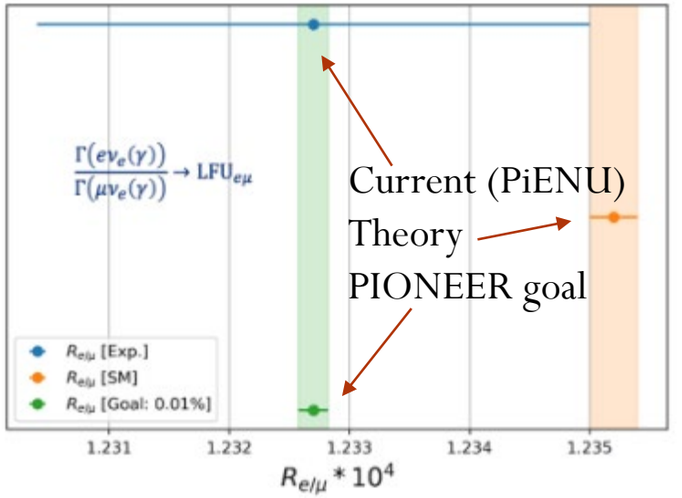
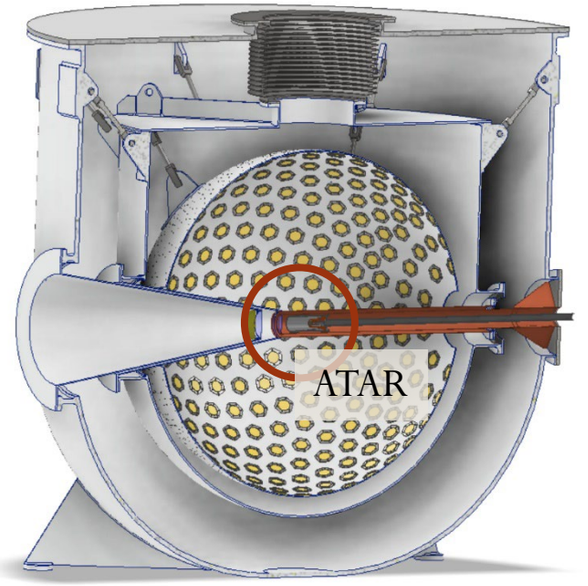
PIONEER detector design and the ATAR



- **PIONEER** is a next generation rare Pion decay experiment at PSI
  - Phase I: improve measurement of **charged lepton flavor universality $R_{e/\mu}$ by an order of magnitude**, reaching SM calculation precision
- **Three main detectors**: **Active Target (ATAR), Calorimeter** (LXe) with 1-2% energy resolution, **Low mass tracker** (μ-RWELL) in between

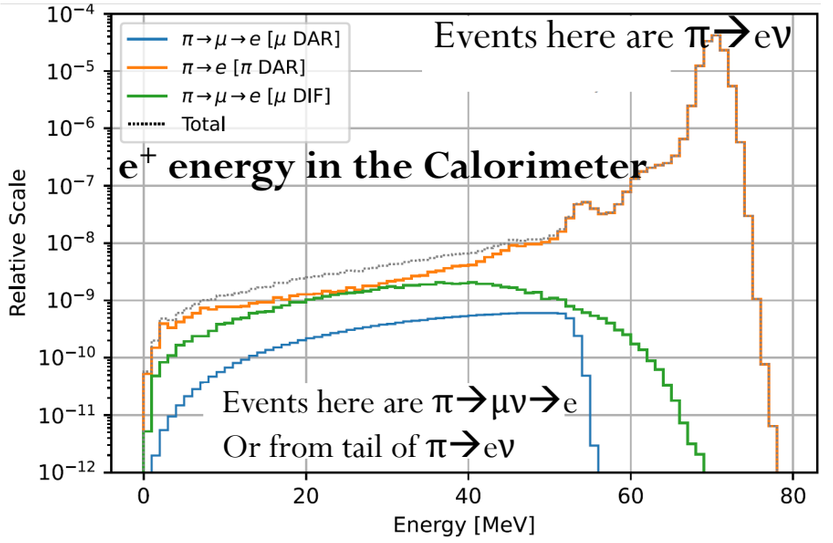
- **Full silicon active target (ATAR)**:
  - **High granularity** in (X,Y, Z), **fast full collection time**, good energy response, high dynamic range
  - 2x2 cm wide, 6 mm thick
- The **chosen sensor is a high granularity Low Gain Avalanche Diode (LGAD) technology**
  - **Why LGADs? High S/N, full fast collection time, great time resolution**
  - Alternative design with standard silicon also in the works

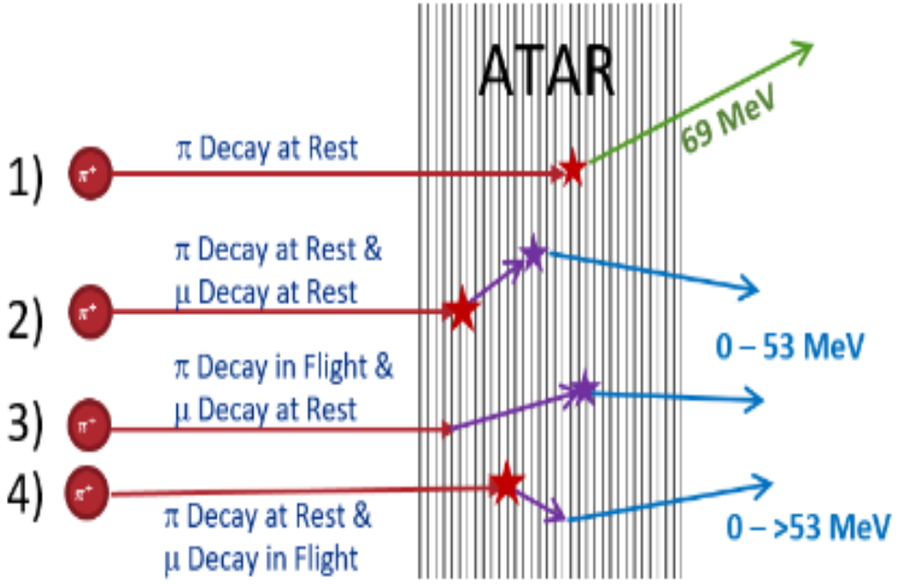


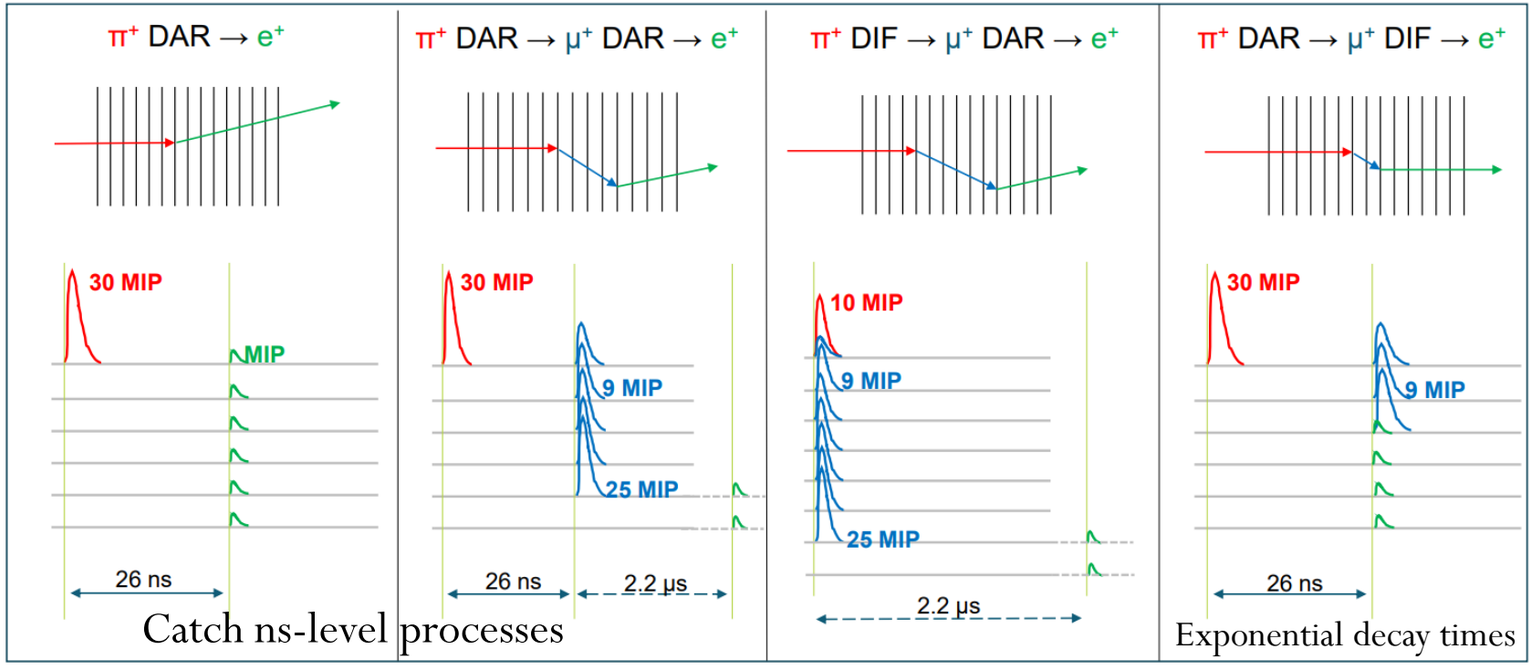
https://arxiv.org/abs/2203.01981

Event recognition in the ATAR

- **Goal: separation of energy spectra of π→eν and π→μν→eνvν**
  - A fraction of events cannot be separated by the energy measurement in the Calorimeter (tail overlap)
- **ATAR is crucial to recognize these decay chains**
- Readout is with fast electronics and fully digitized:
  - Hit position, time and energy → recognition of pions/muons/electrons
  - Need complex event reconstruction







https://indico.cern.ch/event/1175216/contributions/5064176/ https://indico.cern.ch/event/1175216/contributions/5064175/

A full 5D active target!

- Many **ATAR challenges**
  - Recognize hits that are few ns apart with high spatial and time resolution (4D tracking)
  - Good energy resolution on the hits (+ Energy = 5D) and large dynamic range (~1000)
  - Compact design and with minimized blind regions

- The ATAR is being designed for PIONEER but **the single elements can be modules of a general scalable 5D active target**
  - Active elements combined to be very close together

- **Applications of a 5D tracking modular system** would be immediate
  - **Straightforward upgrade of dozens of test-beam facilities around the world**, also useful in laboratory applications
  - **Photon science** (X-ray diffraction and imaging, Compton scattering), fast repetition rate and enough absorption
  - **Live decay detection** in nuclear physics experiments
  - **Pair telescopes**, like the NASA Fermi telescope, to replace cross-strip Si detectors
  - **Medical science** applications