# The 2s-1s transition in muonic atoms and atomic parity violation F. Wauters<sup>1</sup> and N. Deokar<sup>1</sup> on behalf of the muX collaboration<sup>2</sup>

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#### Muonic atoms and the muX project

**Muonic atoms** are formed when negative muons come to rest and subsequently get captured by a nearby atom. They quickly **cascade** down to the Is atomic orbital, emitting Auger electrons and X-rays. Due to the significant overlap between the muon and the **atomic nucleus**, this system is very well suited to study short range  $\mu$ -Z interactions.



### µAPV with 2s1s X-rays

 $\mu$ **APV** arises from the mixing of the opposite parity  $2s_{1/2}$  and  $2p_{1/2}$  states, resulting in a EI component  $\eta$  to the 2S otherwise pure MI 2sIs transition. This enables to search for neutral  $2 \times EI$ parity-violation interactions with muons at low  $Q^2$  [2][3].



The *muX* project at PSI [1] deploys a high-purity germanium (HPGe) detector array to measure medium and high-Z muonic X-rays to determine charge radii of unstable nuclei, and to study the feasibility of a muon atomic parity violation

 $(\mu APV)$  experiment, among other particle, nuclear and applied physics measurements [1].

In addition to an already low **2S population**,

at low Z, a 2s Is  $\mu$ APV measurement is complicated by competing Auger 2s2p and  $2\gamma$  2s1s transitions. At **Z=30**, the M1 transition has a reasonable branching ratio, however, the PV amplitude is small, O(10<sup>-4</sup>). The background under the 2sls photon is dominated by Compton scattered (n>3)pls transitions.

The muX collaboration aims to **observe** the single-photon 2**sls** transition for the first time, optimize the signal-to-background (SB), and determine the reach of a possible  $\mu$ APV experiment.

## muX apparatus

The muX apparatus combines in-beam muon detectors, Michel electron detectors, and a large HPGe detector array consisting of coaxial, planar, and MiniBall cluster detectors.

#### Miniball cluster



The muX setup at the end of the  $\pi E1$  beamline, deploying the full MiniBall HPGe array for the 2019 physics run.

MI + ηEI





Muonic X-rays are time **coincident** with a Bremsstrahlung photons are delayed, necessitating an optimized (intrinsically slow) HPGe

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Since 2017, a varying arrangement of HPGe detectors is particle, nuclear, and applied physics experiments. A high pressure (100 Bar) H2 target can be deployed for µ-transfer reactions.

### Detecting the 2sls transition

The background under a 2sIs X-ray photon is dominated by Compton

scattered (n>2)pls X-rays. The 2s population, and thus the SB can significantly be improved by  $\mu H \rightarrow \mu Z$  transfer, hereby populating low L states in the atomic cascade.





We measured the X-ray spectrum of  $\mu Kr$ after transfer. After subtracting the nuclear

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[1] F.Wauters and A. Knecht *arXiv*:2108.10765, 2021. [2] S. G. Karshenboim et al. Phys. Rev. D 90:073004, 2014. [3] J. Missimer and L. M.Simons *Physics Reports* 118 179-238, 1985 [4] M.Aiba et al., *arXiv*:2111.05788, 2021