



Search for physics beyond the Standard Model with radioactive beams

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on behalf of
the WISArD collaboration

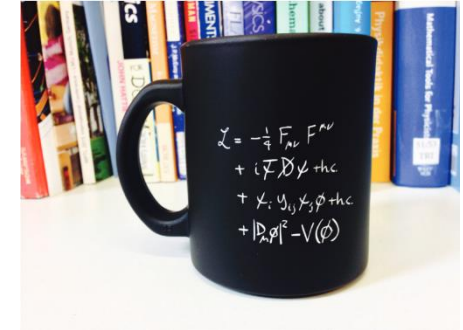
Contents

- Motivation
- The WISArD experiment at ISOLDE/CERN
- Proof-of-principle experiment
- Preliminary results
- Outlook

Standard Model and New Physics

	1 st	2 nd	3 rd	
Quarks	u up	c charm	t top	Gauge Bosons
	d down	s strange	b beauty	
Leptons	e electron	μ muon	τ tau	Gauge Bosons
	ν_e neutrino electron	ν_μ neutrino muon	ν_τ neutrino tau	
				H Higgs Boson
			γ photon	
			W^\pm W boson	
			Z^0 Z boson	
			g gluon	

Standard Model (SM)



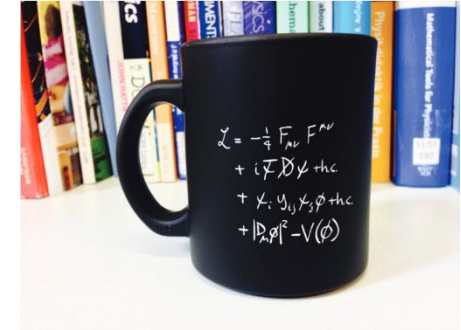
Standard Model and New Physics

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Standard Model (SM)

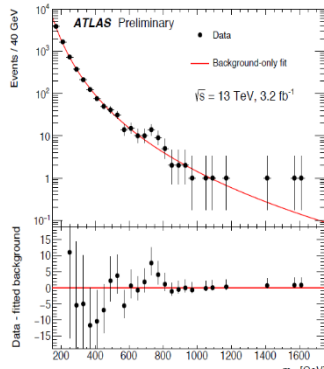


New Physics (beyond SM)



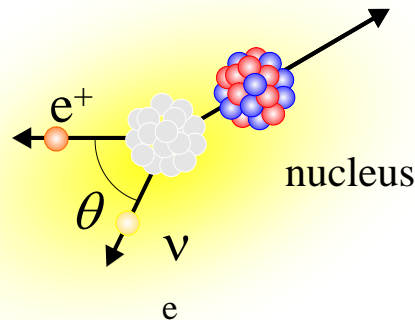
Energy frontier

➤ LHC...



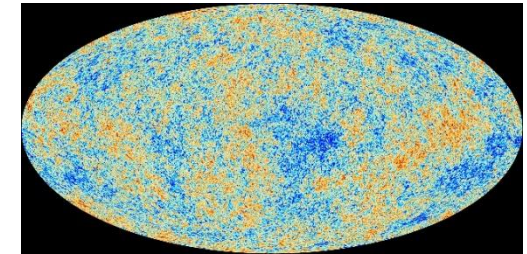
Precision frontier

➤ Nuclear beta decay



Cosmic frontier

➤ Planck...



Weak interaction in the Standard Model

Present structure:

- * **Vector-Axial Vector interaction**
 - * **maximal parity violation**
 - * **no Scalar (S) or Tensor (T) components**
 - * **no time reversal violation**
- $C_V \equiv 1; C_A = -1.27$ (C_A/C_V from n-decay)
- $C_V' = C_V$ & $C_A' = C_A$
- $C_S = C_S' = C_T = C_T' = C_P = C_P' \equiv 0$
- all C's are real
- (except for the CP-violation included in the CKM matrix)

New Physics:

- * **experimental upper limits for $|C_S/C_V|$ and $|C_T/C_A|$ at few % level**
(neutron and nuclear β -decay)

- * **Extending the limits to per mille level allows setting lower limits on new boson (mass ~ 2.5 TeV)**

$$C_i \propto \frac{M_W^2}{M_{new}^2}$$

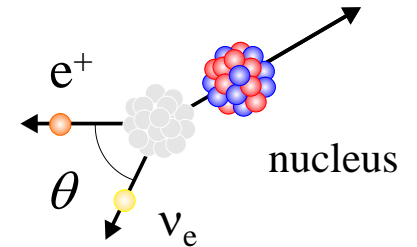
Observables in the nuclear beta decay

Decay rate $d\Gamma \sim d\Gamma_0 \left(1 + a \frac{\mathbf{p}_e \cdot \mathbf{p}_\nu}{E_e E_\nu} + b \frac{m_e}{E_e} + \dots \right)$

$d\Gamma_0$ → phase-space factor

a → *beta-neutrino angular correlation coefficient*

b → Fierz interference term



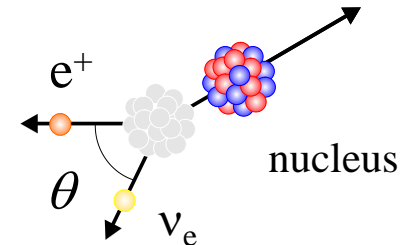
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phase-space
factor

*beta-neutrino
angular correlation
coefficient*

Fierz
interference
term



Pure Fermi transitions

➤ **S=0: Spin of leptons antiparallel**

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

SM: vector current:

- Preferred emission angle: $\theta = 0^\circ$
- Maximum recoil energy

NP: scalar current:

- Preferred emission angle: $\theta = 180^\circ$
- Minimum recoil energy

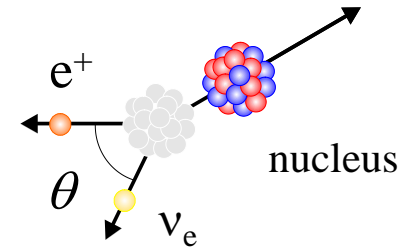
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phase-space factor

beta-neutrino angular correlation coefficient

Fierz interference term



$$\tilde{X} = \frac{X}{1 + b \left\langle \frac{m_e}{E_e} \right\rangle} \quad \text{NOTE!}$$

Pure Fermi transitions

➤ **S=0: Spin of leptons antiparallel**

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Pure Gamow-Teller transitions

➤ **S=1: Spin of leptons parallel**

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

SM: axial-vector current:

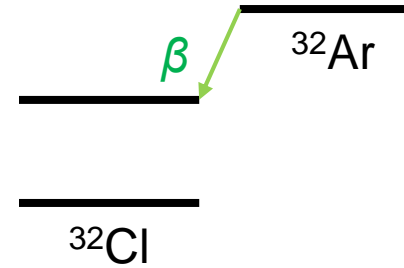
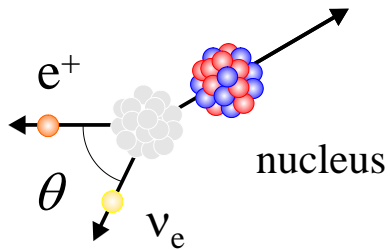
- Preferred emission angle: $\theta = 180^\circ$
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NP: tensor current:

- Preferred emission angle: $\theta = 0^\circ$
- Maximum recoil energy

Indirect correlation measurements

- Max recoil energy \sim keV

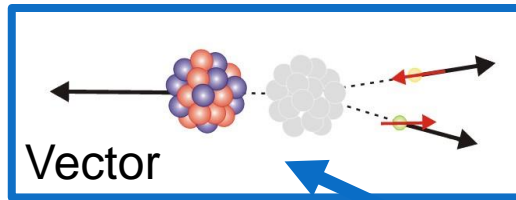


Indirect correlation measurements

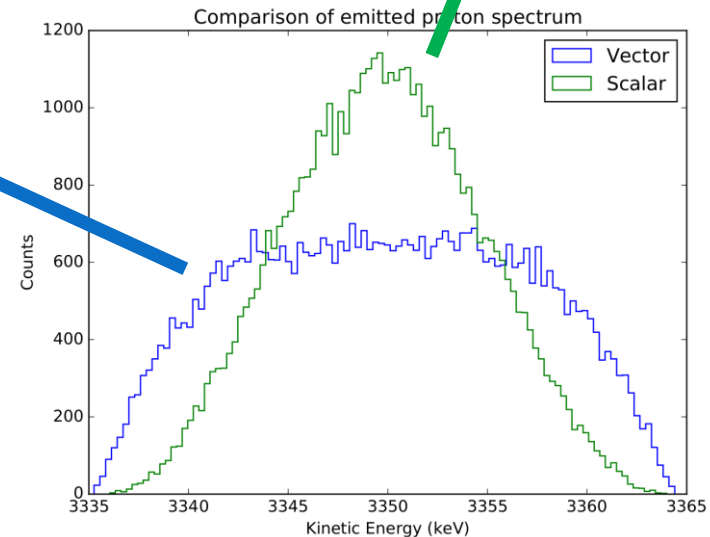
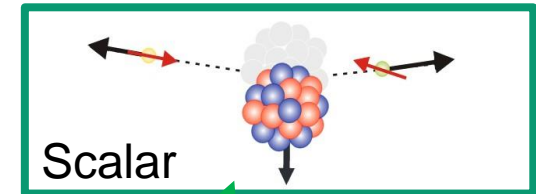
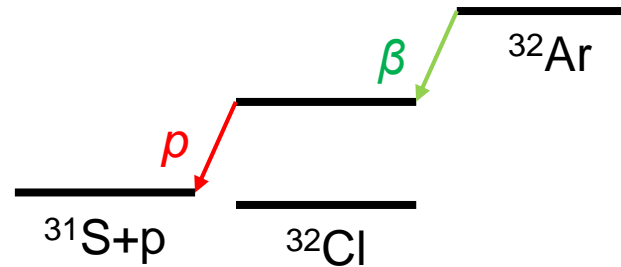
➤ Max recoil energy ~ keV

➤ ^{32}Ar decays by β -decay to ^{32}Cl which subsequently decays by proton emission to ^{31}S

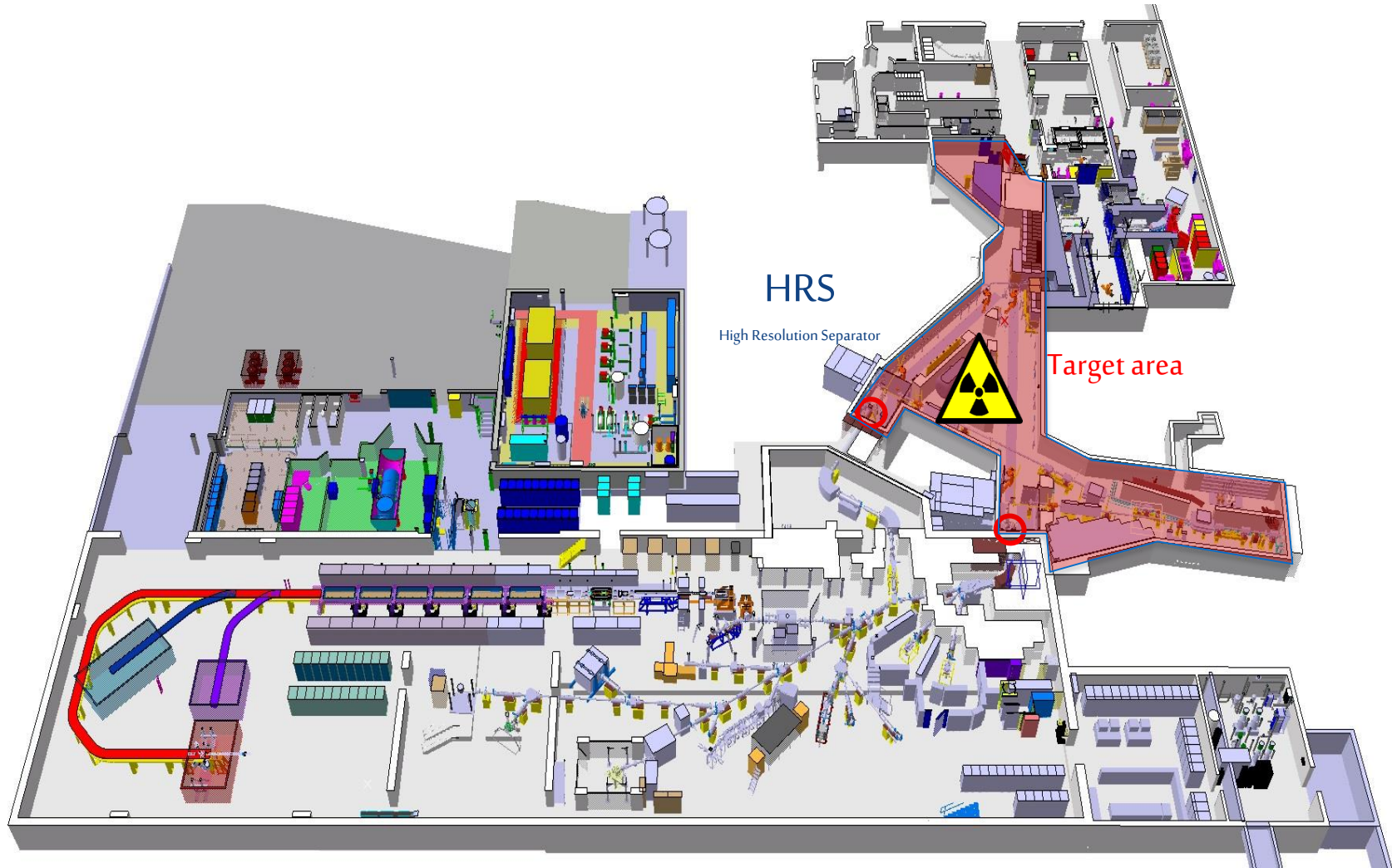
➤ Protons energies ~ several MeV



➤ The energy of the emitted protons is subject to kinematic shift due to the recoiling daughter nucleus

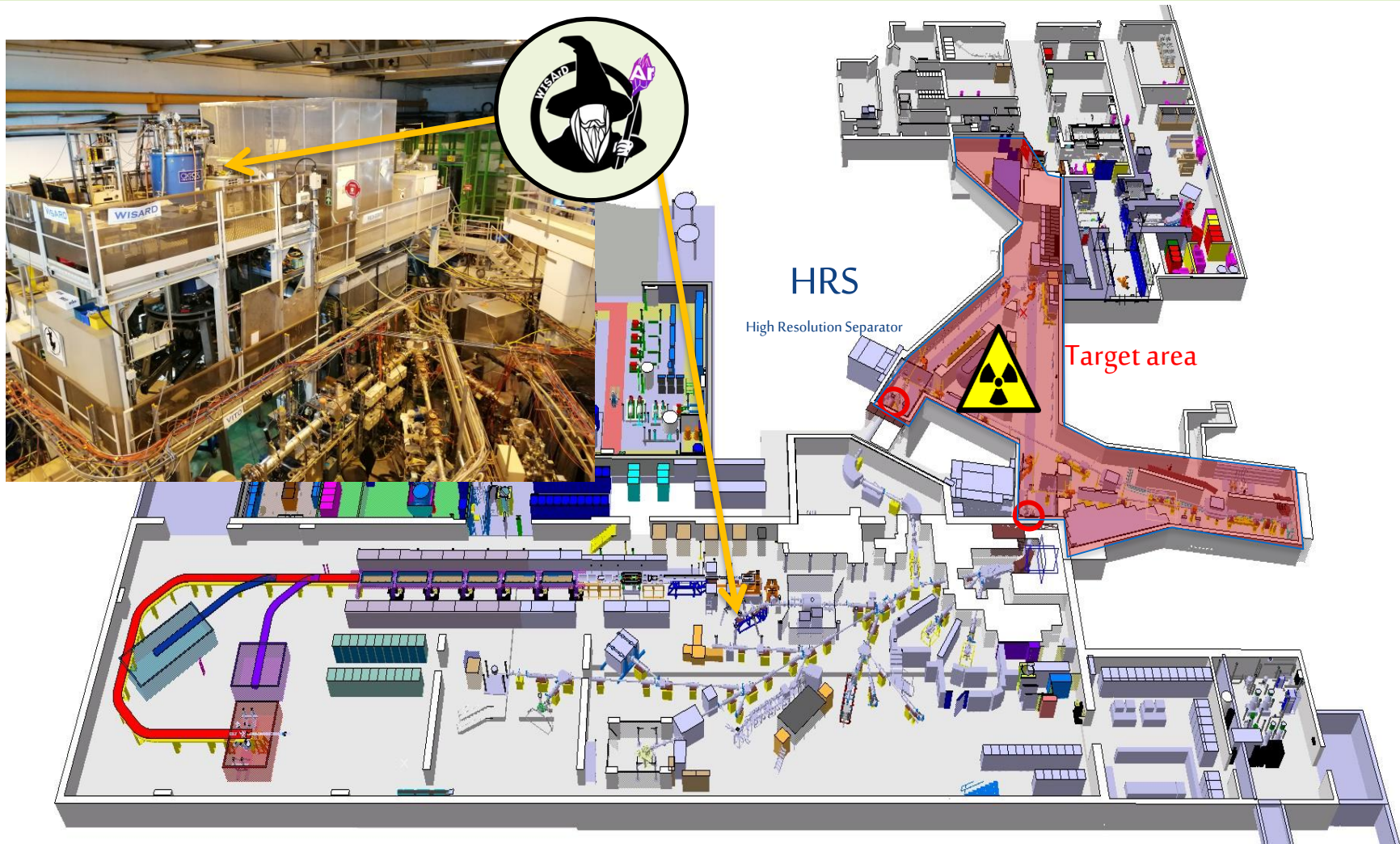


ISOLDE Experimental Hall



ISOLDE

ISOLDE Experimental Hall



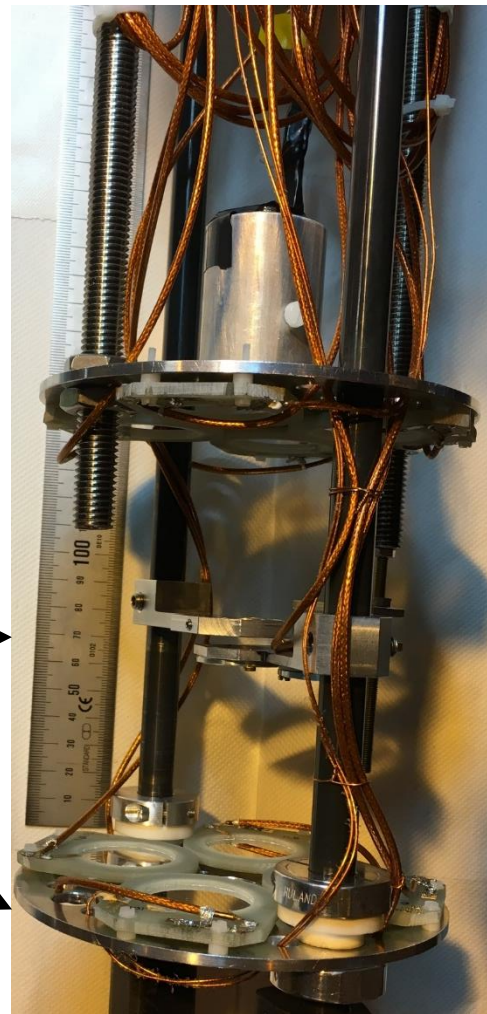
ISOLDE

Proof-of-principle: detection setup

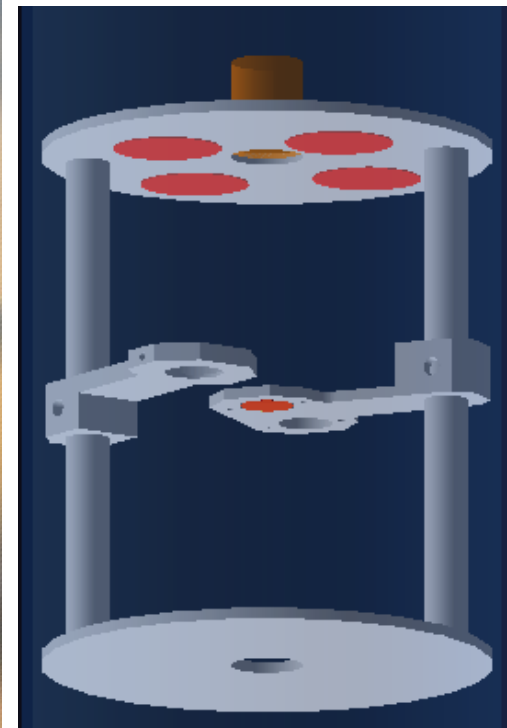
Beta detector* +
SiPM

proton
detectors
planes**

Catcher***



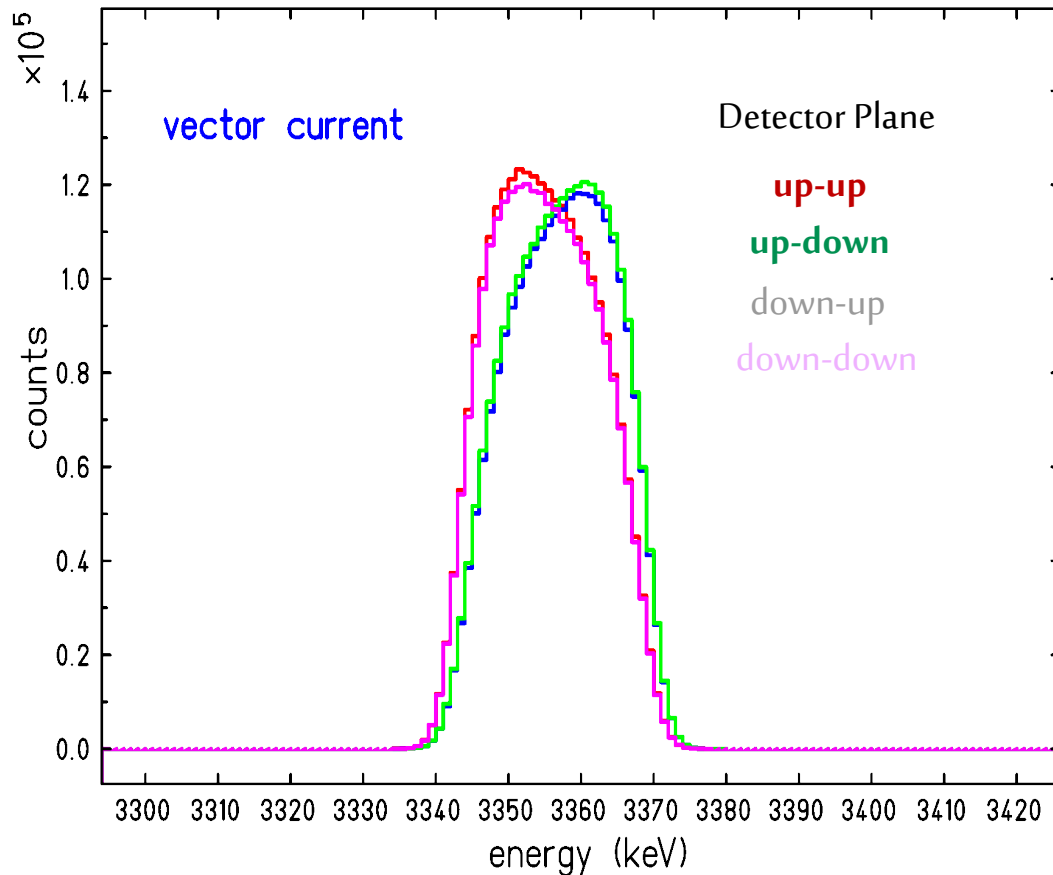
GEANT4 Simulation



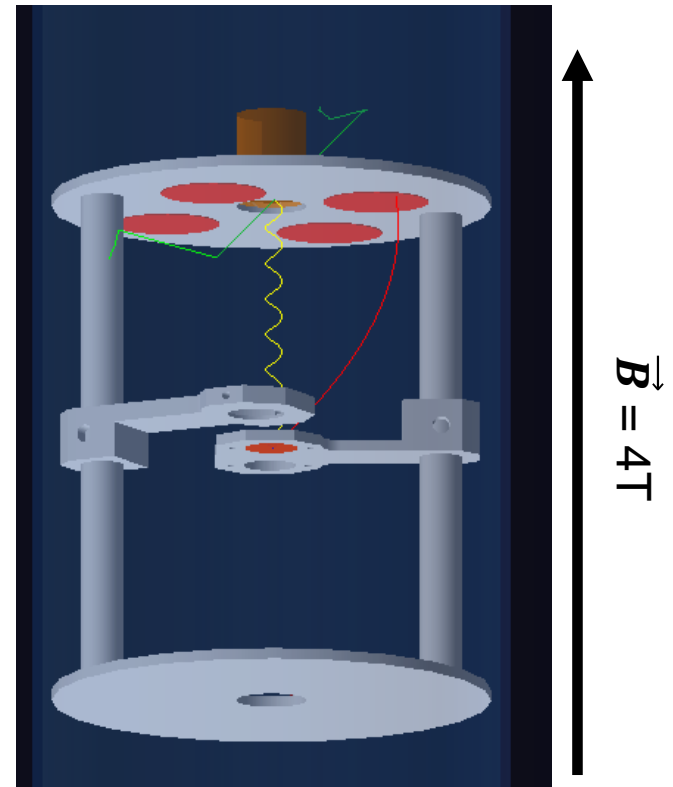
- * Plastic scintillator;
- ** Silicon surface-barrier (thickness = 300 μm);
- *** Aluminized Mylar (thickness = 6.7 μm)

Proof-of-principle: detection setup

Energy shifts observed in the dominant vector contribution



GEANT4 Simulation



Proof-of-principle: Results

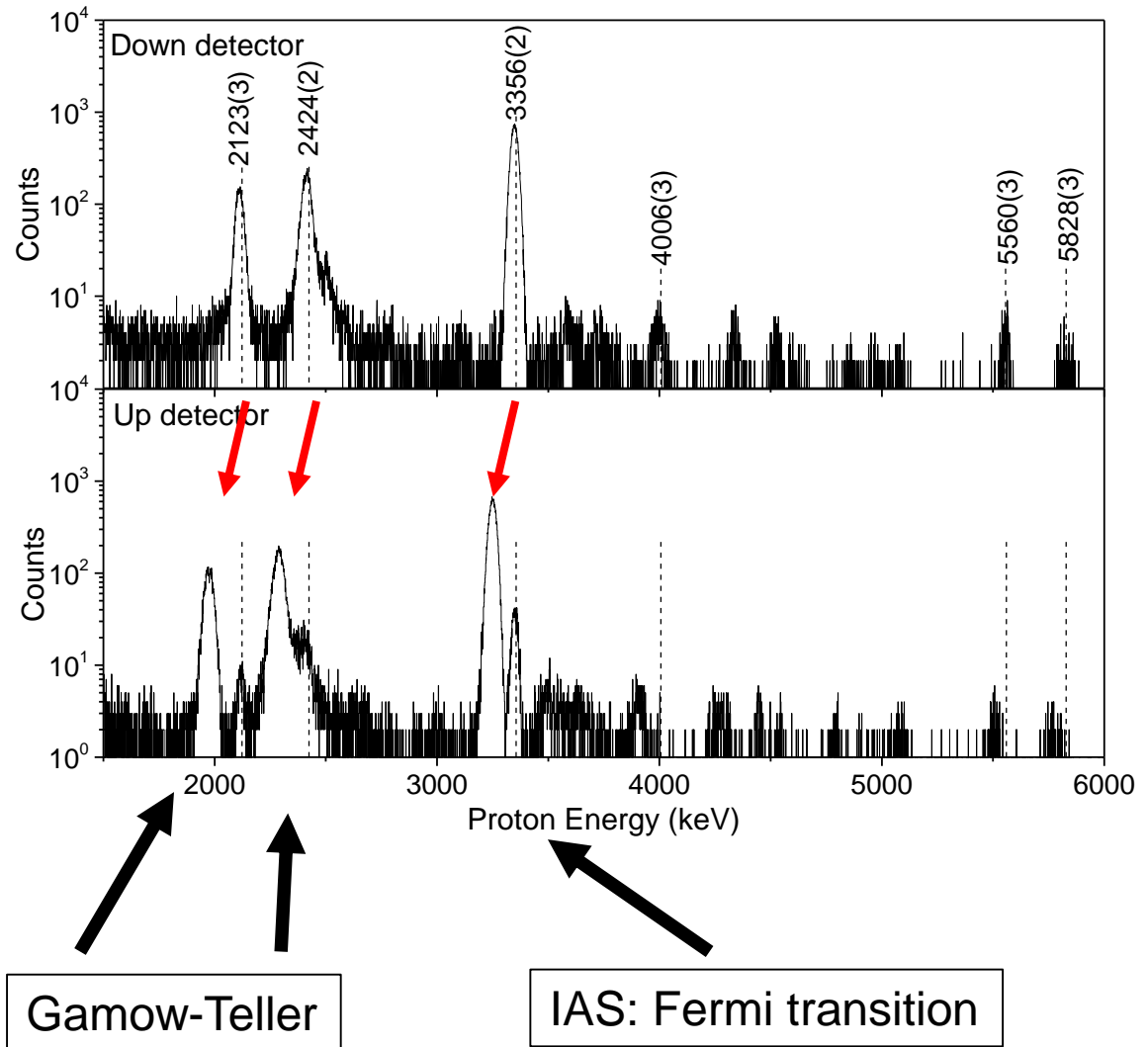
Proton Spectra in SINGLES
November 2018

➤ Lower plate detectors

- Energy shifts observed in all detectors due to the dead layer

➤ Upper plate detectors

- Proton energies shifted due to Catcher thickness ($\delta E \sim 100$ keV for the IAS)



Proof-of-principle: Results

Weighted average energy shifts:

$$\Delta E = |\bar{E}_{coinc} - \bar{E}_{single}|$$

$$\Delta E_F = 4.49(3) \text{ keV}$$

$$\Delta E_{GT} = 3.05(9) \text{ keV}$$



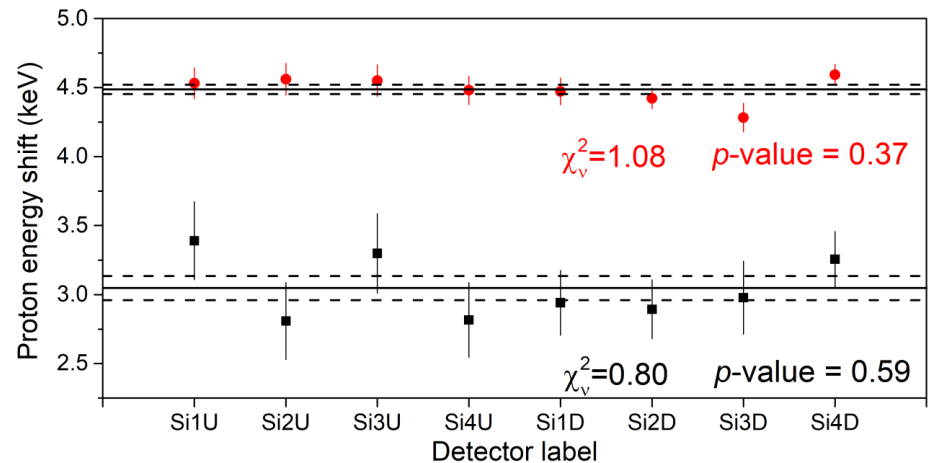
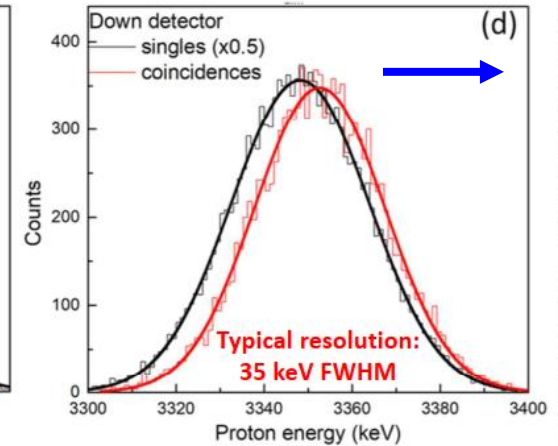
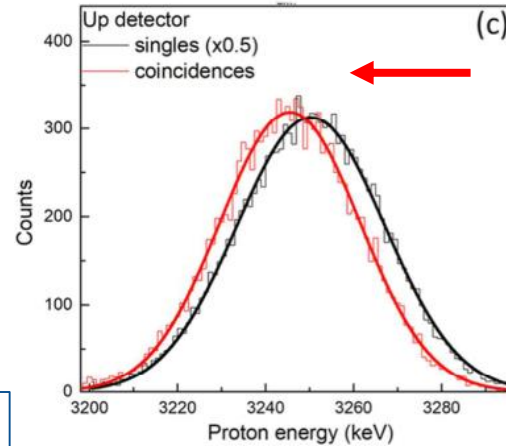
By means of Monte Carlo simulations:



$$\tilde{a}_F = 1.01(3)_{stat} (2)_{syst}$$

$$\tilde{a}_{GT} = -0.22(9)_{stat} (2)_{syst}$$

Example energy shift of one detector (IAS)



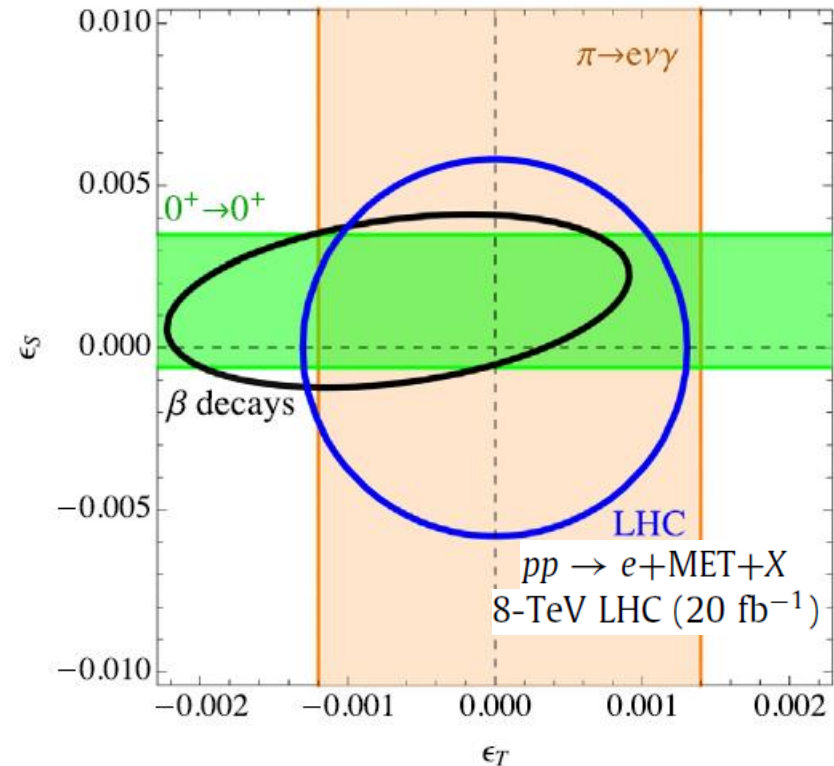
Outlook

Ongoing Upgrades (2019-2021):

- Proton detectors to reach 10 keV (FWHM) (8 segmented quadrants with 5 strips each)
- DAQ extension to match detector requirements
- WISArD beamline instrumentation and diagnostics
- Backscattering of beta particles (detection threshold as function of E and θ and validation + constraints for GEANT4)

Complete work beginning of 2021:

- WISArD experiment with precision goal of 1‰ on $\alpha_F = 1$



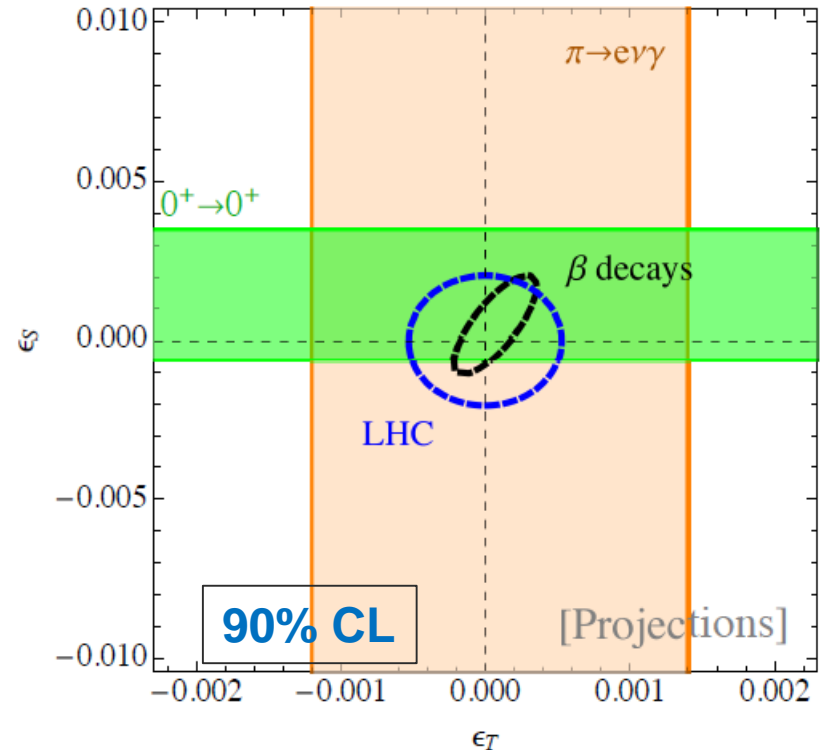
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Prospects for:

- 0.1 s on neutron lifetime
- 0.1 % for A_n , a_n , a_F and a_{GT}
- abs.unc. of 0.001 on b_{GT}
- LHC: 14 TeV, 300 fb⁻¹.

Thank you!

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