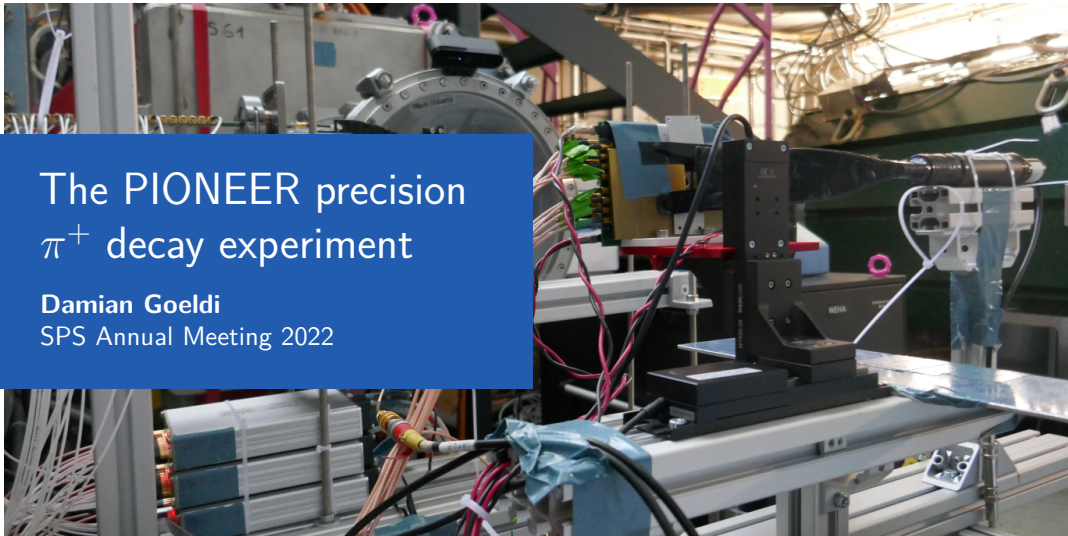


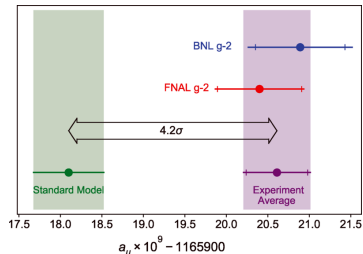
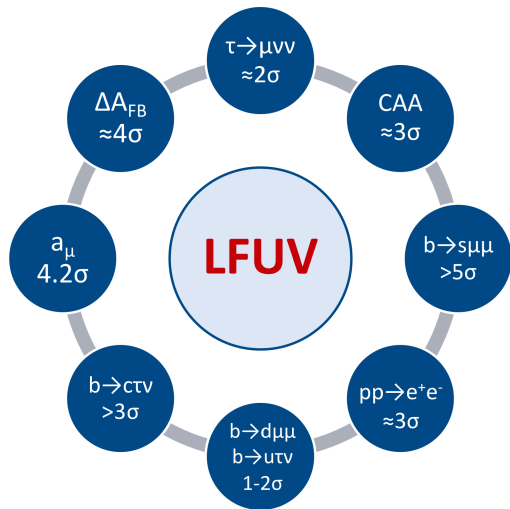
The PIONEER precision π^+ decay experiment

Damian Goeldi

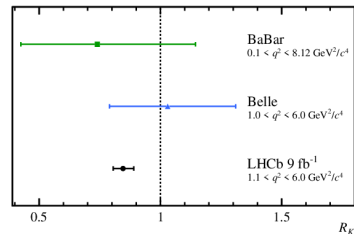
SPS Annual Meeting 2022



More and more hints of lepton flavour universality violations (LFUV)



DOI:10.1103/PhysRevLett.126.141801



PIONEER measurements of π^+ decay

Mode		Fraction (Γ_i/Γ)
Γ_1	$\mu^+ \nu_\mu$	$9.998\,770(4) \times 10^{-1}$
Γ_2	$\mu^+ \nu_\mu \gamma$	$2.00(25) \times 10^{-4}$
Γ_3	$e^+ \nu_e$	$1.230(4) \times 10^{-4}$
Γ_4	$e^+ \nu_e \gamma$	$7.39(5) \times 10^{-7}$
Γ_5	$e^+ \nu_e \pi^0$	$1.036(6) \times 10^{-8}$

	Mass [$\text{eV } c^{-2}$]	Lifetime [s]
$\pi^\pm$	1.396×10^8	2.603×10^{-8}
π^0	1.350×10^8	8.43×10^{-17}
$\mu^\pm$	1.057×10^8	2.197×10^{-6}
$e^\pm$	5.110×10^5	∞

- Phase I

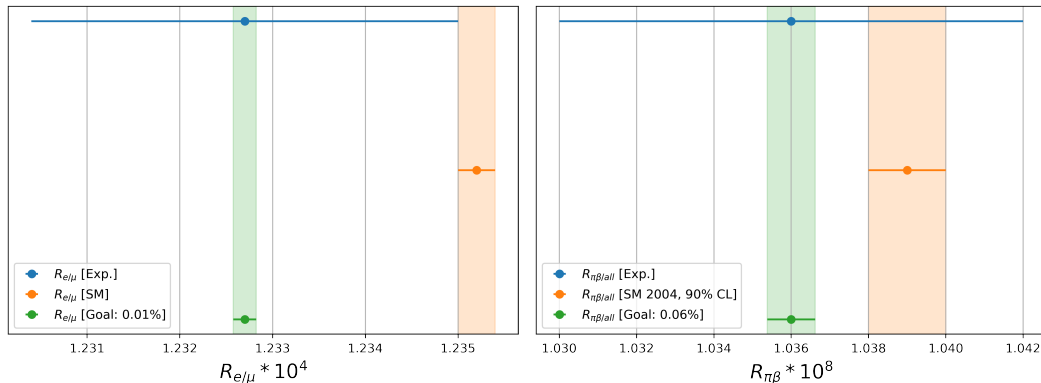
- $R_{e/\mu} = \Gamma_{3,4}/\Gamma_{1,2}$
- LFUV
- Helicity suppressed

- Phase II

- $R_{\pi\beta} = \Gamma_5/\Gamma$
- CKM unitarity
- Helicity and phase-space suppressed

Why $\pi^\pm$ decays?

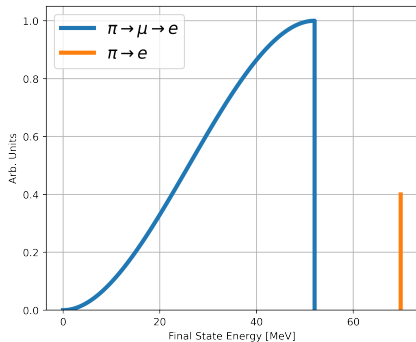
Goals for the PIONEER Measurements



$$R_{e/\mu}^{\text{Exp}} = 1.232\,70(230) \times 10^{-4}$$
$$R_{e/\mu}^{\text{SM}} = 1.235\,24(015) \times 10^{-4}$$

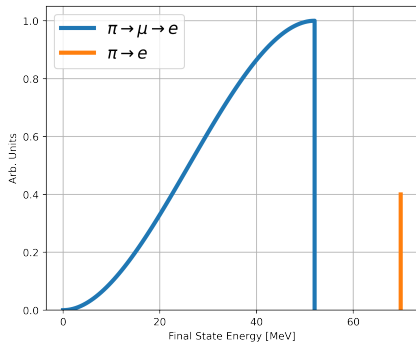
Why is a precise measurement so challenging?

Expectation

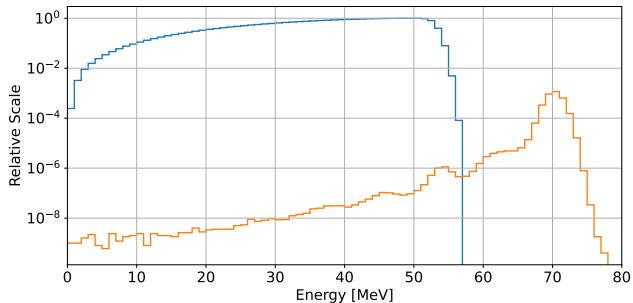


Why is a precise measurement so challenging?

Expectation



Reality

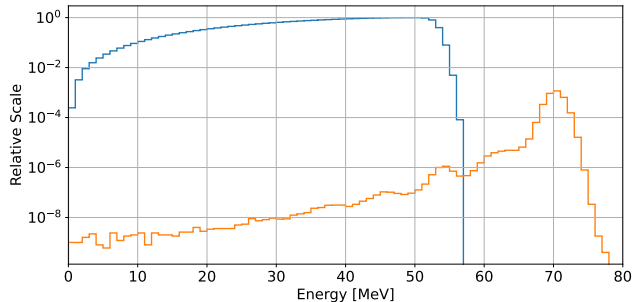


Challenges

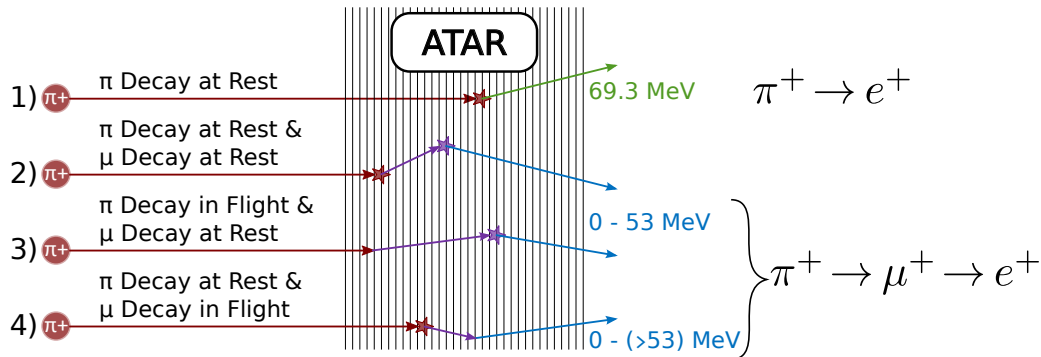
- Non-negligible tail fraction inside muon band
- Caused by
 - Calorimeter size
 - Energy resolution
 - Photonuclear losses

⇒ Reduce tail fraction

- $25 X_0$ size
- 1.5 % resolution
- Still not enough...

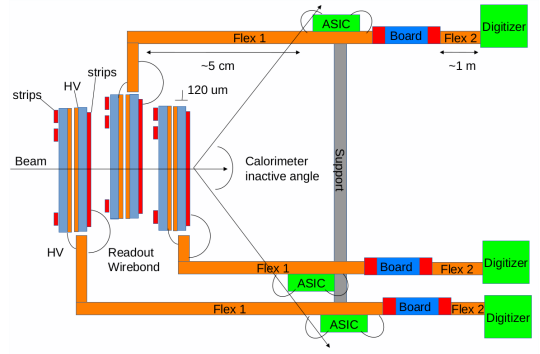
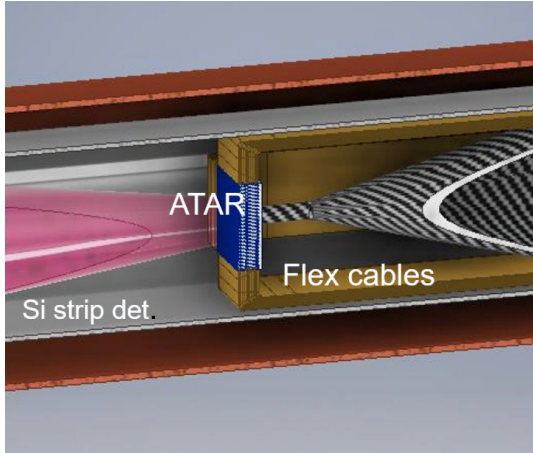


Use an Active TARget to suppress muon branch triggers

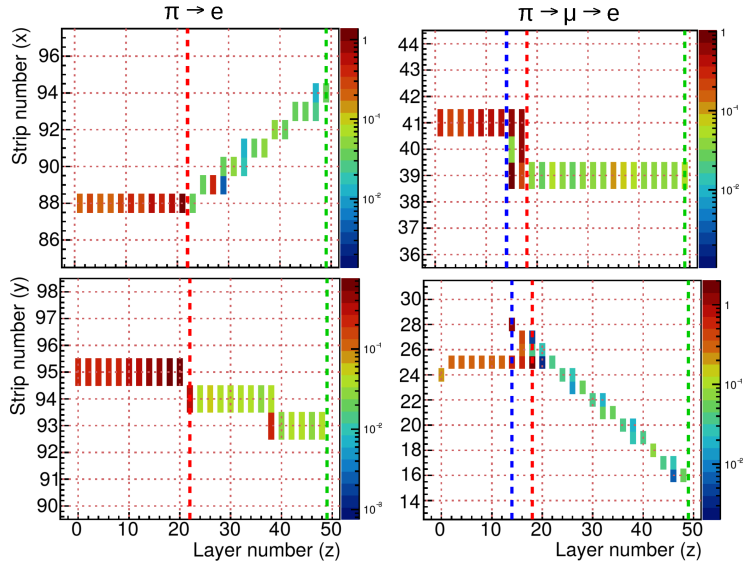


- 1 and 2 have very clear stopping energy deposit signatures
 - 4 is especially tricky as it can mimic 1 in the calorimeter
- ⇒ Need enough space-time and energy resolution to correctly identify all four

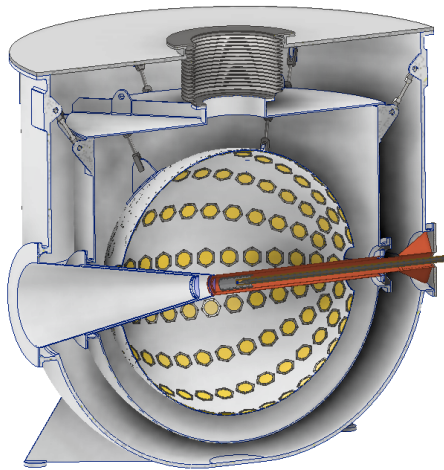
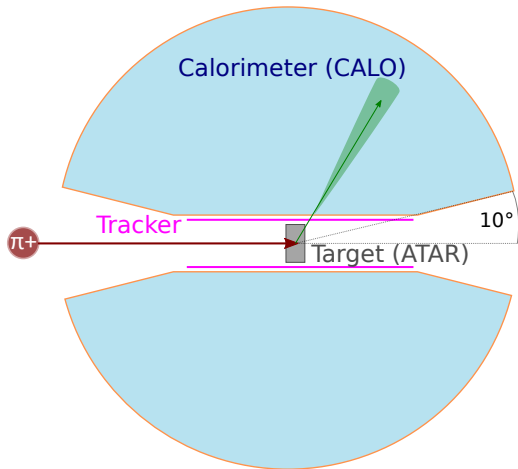
ATAR conceptual design



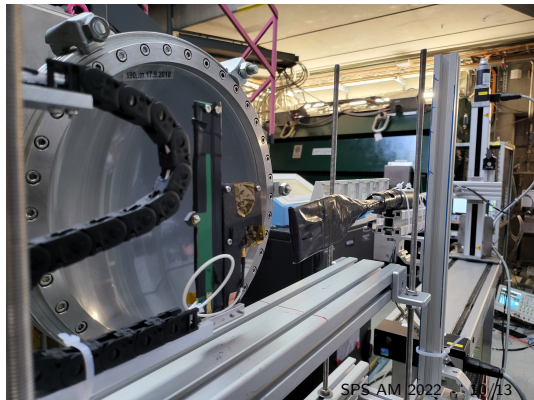
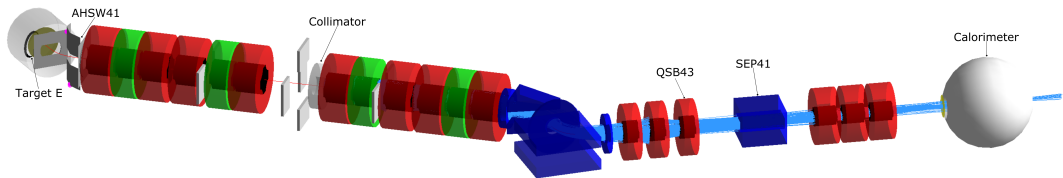
Simulated ATAR event



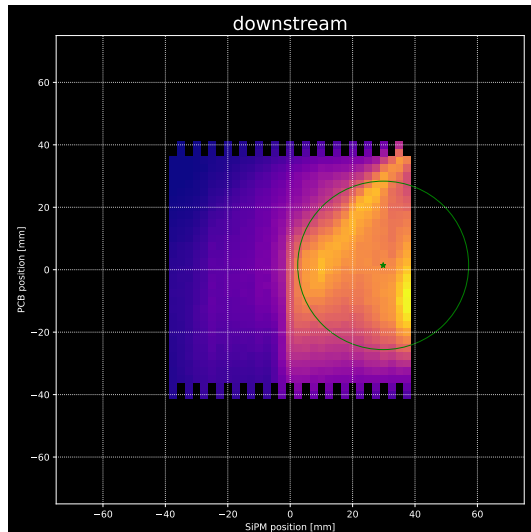
PIONEER conceptual design



2022 test beam time at PSI π E5 beamline

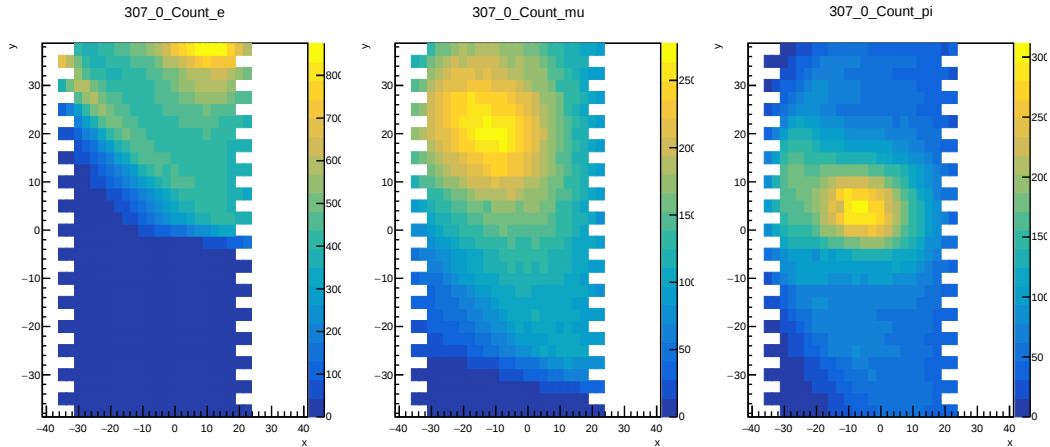


Beam profiling



π^+ , μ^+ , and e^+

We separate them using an electric field



Conclusions and Outlook

- PIONEER is a newly approved PSI experiment
- aiming for a precision pion decay measurement
- down to the SM prediction
- probing lepton flavour universality
- and possibly CKM unitarity in a second phase.
- In a successful May 2022 beam time
- we proved sufficient π^+ flux
- and separation from μ^+ and e^+
- at PSI's π E5 high-intensity beam line.
- <https://psi.ch/pioneer>

The PIONEER collaboration

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