Search for new physics in β-ν correlations
using
trapped ions and a retardation spectrometer

WITCH-project

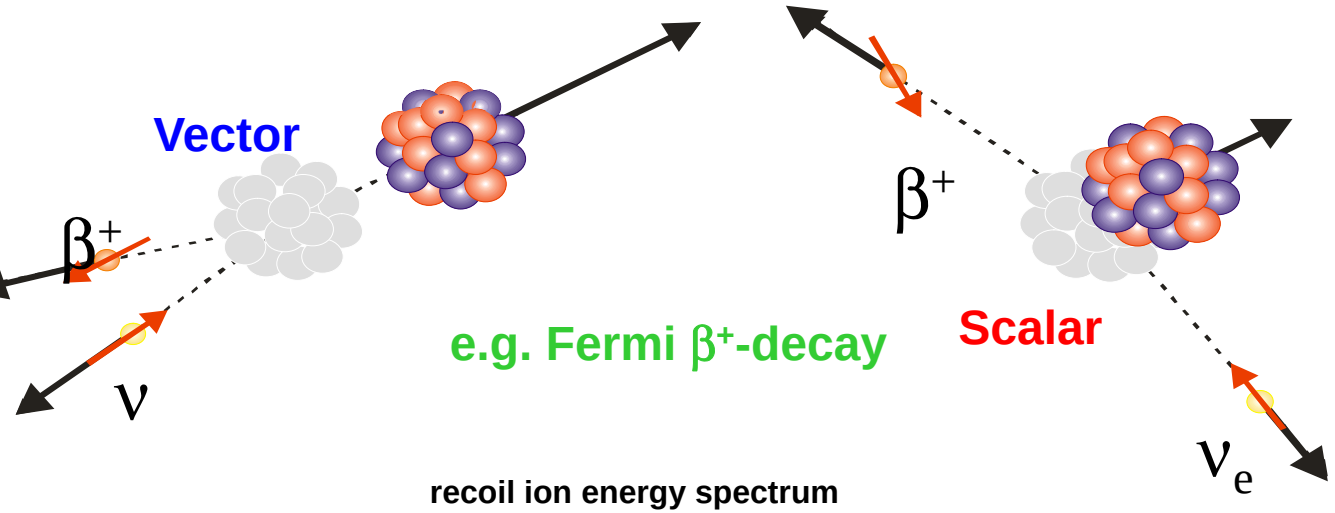
CERN - INTC
11 February 2008

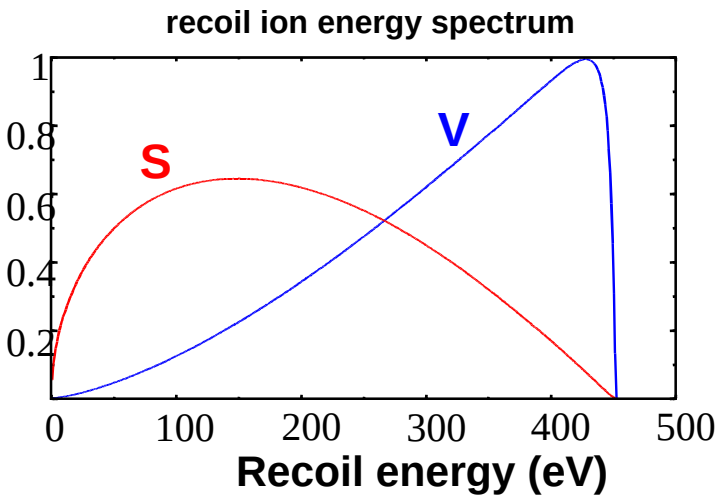
K.U.Leuven, Münster, Prague, CERN

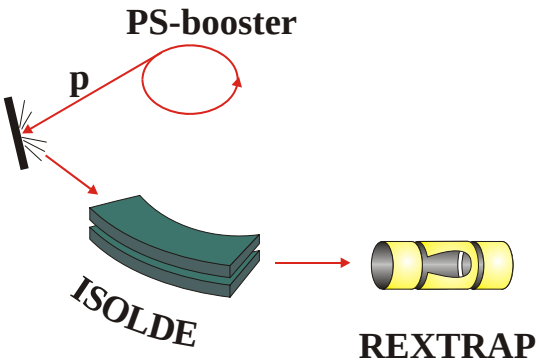
Weak Interaction Trap for CHarged particles

β-ν correlation

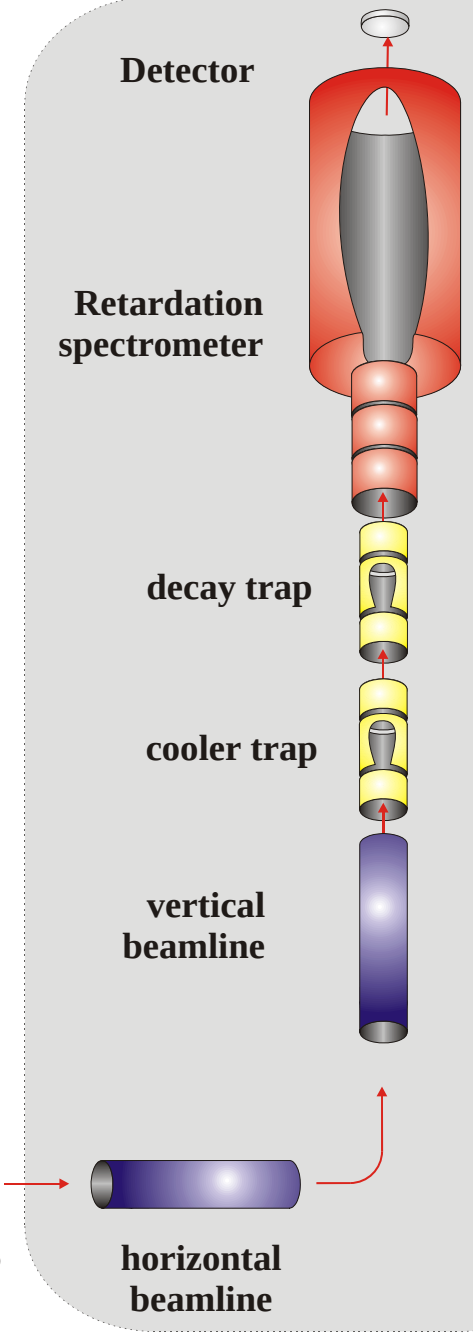
search for scalar/tensor weak interaction by measuring shape of recoil ion energy spectrum after β-decay



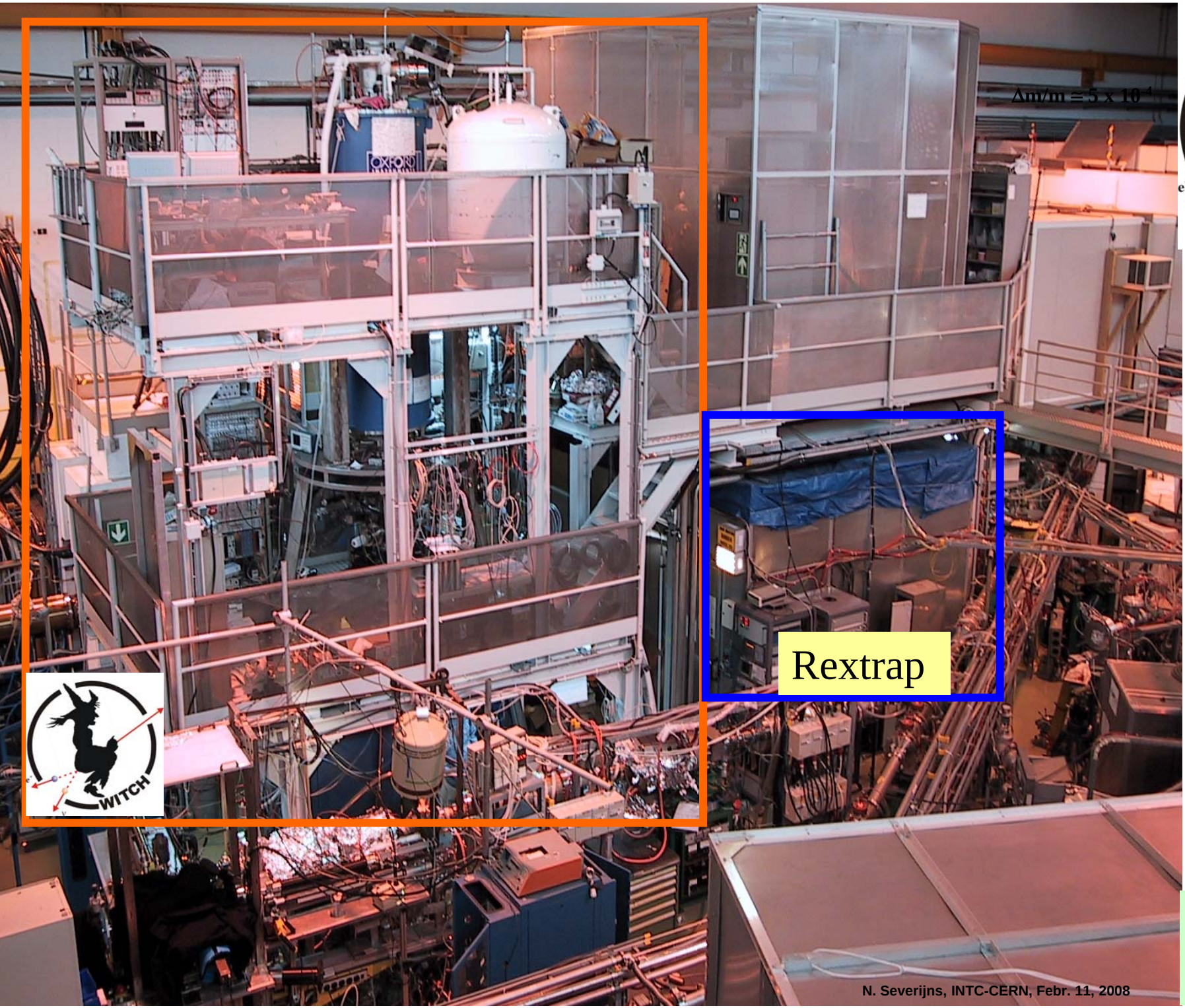




REXTRAP

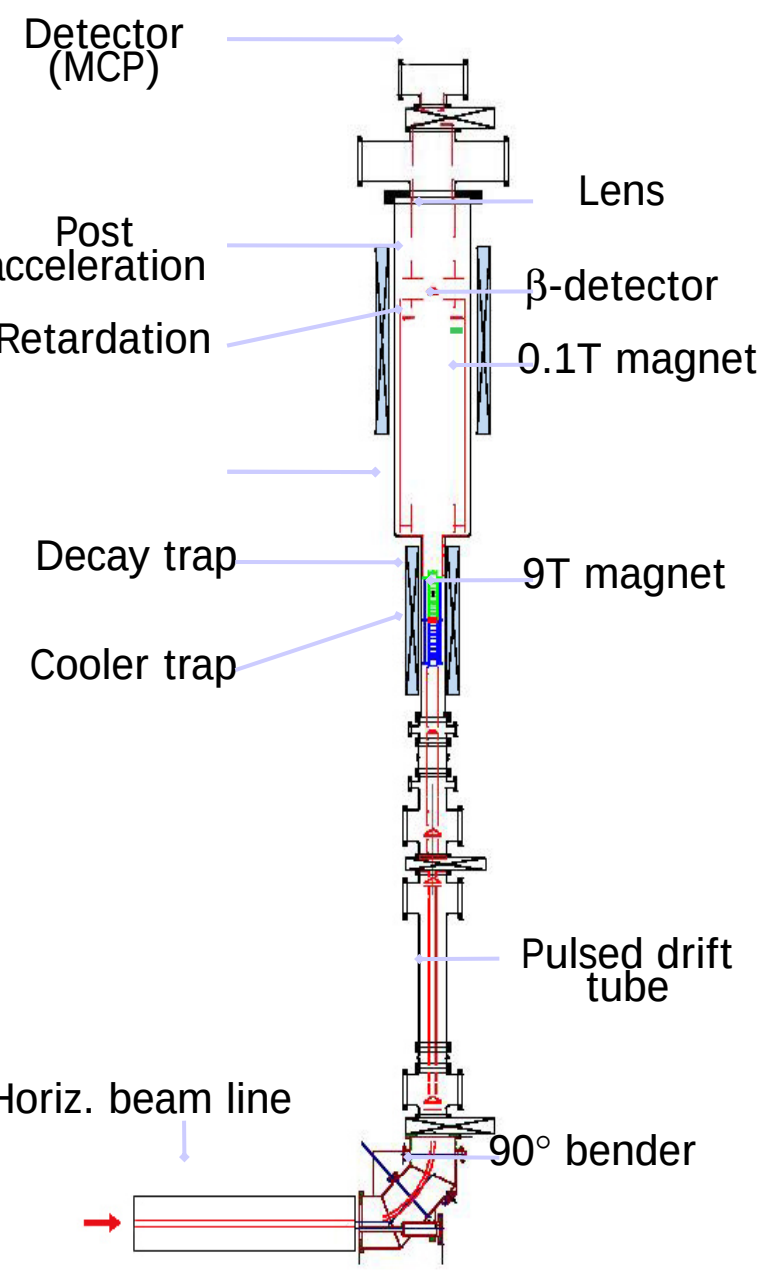


WITCH



decay trap (20 cm)

cooler Trap (20 cm)



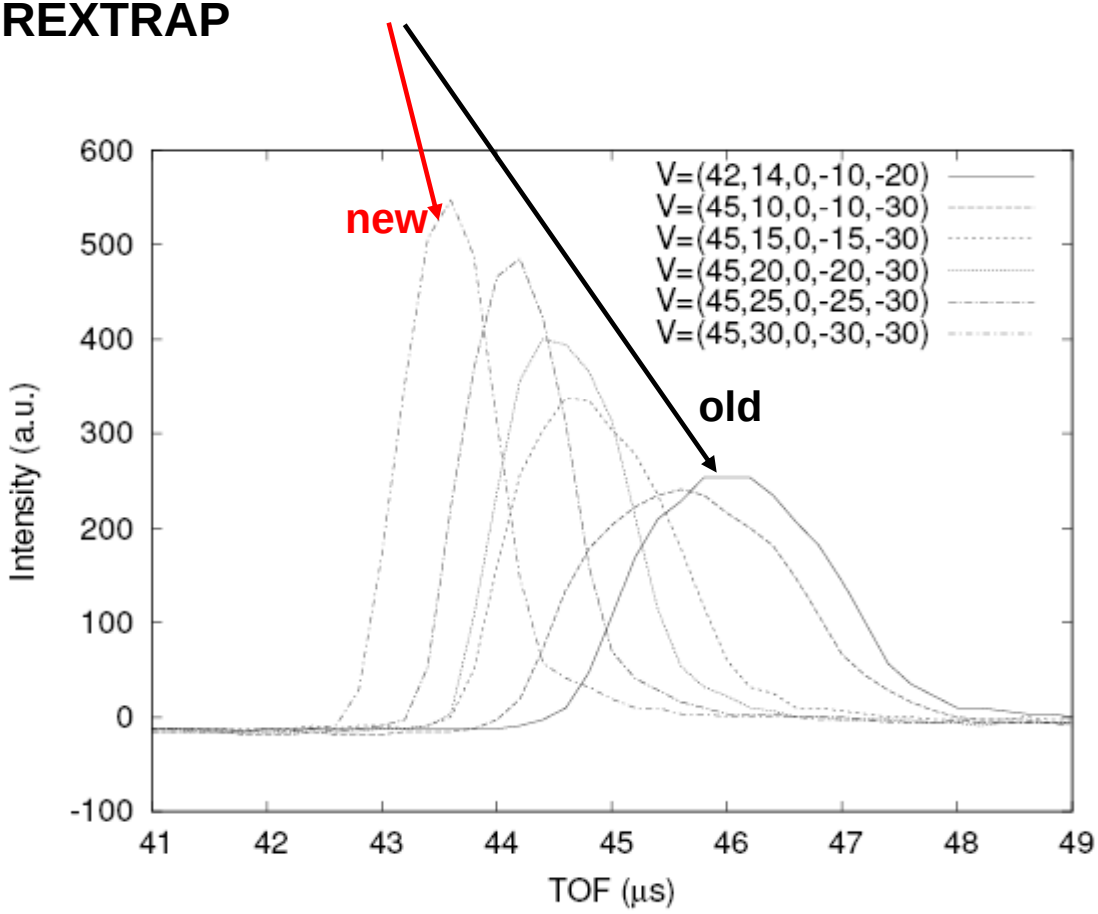
↓ section / efficiency →	Ideal (%)	Jan. 2005 (%)	Dec. 2007 (%)
Transport through horizontal beam line	100	100	100
Pulsed drift tube (30 keV → ~100 eV)	50 – 100	10	50-100
Injection into 9 T field	100	1 – 10	20
Trapping of ions in cooler Penning trap	100	50	50
Transfer to decay trap	100	70	70
Storage in decay trap	100	(100)	100
Fraction of lowest charge state after beta decay	10 (β^+ decay)	(10) (β^+ decay)	(10) (β^+ decay)
Fraction of ions from trap to spectrometer	45	(45)	(45)
Transmission of retardation spectrometer	100	(100)	~ 100
MCP detector efficiency	60	(50)	52 [a]
Total efficiency (REXTRAP → recoil ion MCP)	~ 1 – 2	~10^{-3}- 10^{-2}	~ 0.1 – 0.2

[a] E. Lienard et al., Nucl. Instr. & Meth. A 551 (2005) 375.

(numbers between brackets were not yet measured)

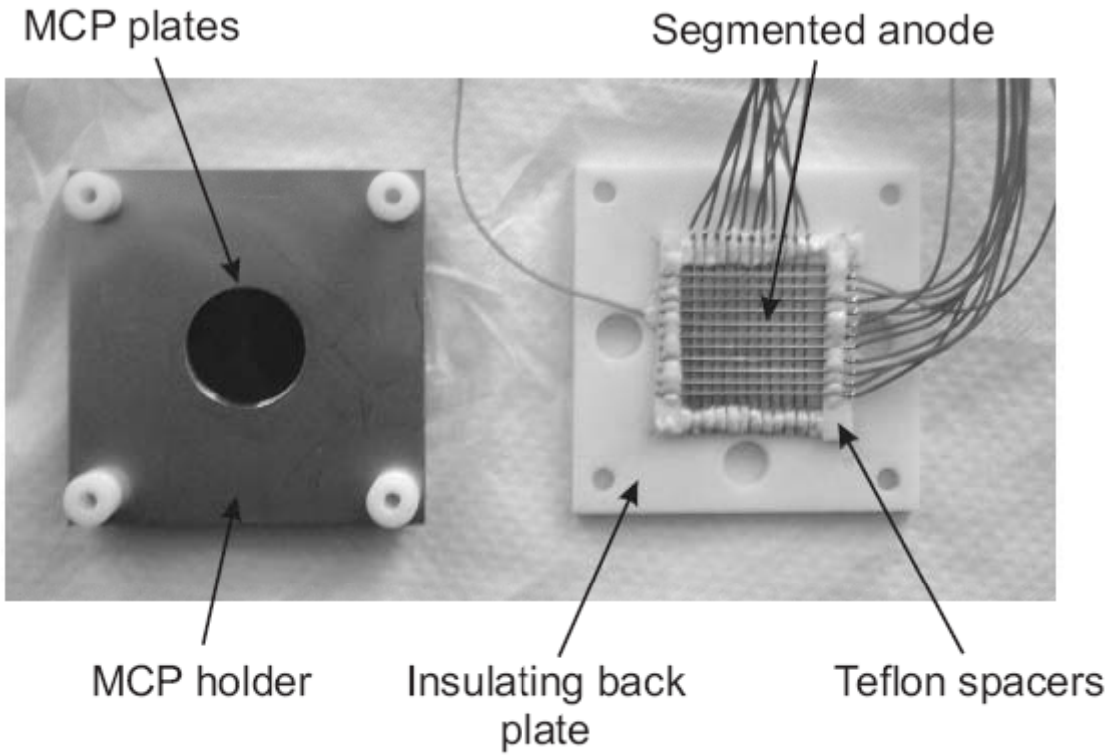
Pulsed drift tube
(h = 70 cm)

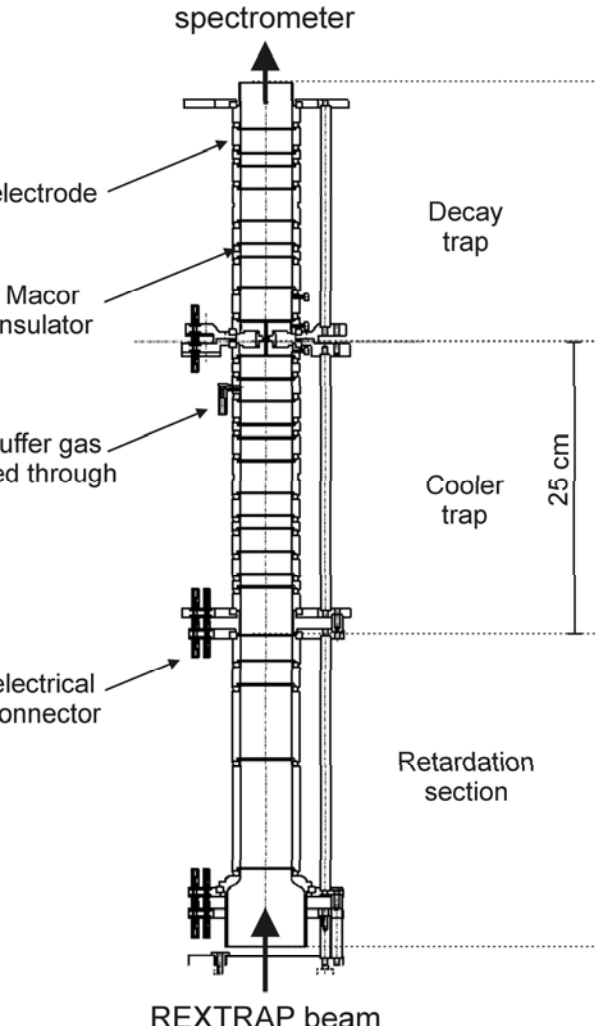
Improved PDT efficiency by shortening beam pulse delivered by REXTRAP

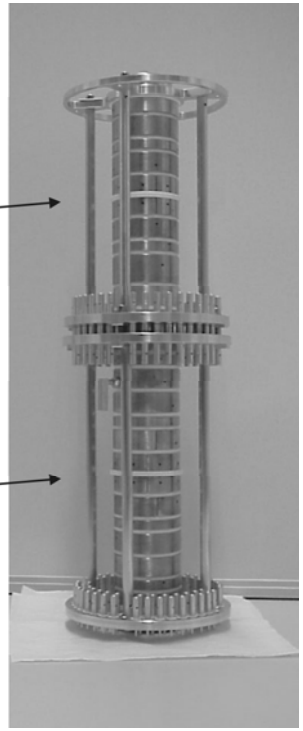


Improved injection into B-field and overall beam transport due to

- **study of MCP behavior with pulsed beams & segmented anode design**
- **improved control system (home made; soon switch to GSI Control System)**

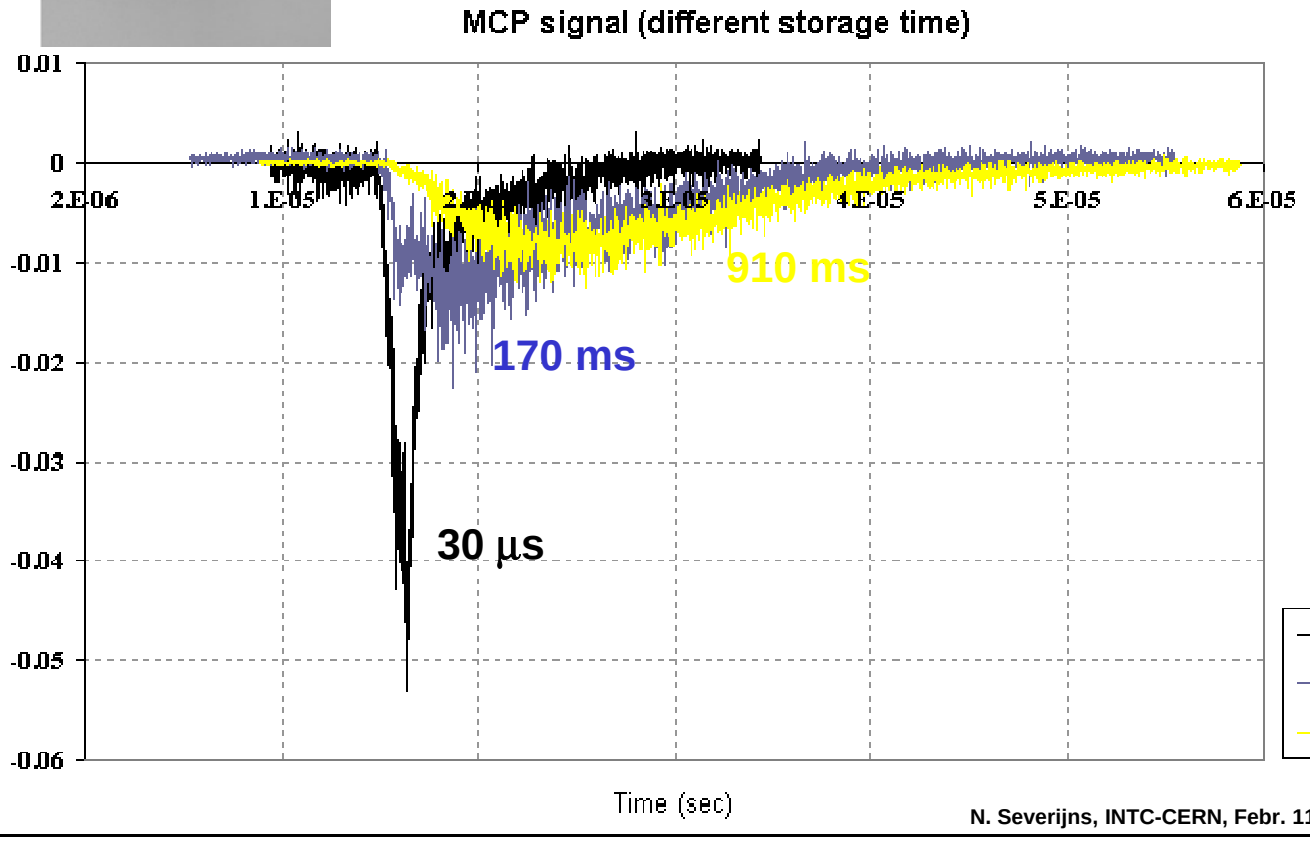


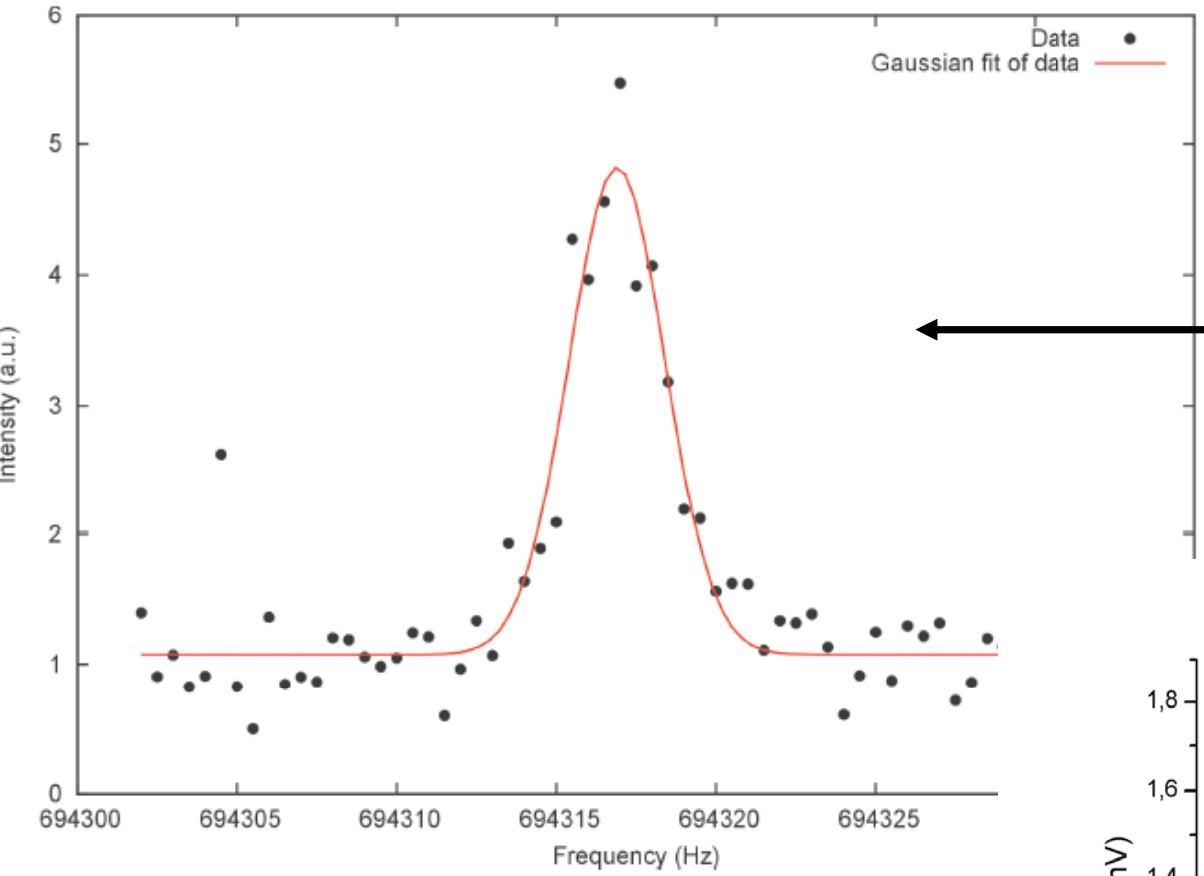




Double Penning trap structure of the WITCH-set-up

Storage of ^{39}K-ions in cooler trap (TOF spectrum) →

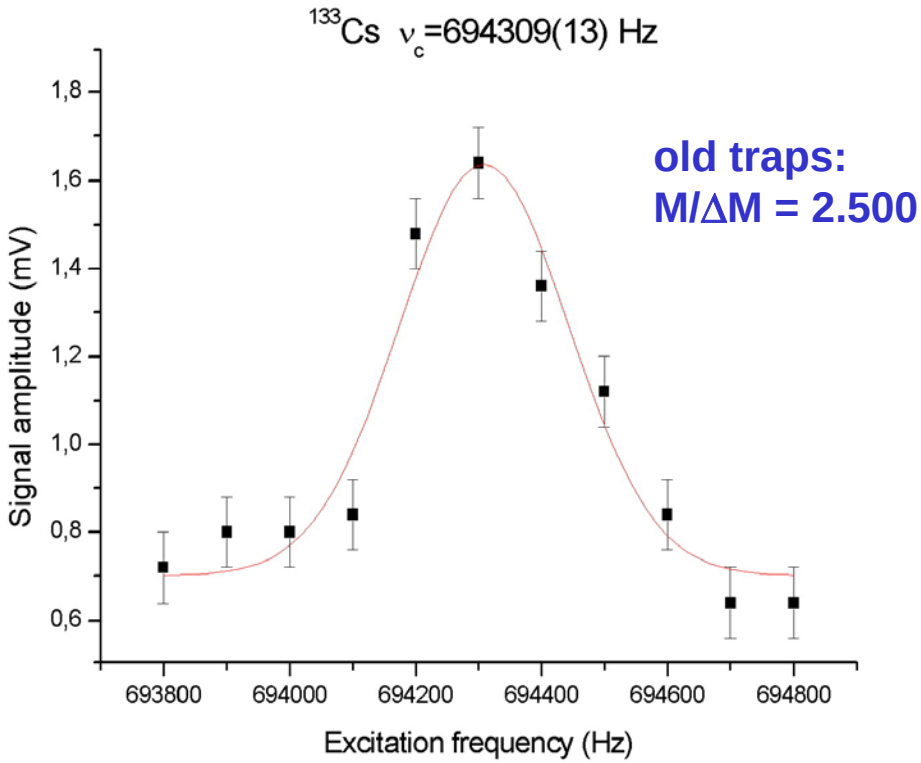




new & better coated
Penning traps
→ improved mass resolution

M/ΔM = 200.000

^{133}Cs cooling resonances

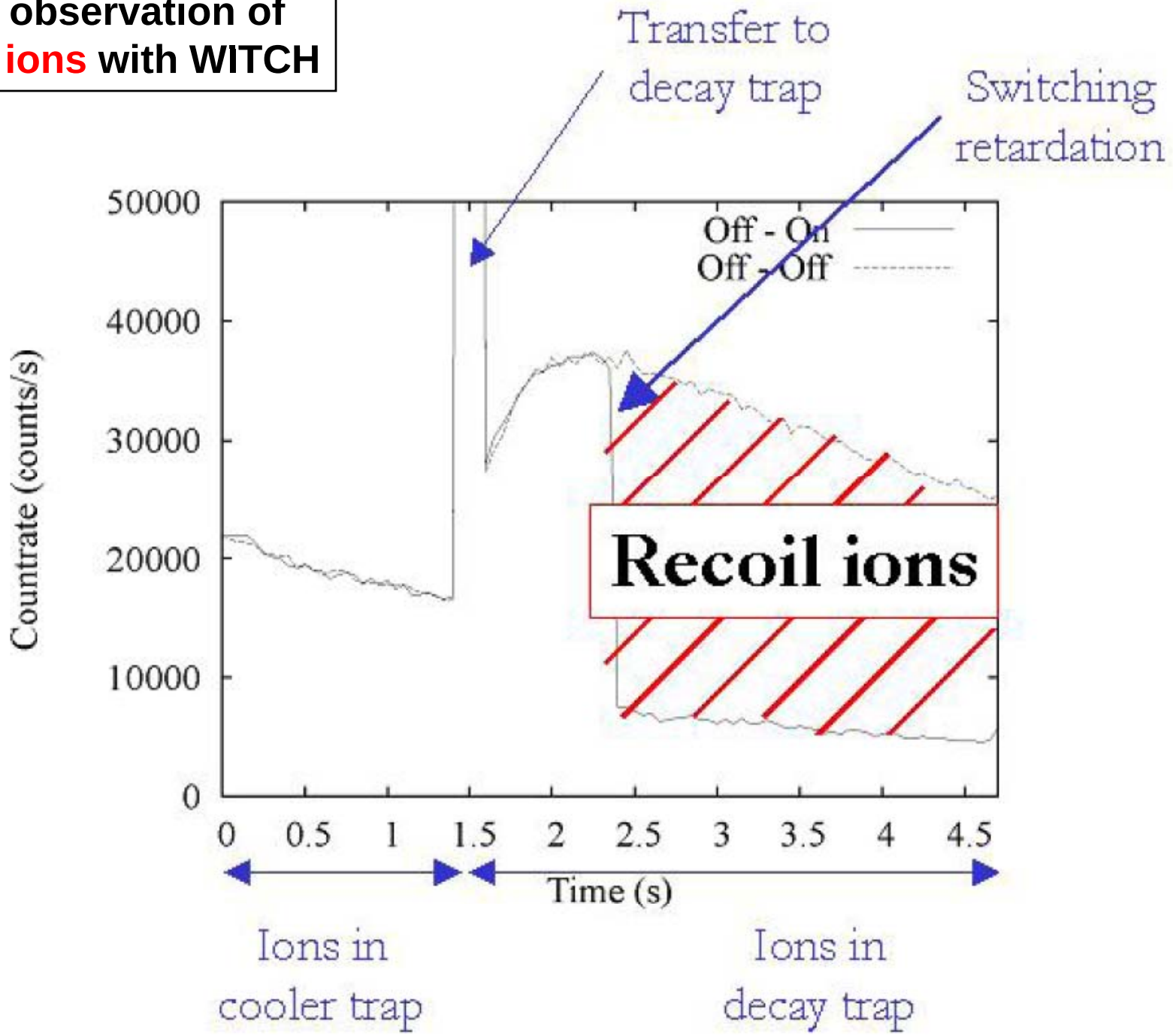


old traps:
M/ΔM = 2.500

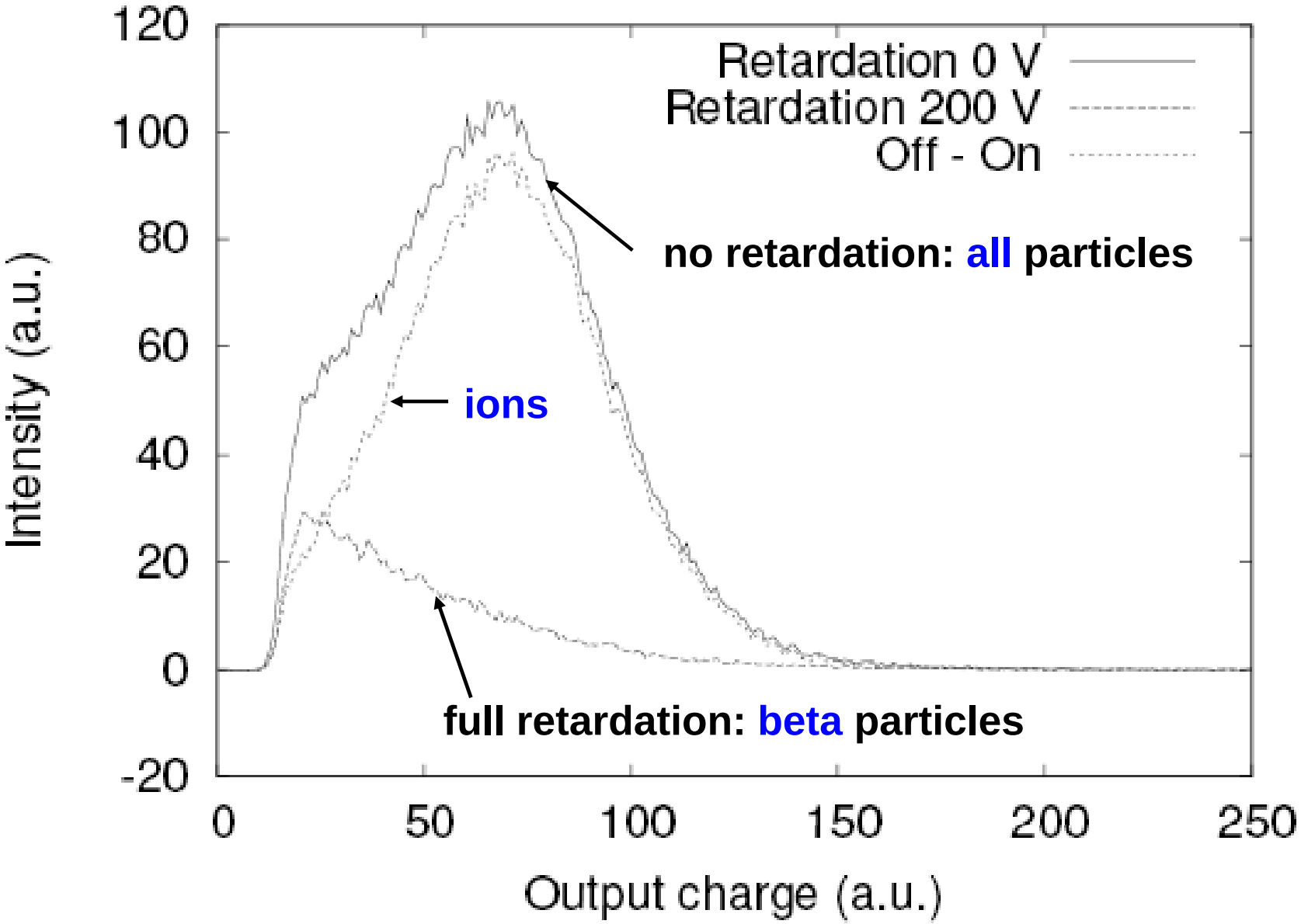
First observation of recoil ions with WITCH

^{124g,m}In

Nov. 2006

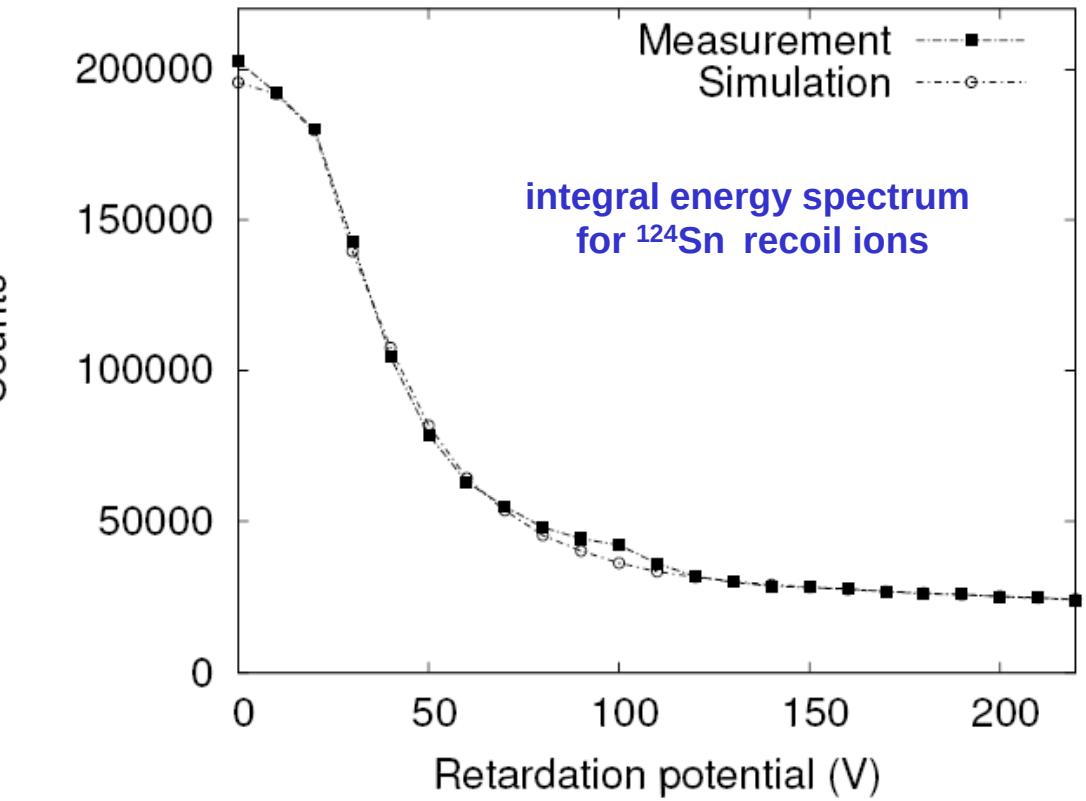


Pulse height distribution on recoil ion MCP detector



^{124g,m}In

Nov. 2006

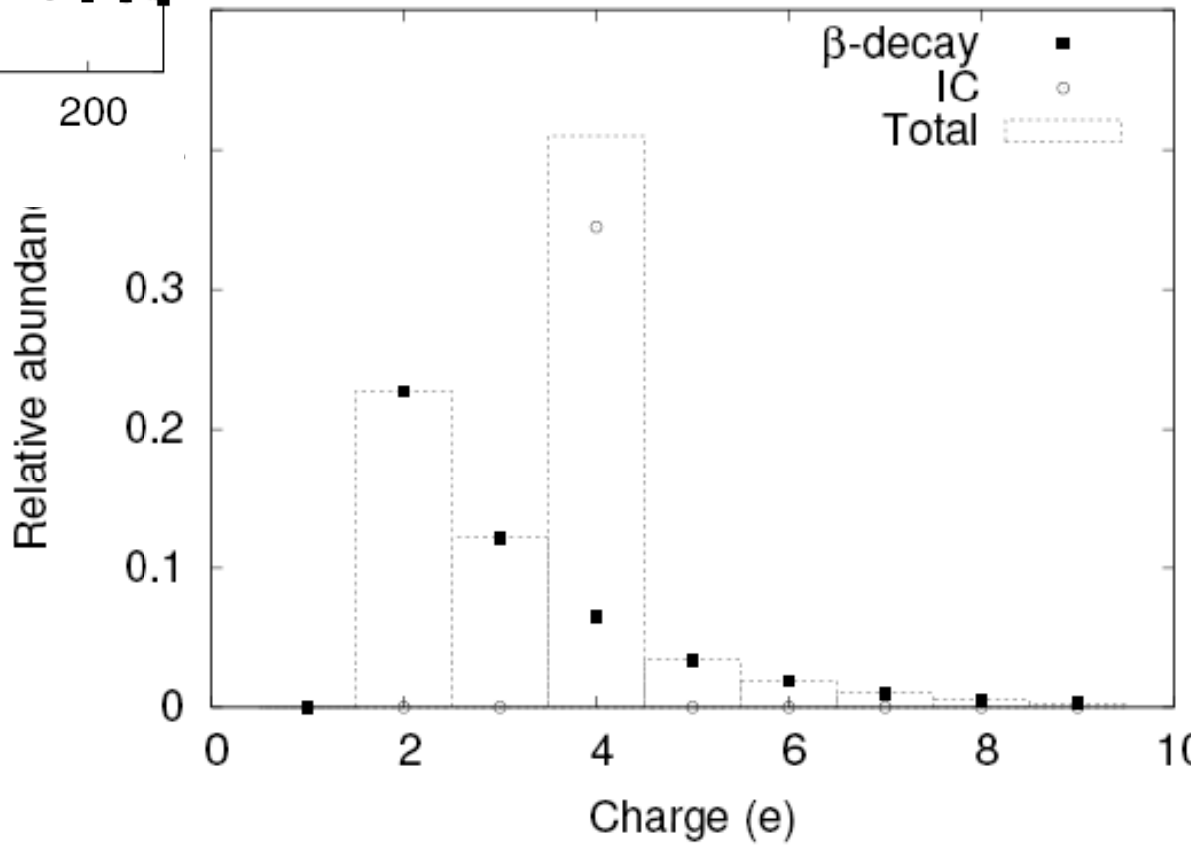


First recoil ion energy spectrum with WITCH

^{124g,m}In

Nov. 2006

charge state distribution of ^{124}Sn recoil ions



First run with ^{35}Ar

Oct. 2007

failed due to:

- **>> contamination with stable ^{35}Cl (target group dealing with this)**
- **> losses of ^{35}Ar due to charge exchange in REXTRAP (improvements planned)**
- **> losses of ^{35}Ar due to charge exchange in WITCH (vacuum upgrade ongoing)**
- **'secondary ions', not created by beta decays ('Penning traps' in spectrometer ?)**

Ongoing/planned improvements

target group REXTRAP (06/2008 ?)

- use "Cl-free" target material and target cleaning procedure
- remove remaining ^{35}Cl with selective mass cooling in REXTRAP
- increase Ar lifetime in REXTRAP

05/2008

- improve WITCH vacuum to $\leq 1 \times 10^{-9}$ mbar (NEG getter strip pumps)
- improve buffer gas system

07/2008
meeting with F. Glück mid-March

- study origin of 'secondary ions' and solve problem

08/2008

- pulsed buffer gas injection in 2nd Penning trap (further cooling after transfe

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07/2008

- new support structure for Penning traps (e.g. to add detectors)

09/2008

- install magnetic shielding (→ independent from REX-ISOLDE)

09/2008

- improve intensity of WITCH 60 kV ion source (→ independent from REXTRAP)

coordinator

- use ISCOOL buncher (better beam quality)

New detectors

- install detector for normalization between the two Penning traps
- develop set-up to measure charge state distribution after beta decay
- tape station on top of WITCH
- compact beta spectrometer
- …

Beam time request

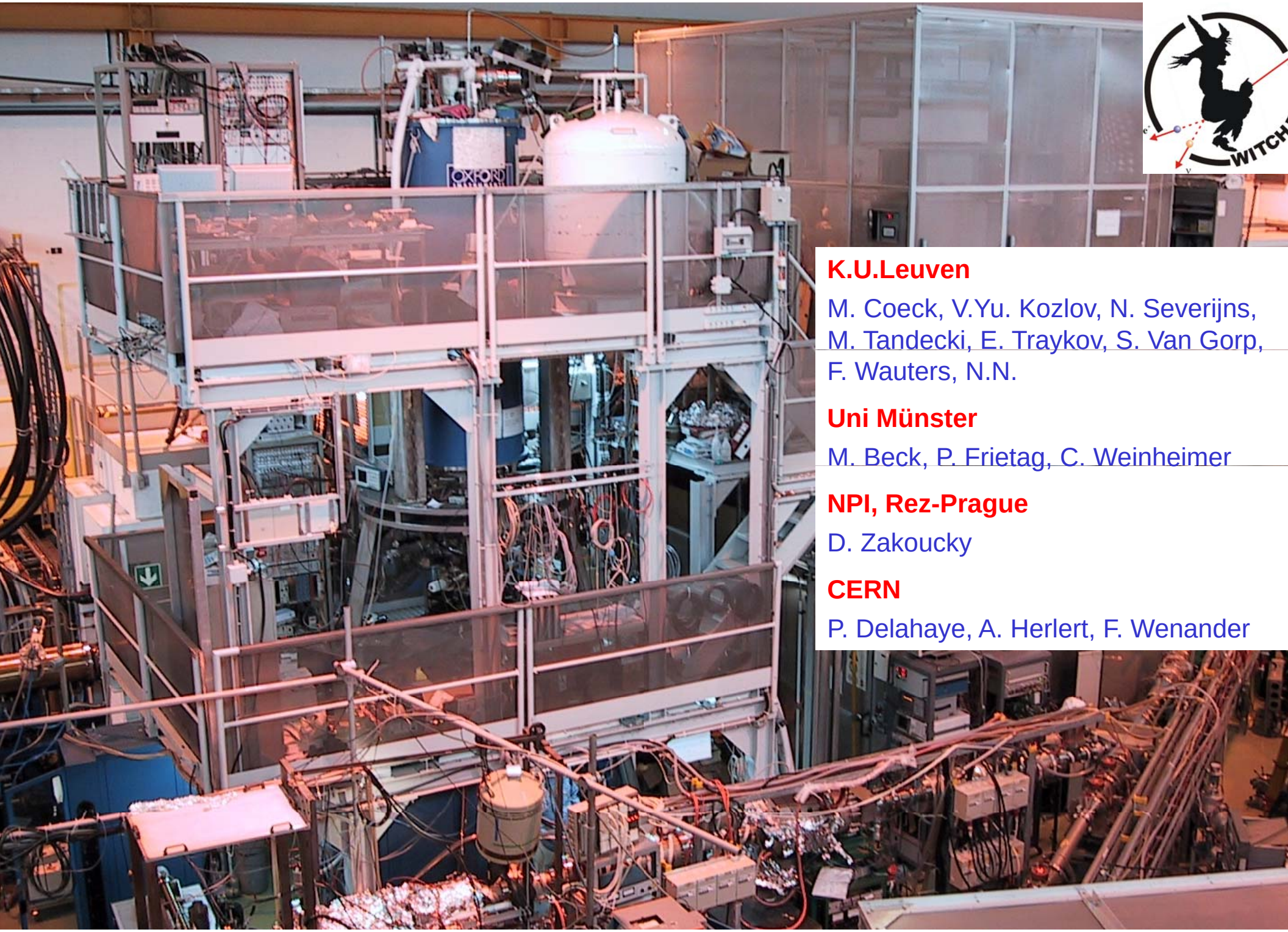
Beam	run	shifts	Min. intensity
^{35}Ar	1	6	1 x 10^7/s
^{35}Ar	2	15	1 x 10^7/s
^{35}Ar	3	6	1 x 10^7/s
		Total = 27	

: test

: data taking

: systematic effects

- precision aim: 0.5% on beta-neutrino correlation coefficient *a* that will be extracted from the shape of the recoil ion energy spectrum
- systematic effects still to be addressed (needs data first)



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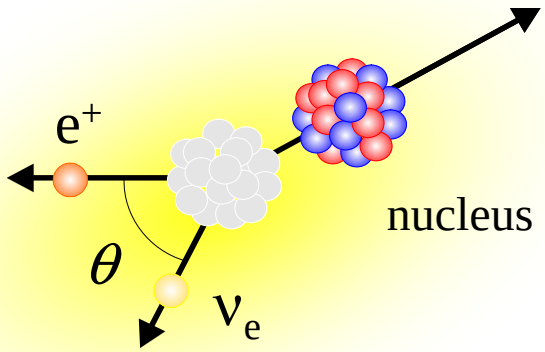
β-ν correlation

$$\Rightarrow \quad W(\theta) = 1 + \frac{\bar{p}\cdot\bar{q}}{E_e E_\nu}\,\tilde{a}$$



with $\tilde{a} \equiv \dfrac{a}{1+\dfrac{\Gamma m}{E_e} b}$ and $\Gamma = \sqrt{1-(\alpha Z)^2}$

$$a_F \cong 1 - \frac{|C_S|^2 + |C'_S|^2}{|C_V|^2}$$

$$a_{GT} \cong -\frac{1}{3}\left[1 - \frac{|C_T|^2 + |C'_T|^2}{|C_A|^2}\right]$$

$$b_F \cong Re\,\frac{C_S + C'_S}{C_V}$$

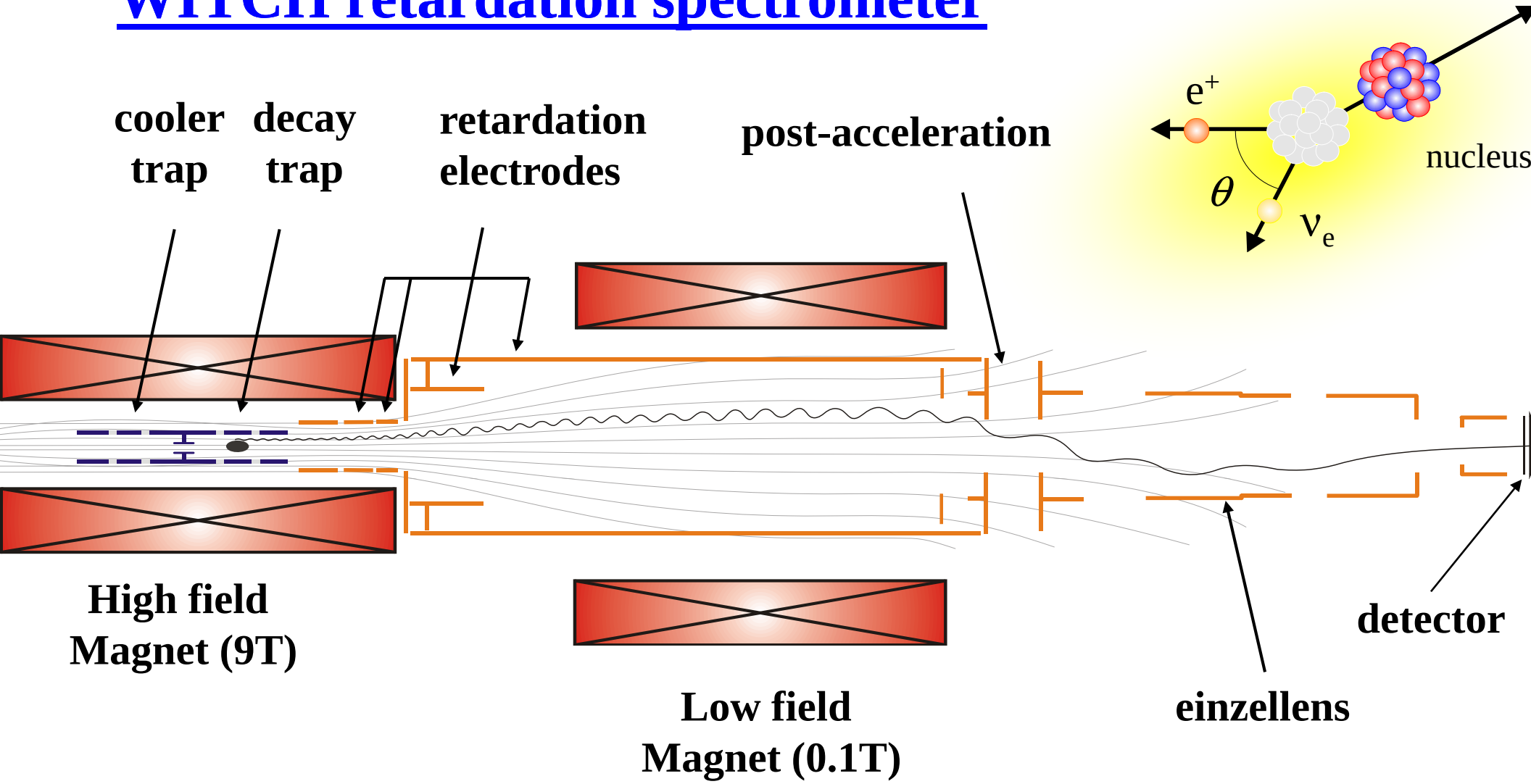
$$b_{GT} \cong Re\,\frac{C_T + C'_T}{C_A}$$

(assuming maximal P-violation and T-invariance for V- and A-interactions)

recoil corr. (induced form factors) ≈ 10^{-3} ; radiative corrections ≈ 10^{-4}

a_{GT} and a_F independent of nuclear matrix elements

WITCH retardation spectrometer



Energy conversion

$$\frac{E_{\perp 1}^{kin}}{E_{\perp 0}^{kin}} = \frac{B_1}{B_0} = \frac{0.1T}{9T} = 1.1\%$$

Other physics possibilities with WITCH:

- in-trap & trap-assisted spectroscopy
- charge state distributions
- search for heavy neutrino's
- …