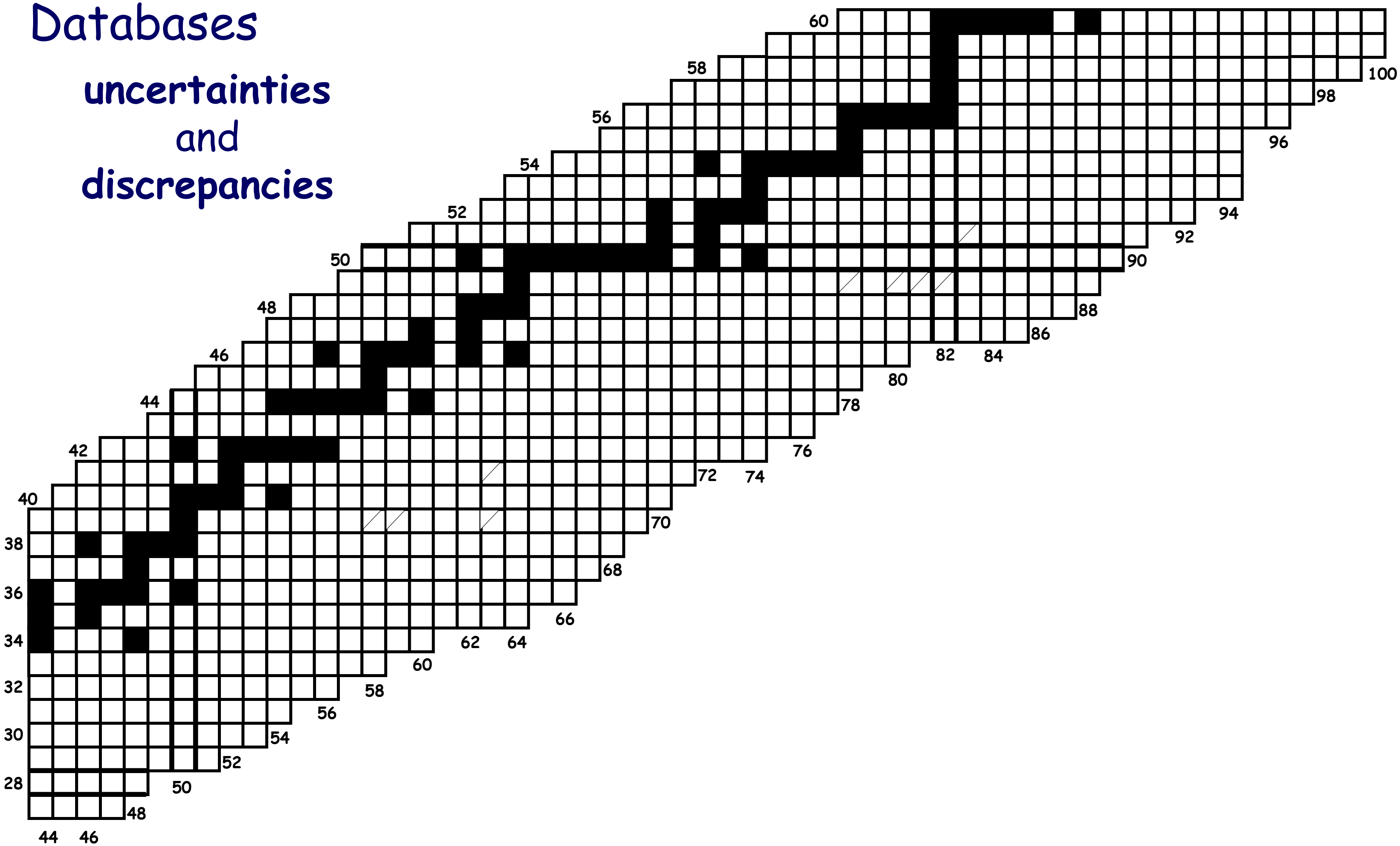
Databases

P_n values



Databases

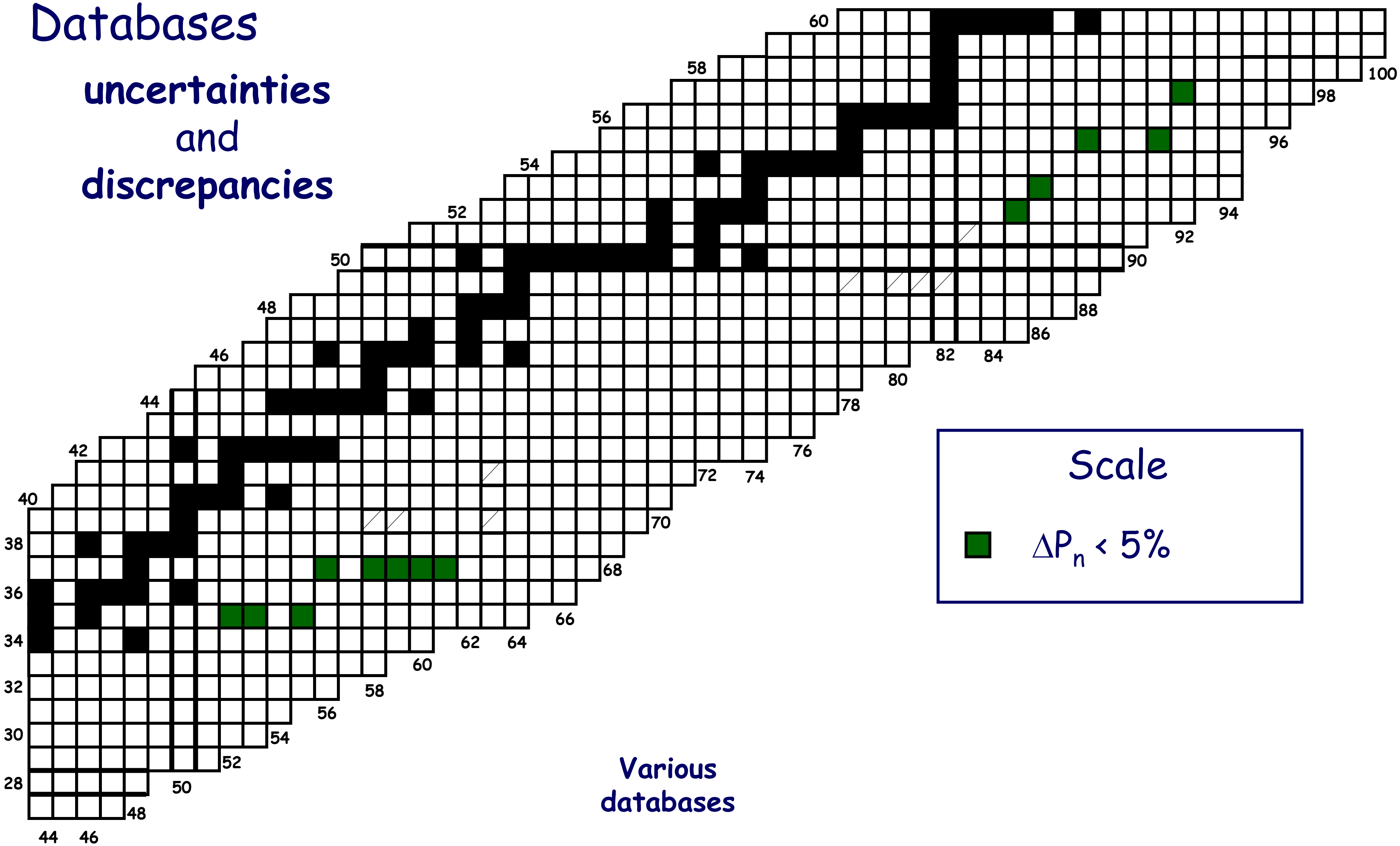
uncertainties and discrepancies



I- P_n and ΔP_n

Databases

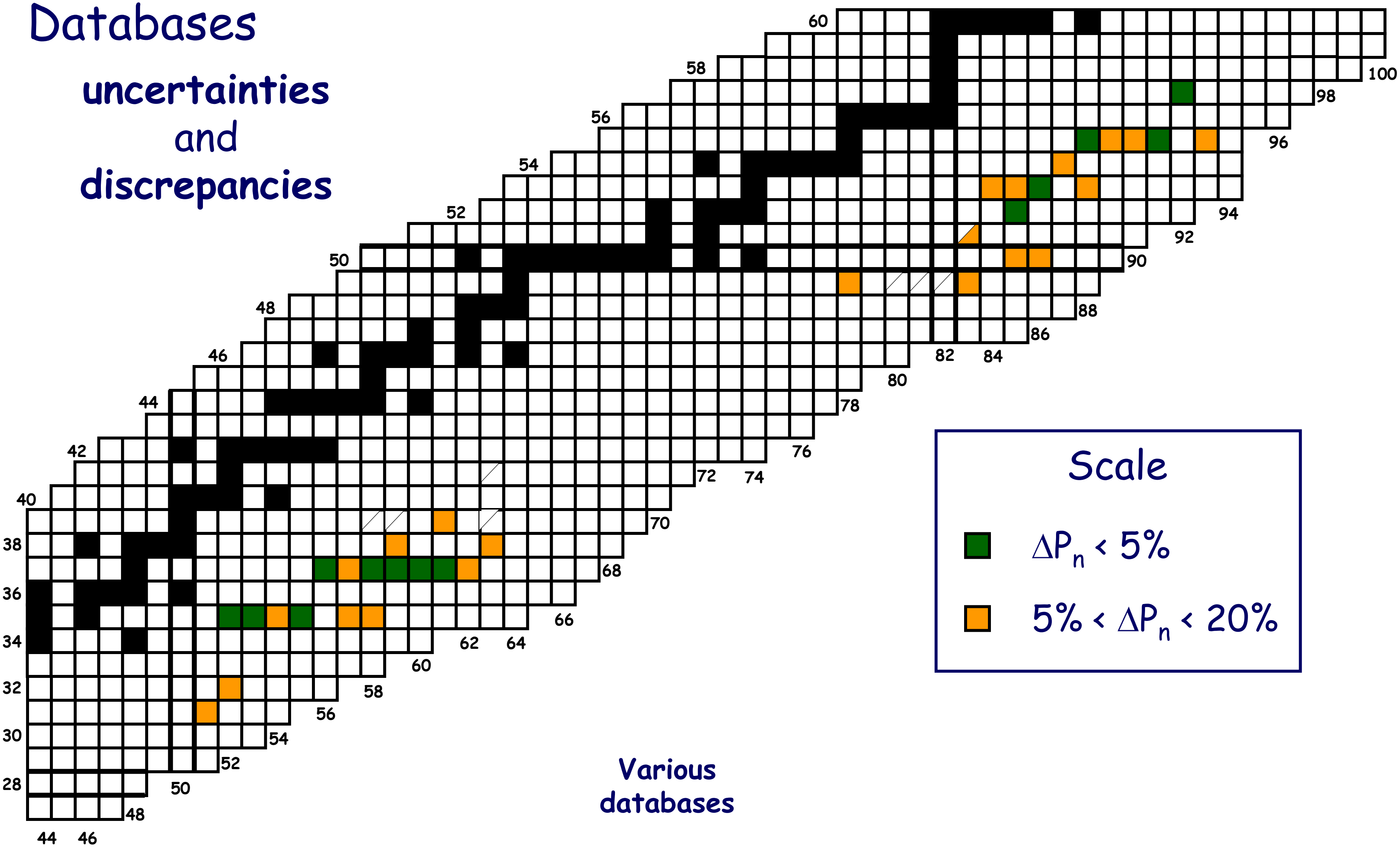
uncertainties and discrepancies



Various databases

Databases

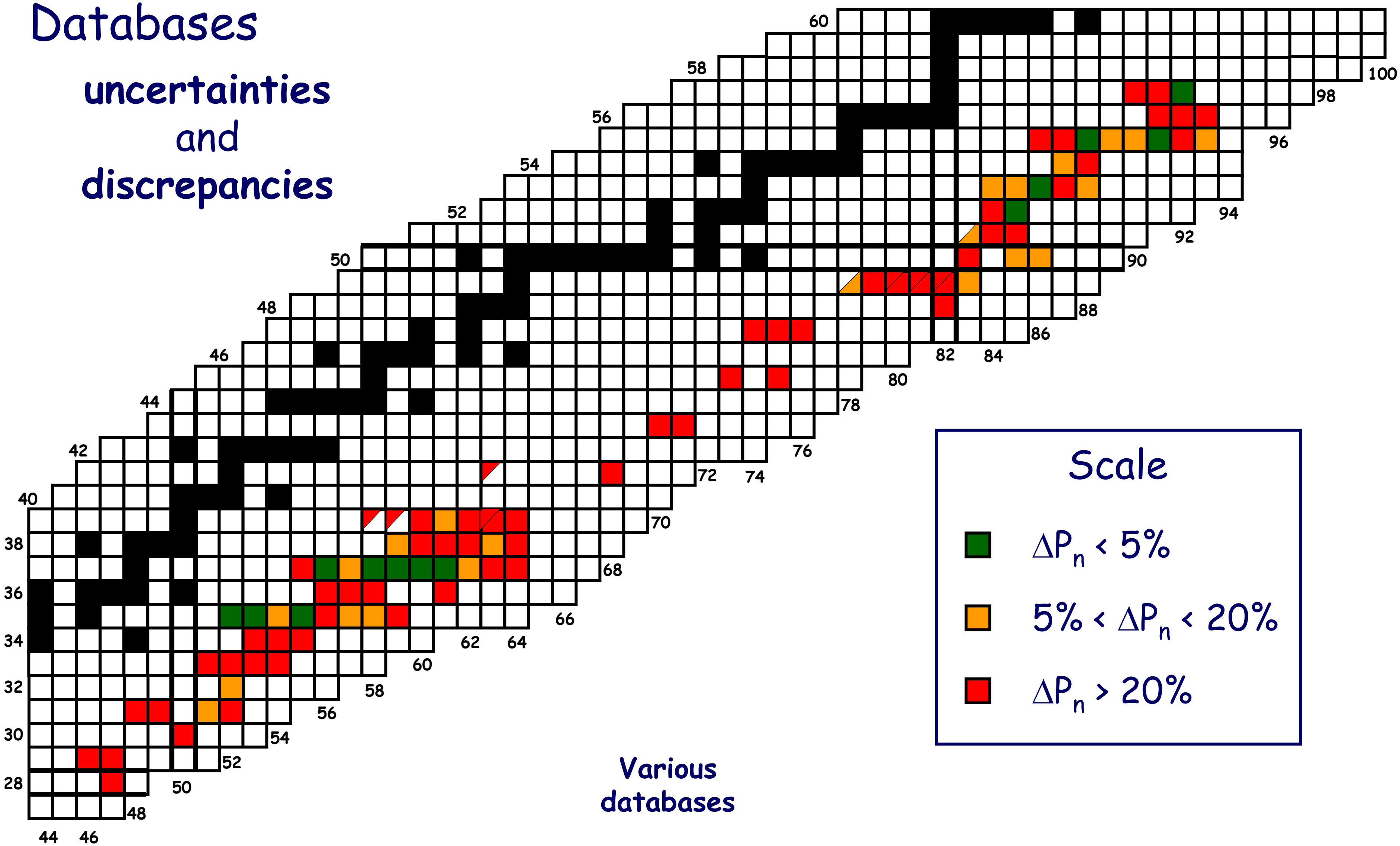
uncertainties and discrepancies



Various databases

Databases

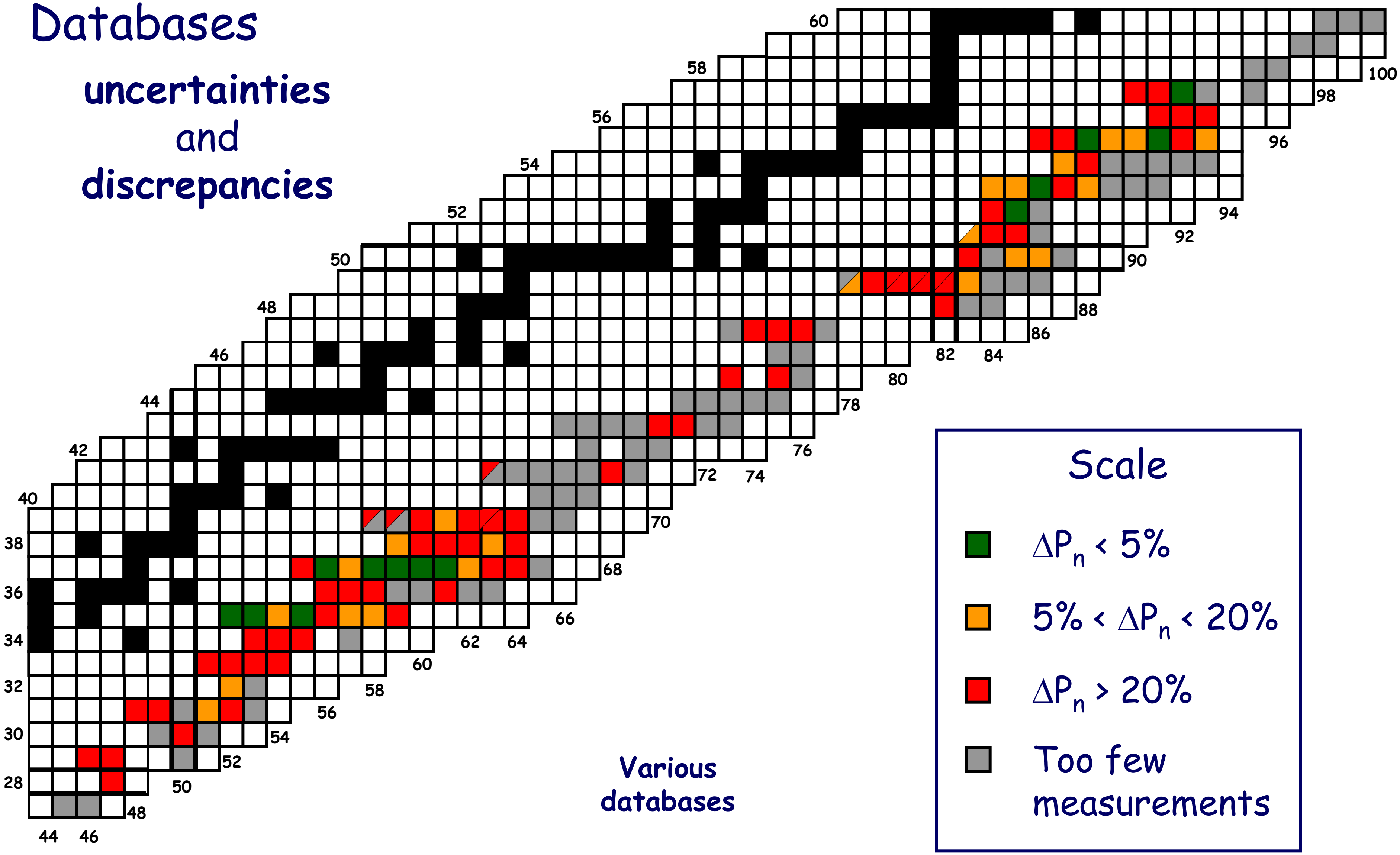
uncertainties and discrepancies



Various databases

Databases

uncertainties and discrepancies

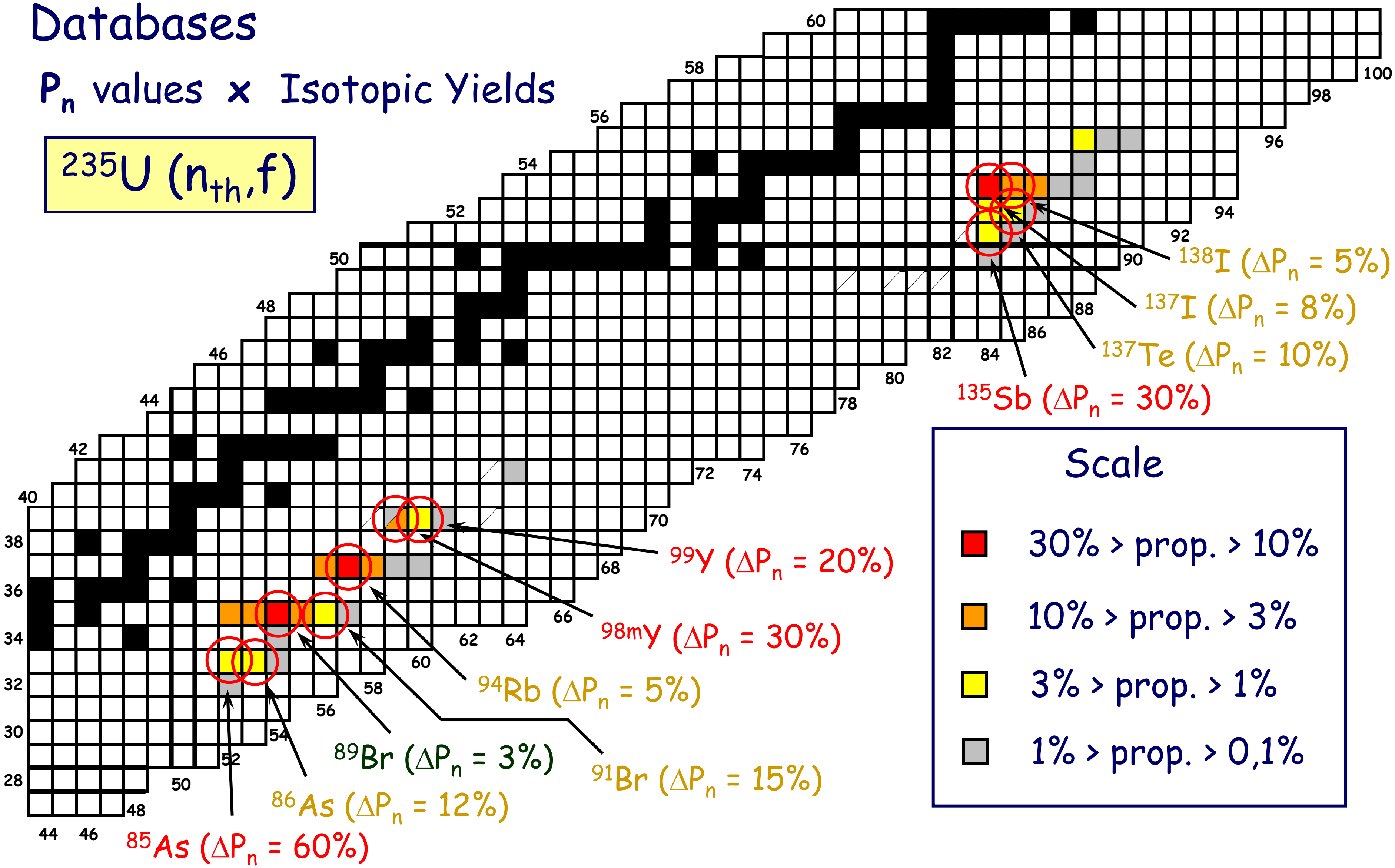


I- P_n and ΔP_n

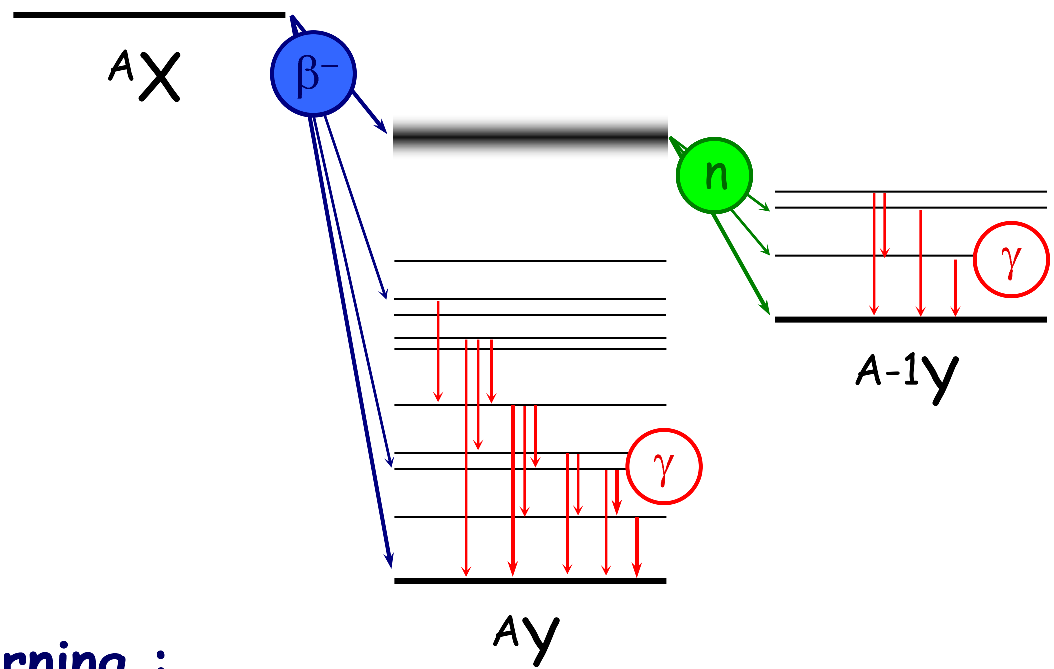
Databases

P_n values × Isotopic Yields

^{235}U (n_{th},f)



Neutron – Beta spectrometry



P_n = ratio of (β^-,n) decay over total β^- decay

$$P_n = \frac{n}{\beta}\,\frac{\varepsilon_\beta}{\varepsilon_n}$$

Not known: determined with well known P_n values

Warning :

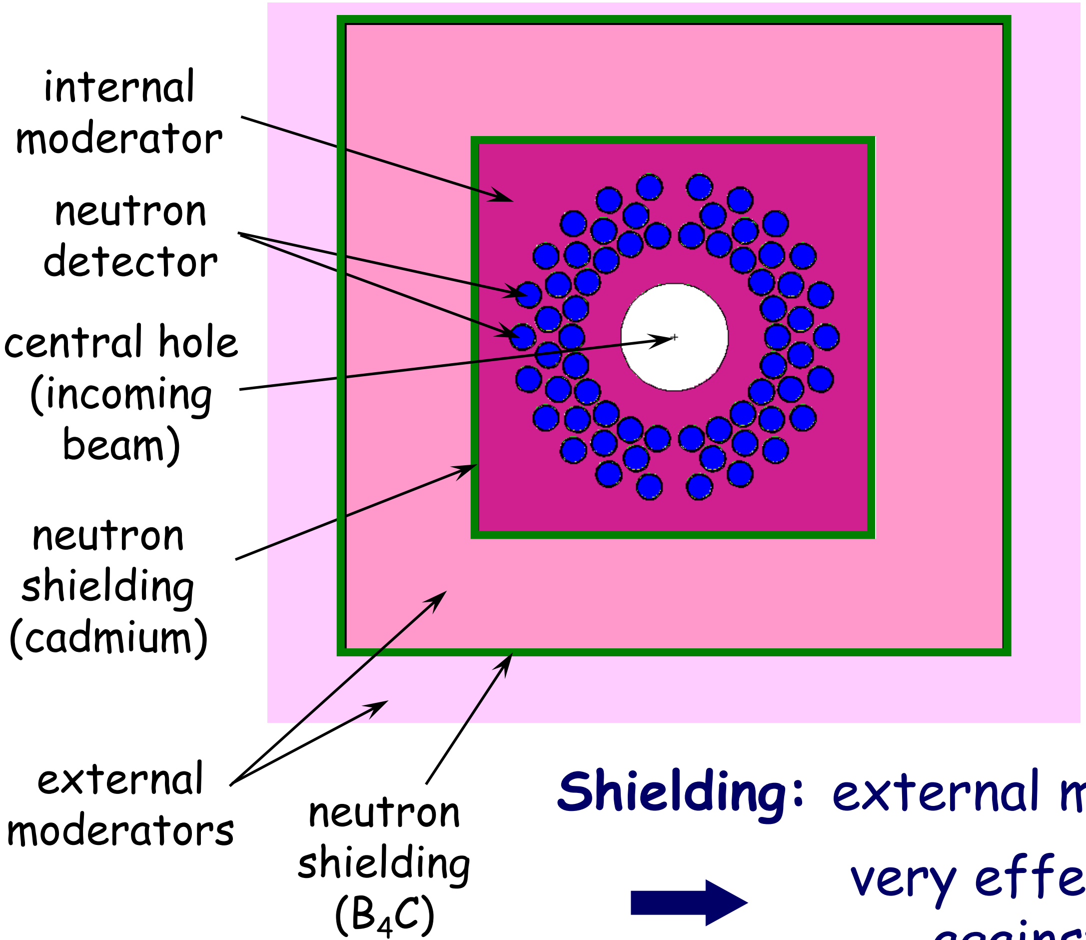
$\frac{\varepsilon_\beta}{\varepsilon_n}$ must be **constant**

➡ ε_β and ε_n must be constant

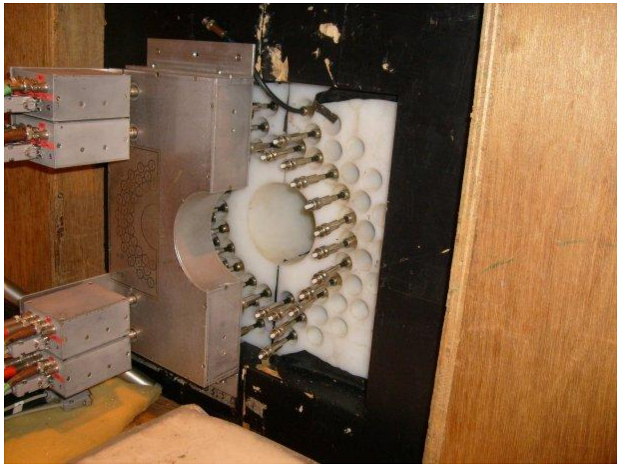
➡ specific design of detectors

Usual design

Example of the Kratz's long-counter



Picture of the Kratz's long counter



Several rings:
- maximum efficiency
- information on neutron energy (via ring ratio calculations)

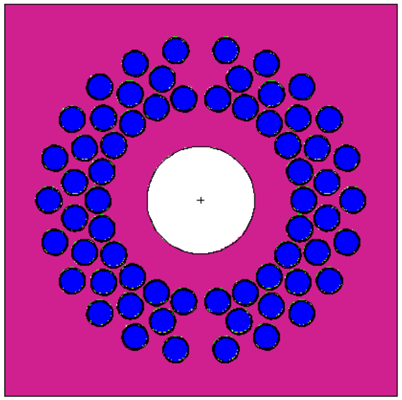
Shielding: external moderator + neutron absorber

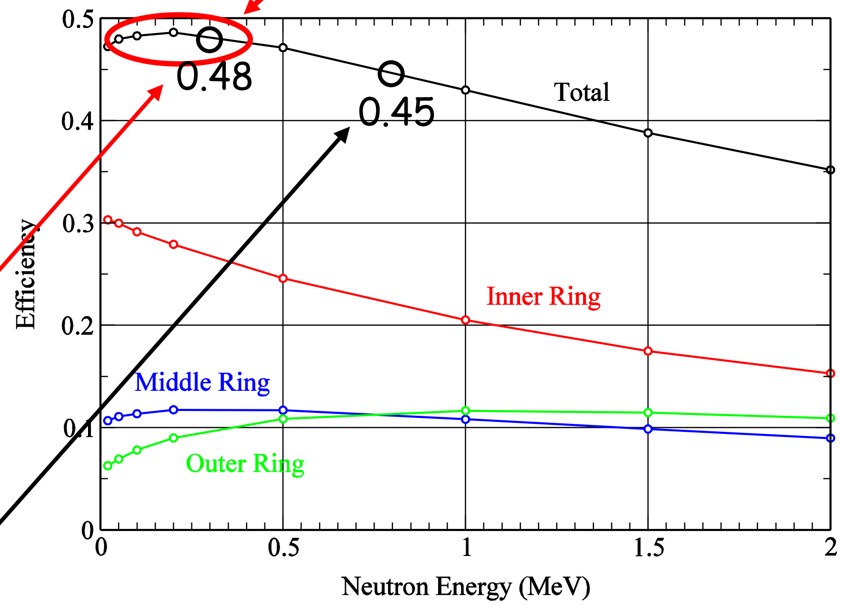
→ very effective **background reduction** against **slow** and **fast** neutrons

II- Method and detectors

Efficiency curves

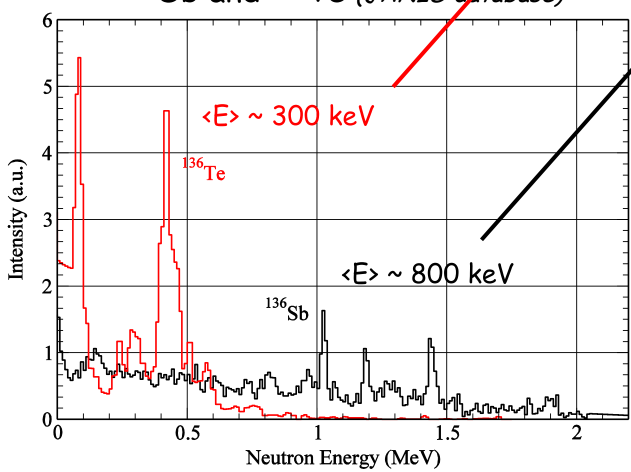
Simulations with MCNP code





Neutrons of **low energy** favorized

Delayed neutron spectrum of ^{136}Sb and ^{136}Te *(JANIS database)*



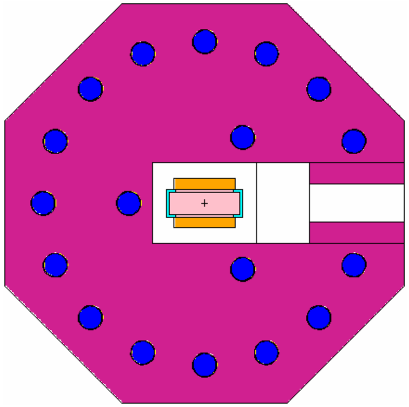
➡ Difference of 6% on ε_n

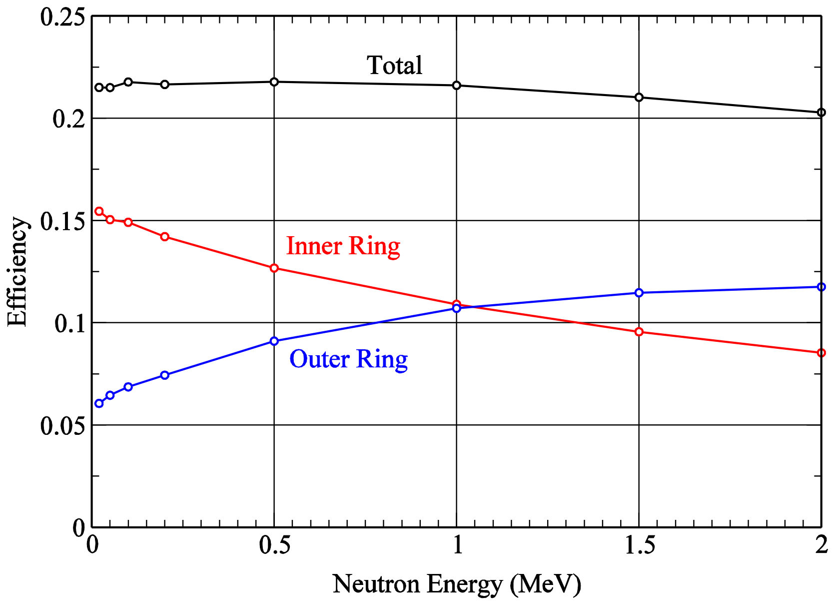
Kratz's long-counter:
optimized for efficiency

New detector design

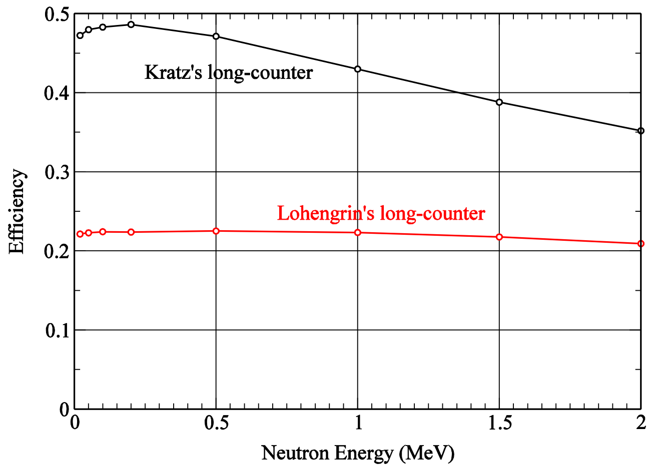
Simulations with MCNP code

Lohengrin's long-counter





Kratz's VS Lohengrin's



➡ Negligible differences in ε_n **up to 1 MeV**

Lohengrin's long-counter: lower efficiency but better characteristics for P_n measurements

Experiment on the Lohengrin spectrometer

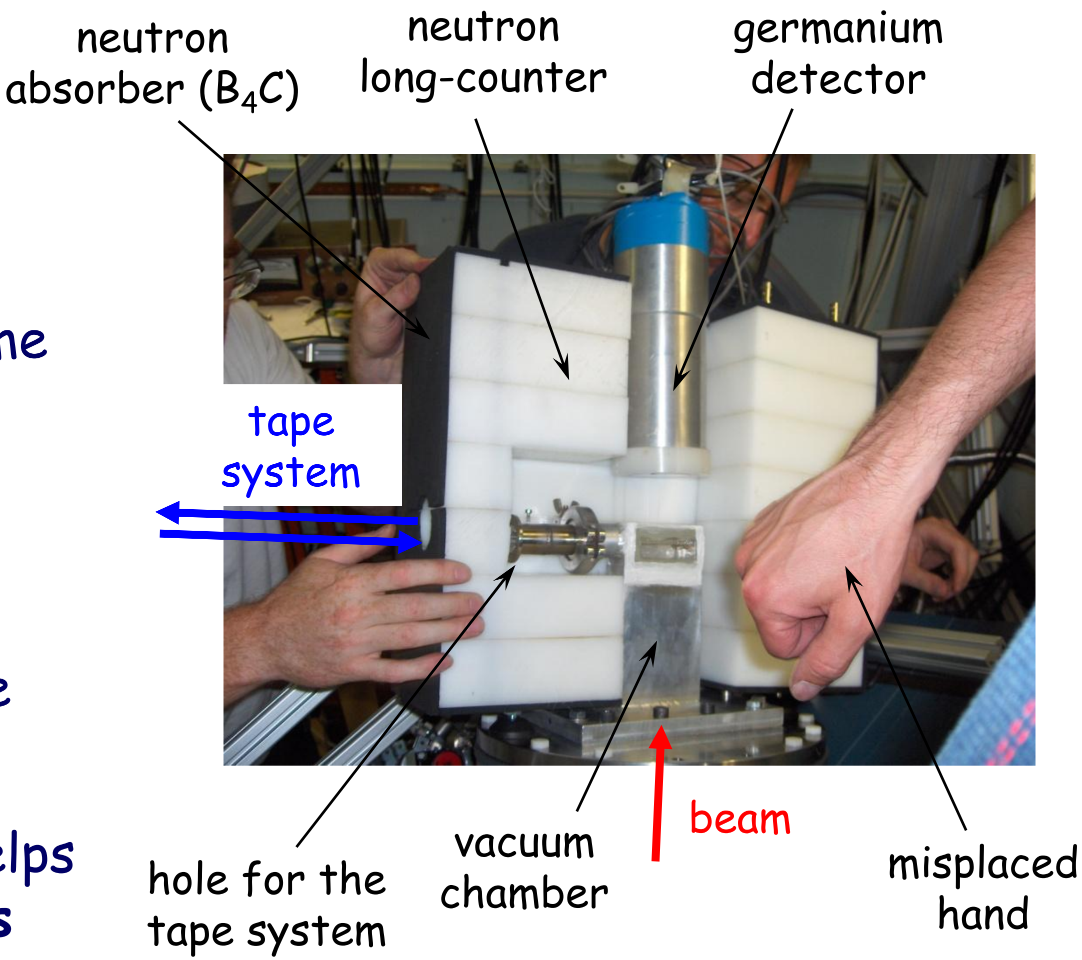
Hybrid method:
- neutron long-counter
- germanium detector

Mass separation:
Several isotopes in the same mass chain

→ Analysis of the **decay curves**

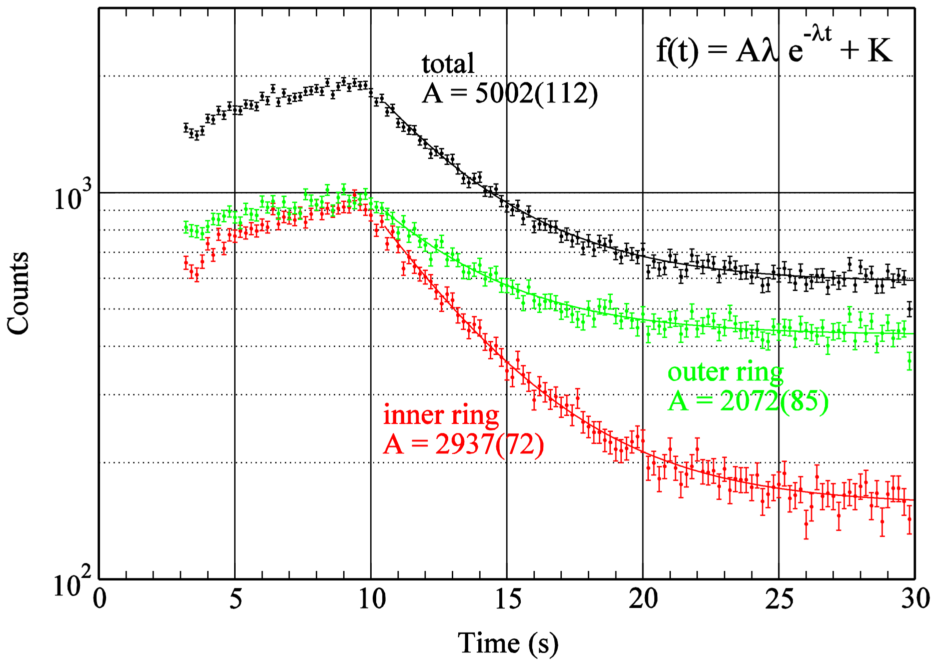
→ **Tape system** to remove long-lived nuclei

→ Germanium detector helps to **detect contaminants**



First Results: a strong emitter

^{94}Rb : $T_{1/2}$ = 2,7s, P_n = **10,5(5)%**



Ring counting rate:

τ 3 inner tubes > τ 15 outer tubes

➡ 3 tubes is not that small

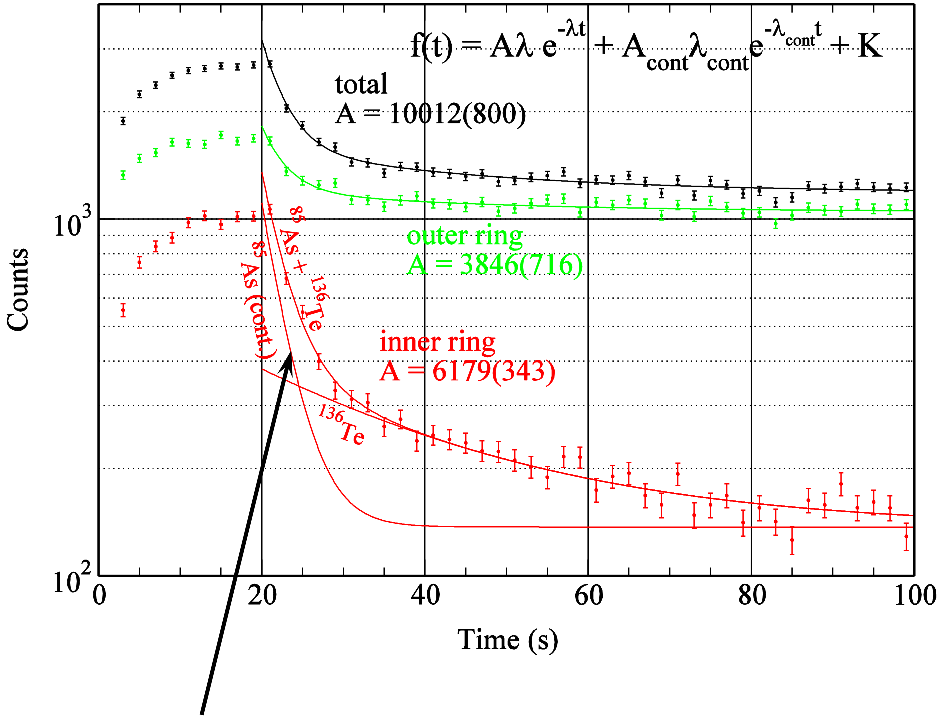
bg / outer tube ~ 2 x bg / inner tube

➡ Background too high for this low counting rate

Only high strong emitters (high $P_n.Y_i$) can be measured

First Results: a weak emitter

^{136}Te : $T_{1/2}$ = 17,7s, P_n = **1,31%** (0% in JEFF)



Additionnal issue:

Mass separator: possible **contaminant** emitting neutron

A=85 go through Lohengrin with A=136

^{136}Sb ($T_{1/2}$ = 0,92s) hidden by strong ^{85}As ($T_{1/2}$ = 2,0s)

Comparisons

	Database	^{94}Rb	^{99}Y	^{136}Te
P_n	compilation from Rudstam (1993)	(10,01 ± 0,23)%	(1,9 ± 0,4)%	(1,30 ± 0,06)%
	Table of Isotopes books (1998)	(10,4 ± 0,4)%	(1,03 ± 0,04)%	(1,1 ± 0,6)%
	compilation from Pfeiffer (2002)	(9,1 ± 1,1)%	(2,2 ± 0,5)%	(1,26 ± 0,2)%
	compilation from Audi (2003)	(10,01 ± 0,23)%	(1,9 ± 0,4)%	(1,31 ± 0,05)%
	JEFF3.1 database (2005)	(10,1 ± 0,2)%	1,7 %	0%
	chart of nuclide from NNDC	(10,5 ± 0,4)%	(1,9 ± 0,4)%	(1,31 ± 0,05)%
	Our results (préliminairy)	***(10,99 ± 0,29)%***	***(1,73 ± 0,18)%***	***(1,28 ± 0,13)%***

Quite precise measurements for ^{94}Rb and ^{99}Y P_n values
(a little bit high for ^{94}Rb ?)

No amelioration of the ^{136}Te P_n value accuracy
(but we confirm the JEFF's mistake)

Calibration check

with a gamma source

$\varepsilon_{n\ exp}$ = (23,8 ± 2,5)%

$\varepsilon_{n\ simu}$ ~ 22% sur [0;1 MeV]

Conclusion

P_n values are not very well known

there are a **lot of discrepancies** between databases

even for nuclei crucial for nuclear energy

New neutron long-counter

based on a **constant efficiency up to 1 MeV**

first experiment shows **good results** but a **too high background**

Improvements:

new shielding in progress

beta chamber with **constant efficiency** planed

→ precise measurements of P_n values

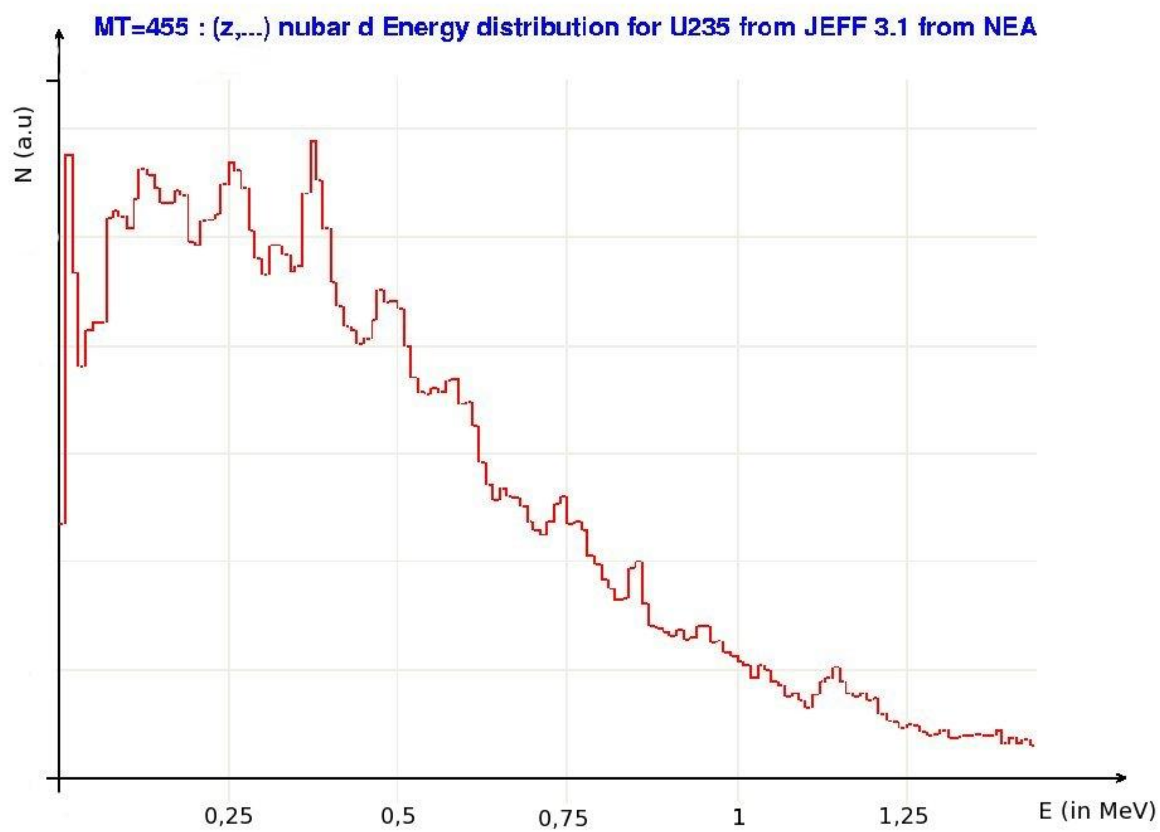
use of this detector on other facilities

Nuclei of interest (for DESIR?)
from the nuclear technology point of view

Nucleus	% of all DN	$\Delta P_n/P_n$
^{137}I	13 to 40%	8%
^{98m}Y	5 to 16%	30%
^{94}Rb	7 to 12%	5%
^{135}Sb	0.3 to 3%	30%
^{99}Y	2 to 4%	10%
^{91}Br	0.5 to 2%	15%
^{137}Te	0.2 to 1.5%	10%
^{86}As	0.2 to 1%	60%

Presentation

Energy spectrum of the delayed neutrons



Fast neutrons (40% with E > 0,5 MeV)

Integral measurements

VS summation calculation: $$Nd_{tot} = \sum_i Y_i^c \cdot P_{ni}$$

Nuclei	^{233}U	^{235}U	^{239}Pu	^{241}Pu	^{242m}Am	^{243}Cm	^{245}Cm
summation calculation (pcm)	297	604	253	509	241	93	217
integral measurements (pcm)	271	652	261	644	261	121	257
discrepancy	*+10%*	*-7%*	*-3%*	*-21%*	*-8%*	*-23%*	*-16%*

There is something wrong

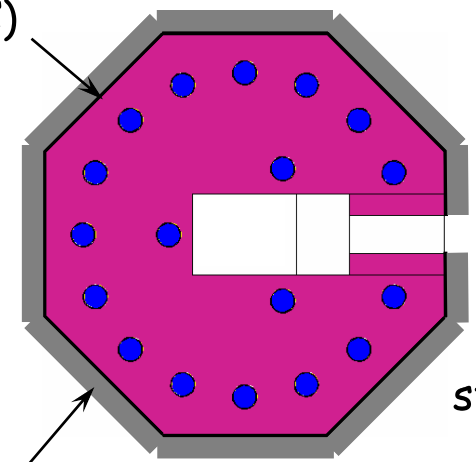
Needs of new measurements:

- isotopic yields Y_i (for each target nucleus)
- probabilities $P_{n,i}$ (only one time and for all)

Improvements on neutron detector

More effective neutron shielding:

old shielding
(thin B_4C)



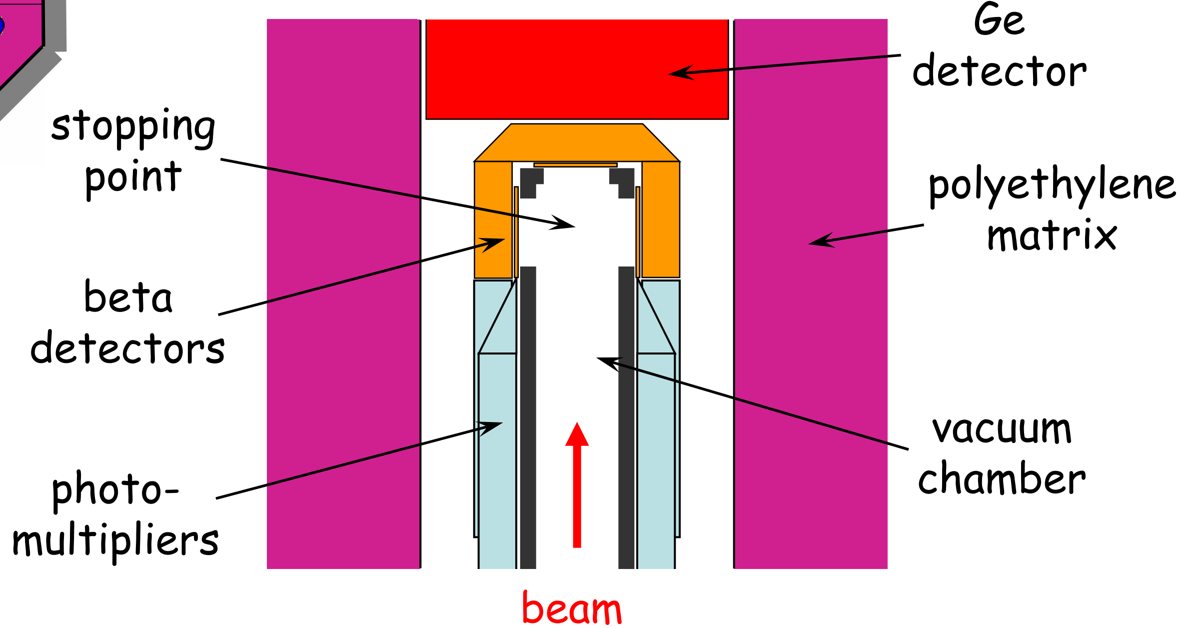
additional shielding
(thick borated polyethylene)

Thermalization
AND capture of
fast neutrons

Next experiment planed in autumn:

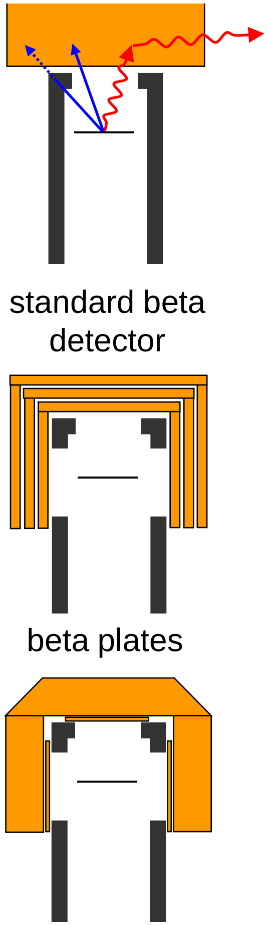
- check the background
- test the beta-chamber

(beta detectors adapted to this **compact geometry**)

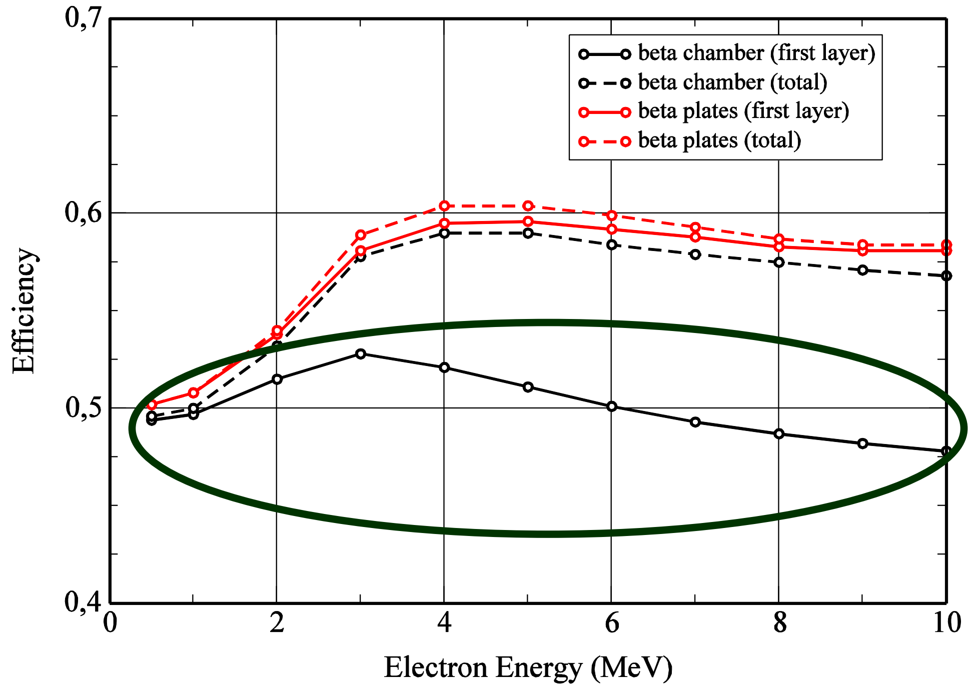


Improvements on beta detectors

« beta chamber » detector :



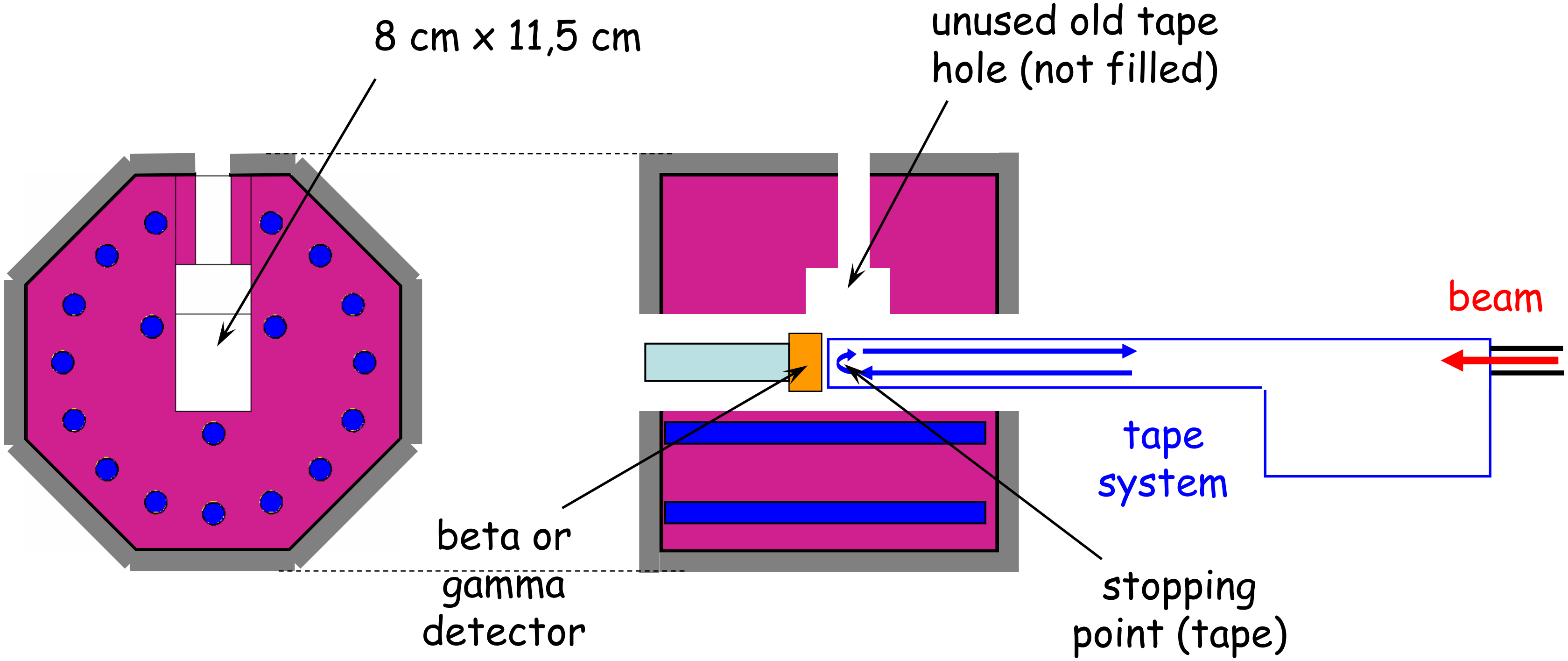
- high sensitivity to gamma rays ($\varepsilon_{Compton}$ ~ 10-20%)
- beta detection efficiency not constant (because of aluminum)



nearly **constant efficiency** (±5%)

Other facilities

It can be used in **other facilities** than Lohengrin !



Efficiency must be **simulated** to check the effect of new **surrounding material**