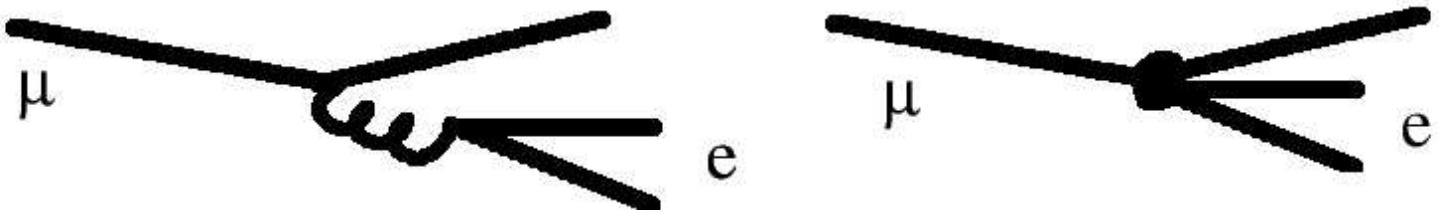
Introduction to $\mathcal{TWIST}$

A. Gaponenko, for the $\mathcal{TWIST}$ collaboration

- The physics of muon decay
- The detector
- Status/conclusions

Muon decay—I



The general matrix element:

$$\frac{4G_F}{\sqrt{2}} \sum_{\substack{\gamma=S,V,T \\ \varepsilon,\mu=R,L}} g^{\gamma}_{\mu\nu} \left\langle \bar{e}_{\varepsilon} \middle| \Gamma^{\gamma} \middle| (\nu_e)_n \right\rangle \left\langle (\bar{\nu}_{\mu})_m \middle| \Gamma_{\gamma} \middle| \mu_{\mu} \right\rangle,$$

$$\Gamma^S = 1, \qquad \Gamma^V = \gamma^{\alpha}, \qquad \Gamma^T = \frac{i}{\sqrt{2}} \sigma^{\alpha\beta},$$

- 10 complex coupling constants $\Longrightarrow$ 19 independent real parameters.
- The Standard Model: $g^V_{LL} = 1$, the rest are zero.

Muon decay—II

Michel spectrum:

$$\frac{d^2\Gamma}{dx\, d\cos(\theta)} \propto F_{\rm IS}(x) + P_\mu \cos(\theta)\, F_{\rm AS}(x)$$

where $x = E_e/E_e^{\rm max}$, and

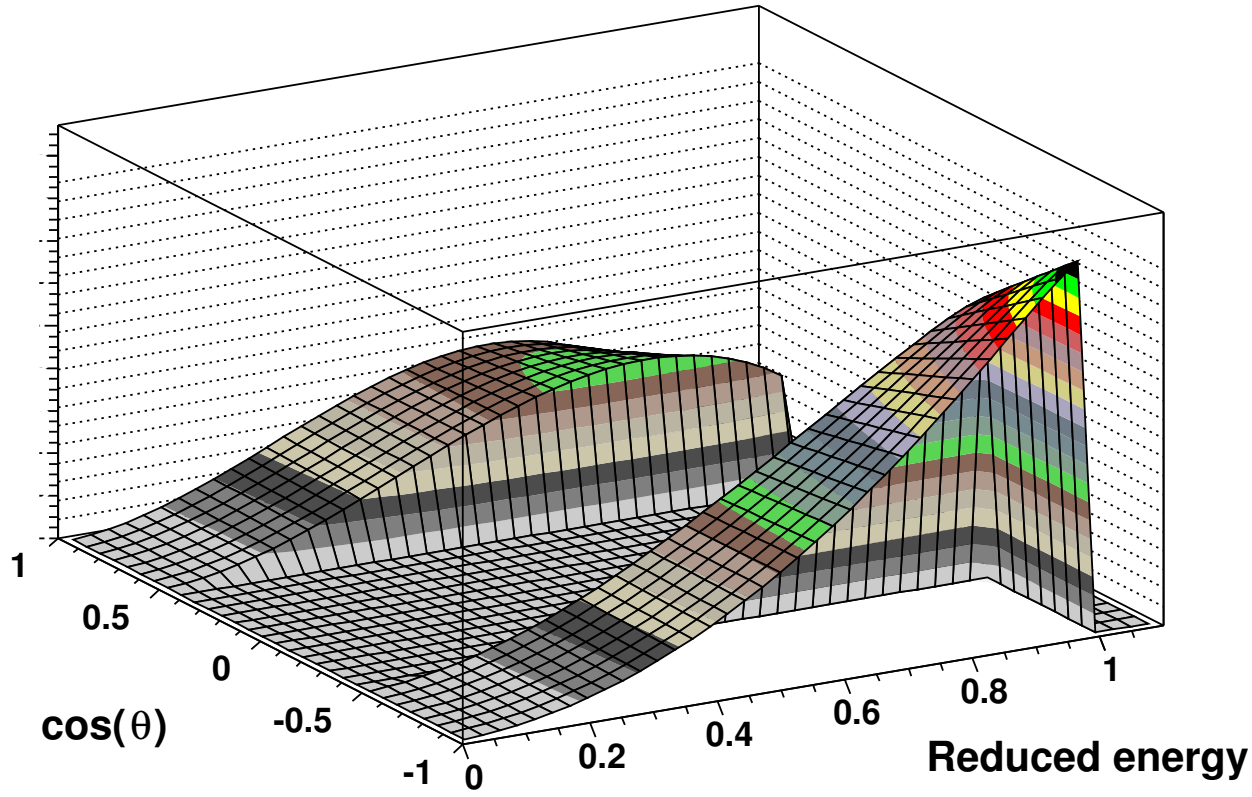
$$F_{\rm IS} = x^2(1-x) + \frac{2}{9}\rho\,(4x^3 - 3x^2) + \eta\,\frac{m_e}{E_e^{\rm max}}\,x(1-x)$$

$$F_{\rm AS} = \frac{1}{3}\xi\,x^2\left[1 - x + \frac{2}{3}\delta\,(4x-3)\right]$$

- $\mathcal{TWIST}$ will measure the shape of a large part of the 2D spectrum to high precision $\Longrightarrow$ *Simultaneous measurement* of 3 (or 4) Michel parameters for the first time .

Michel spectrum

The middle region is not shown because
it can not be seen by $\mathcal{TWIST}$.



Current best measurements

From the Review of Particle Physics

ρ	$=$	0.7518 ± 0.0026	(Derenzo, 1969)
η	$=$	-0.007 ± 0.013	(Burkard *et al.*, 1985)
δ	$=$	$0.7486 \pm 0.0026 \pm 0.0028$	(Balke *et al.*, 1988)
$P_\mu \xi$	$=$	$1.0027 \pm 0.0079 \pm 0.0030$	(Beltrami *et al.*, 1987)
$P_\mu \frac{\xi\delta}{\rho}$	$>$	$0.99682, \ CL = 90\%$	(Jodidio *et al.*, 1986)

Right-handed interactions in $\mathcal{TWIST}$: a model-independent test

Fetscher *et al.*: probabilities $Q_{\varepsilon\mu}$ for a μ-handed muon to decay into an ε-handed electron. $\sum_{\varepsilon,\mu} Q_{\varepsilon\mu} = 1, \quad 0 \leq Q_{\varepsilon\mu} \leq 1.$

Right-handed content of the muon:

$$
\begin{aligned}
Q_R^\mu &= Q_{RR}^\mu + Q_{LR}^\mu \\
&= \frac{1}{4}\left|g_{RR}^S\right|^2 + \frac{1}{4}\left|g_{LR}^S\right|^2 + \left|g_{RR}^V\right|^2 + \left|g_{LR}^V\right|^2 + 3\left|g_{RR}^T\right|^2 \\
&= \frac{1}{2}\left\{1 + \frac{1}{3}\,\xi - \frac{16}{9}\,\xi\delta\right\}
\end{aligned}
$$

$\mathcal{TWIST}$ measures not ξ but $P_\mu\xi$. However, $P_\mu \neq 1$ implies a right-handed interaction in muon production.

Left-Right symmetric models—I

$$W_L = \cos\zeta\, W_1 + \sin\zeta\, W_2$$

$$W_R = -\sin\zeta\, W_1 + \cos\zeta\, W_2$$

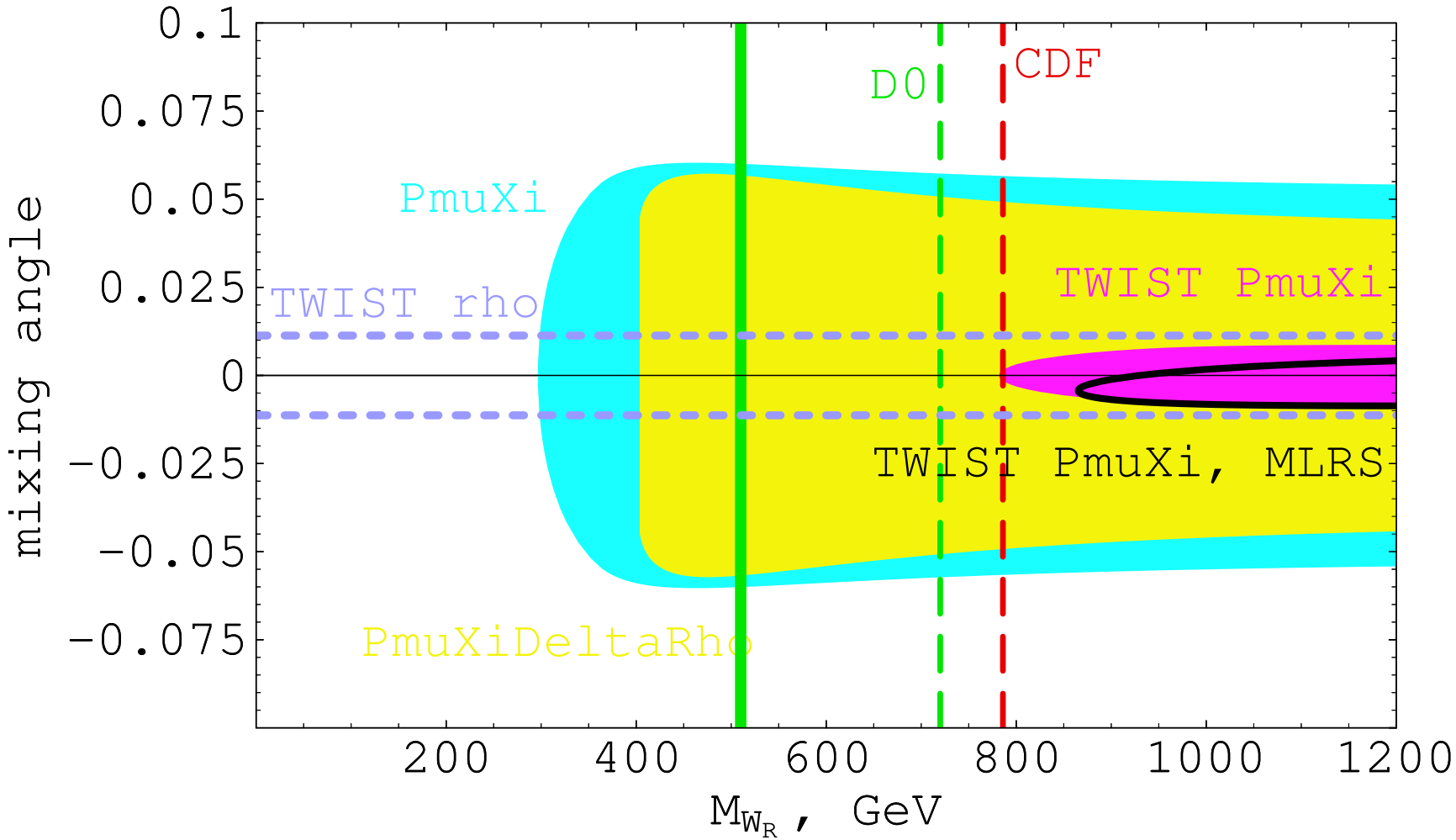
$$\rho = \frac{3}{4}\left(1 - 2\zeta^2\right)$$

$$\xi = 1 - 2\left(t^2 + \zeta^2\right)$$

$$P_\mu = 1 - 2\zeta^2 - 2t^2\,\frac{|V_{ud}^R|^2}{|V_{ud}^L|^2} - 4\zeta t\,\frac{|V_{ud}^R|}{|V_{ud}^L|}$$

where $t = M_1^2/M_2^2$.

Left-Right symmetric models—II



Some other models affecting Michel parameters

- SUSY with R-parity violation:

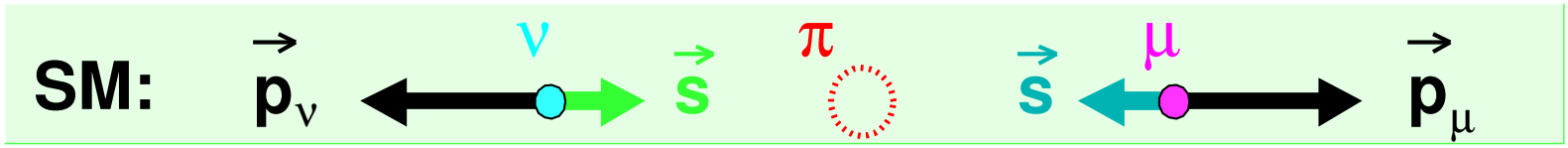
$$\Delta\rho = \frac{3\varepsilon^2}{16}, \quad \Delta\eta = \frac{\varepsilon}{2}, \quad \Delta\xi = -\frac{\varepsilon^2}{4}, \quad \Delta\delta = 0.$$

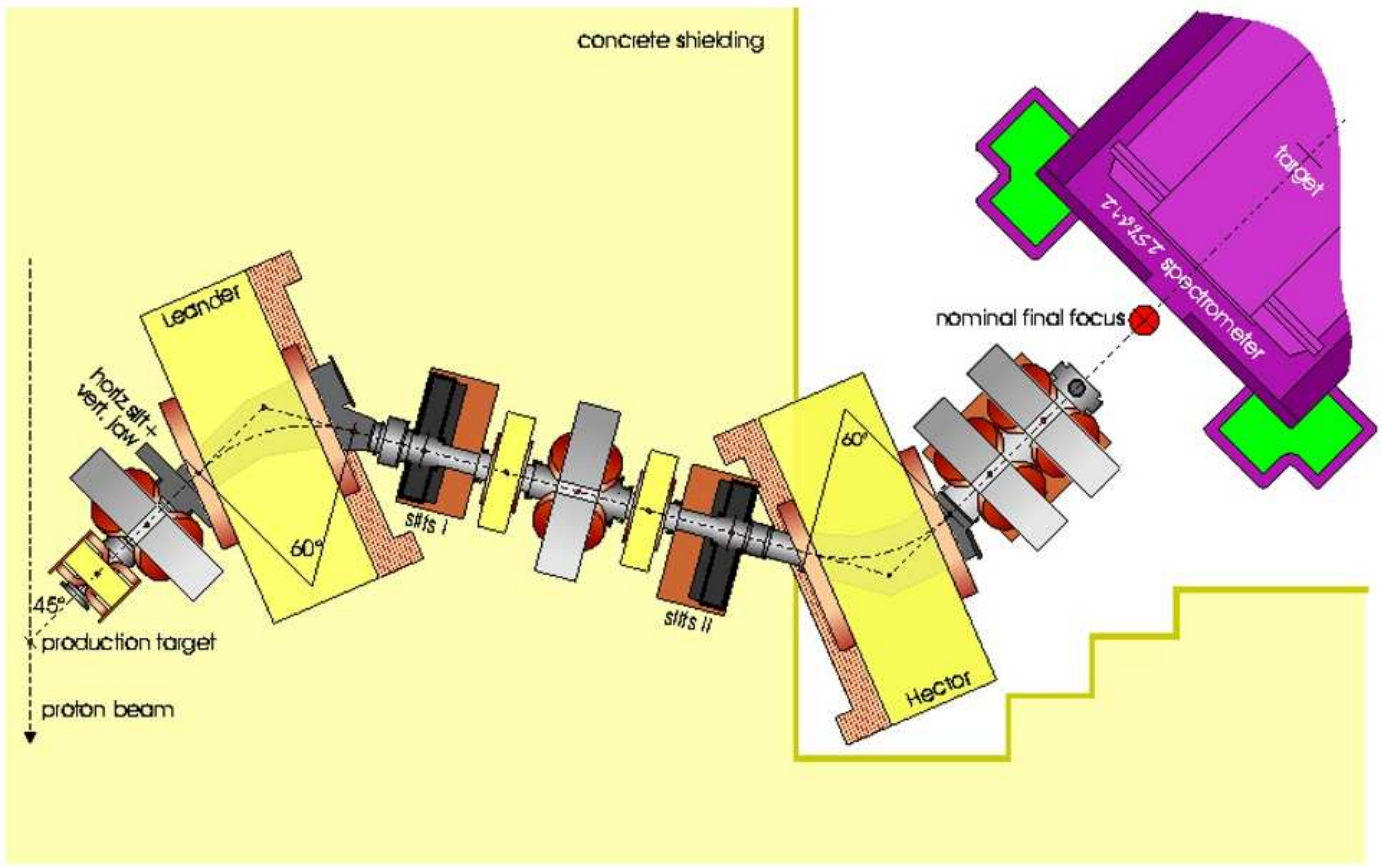
- K.S. Babu and Sandip Pakvasa (hep-ph/0204236, April 2002). To accomodate the LSND result:

$$\Delta\rho \approx -0.0015, \quad \Delta\eta = 0, \quad \Delta\xi \approx -0.0026, \quad \Delta\delta \approx -0.0015.$$

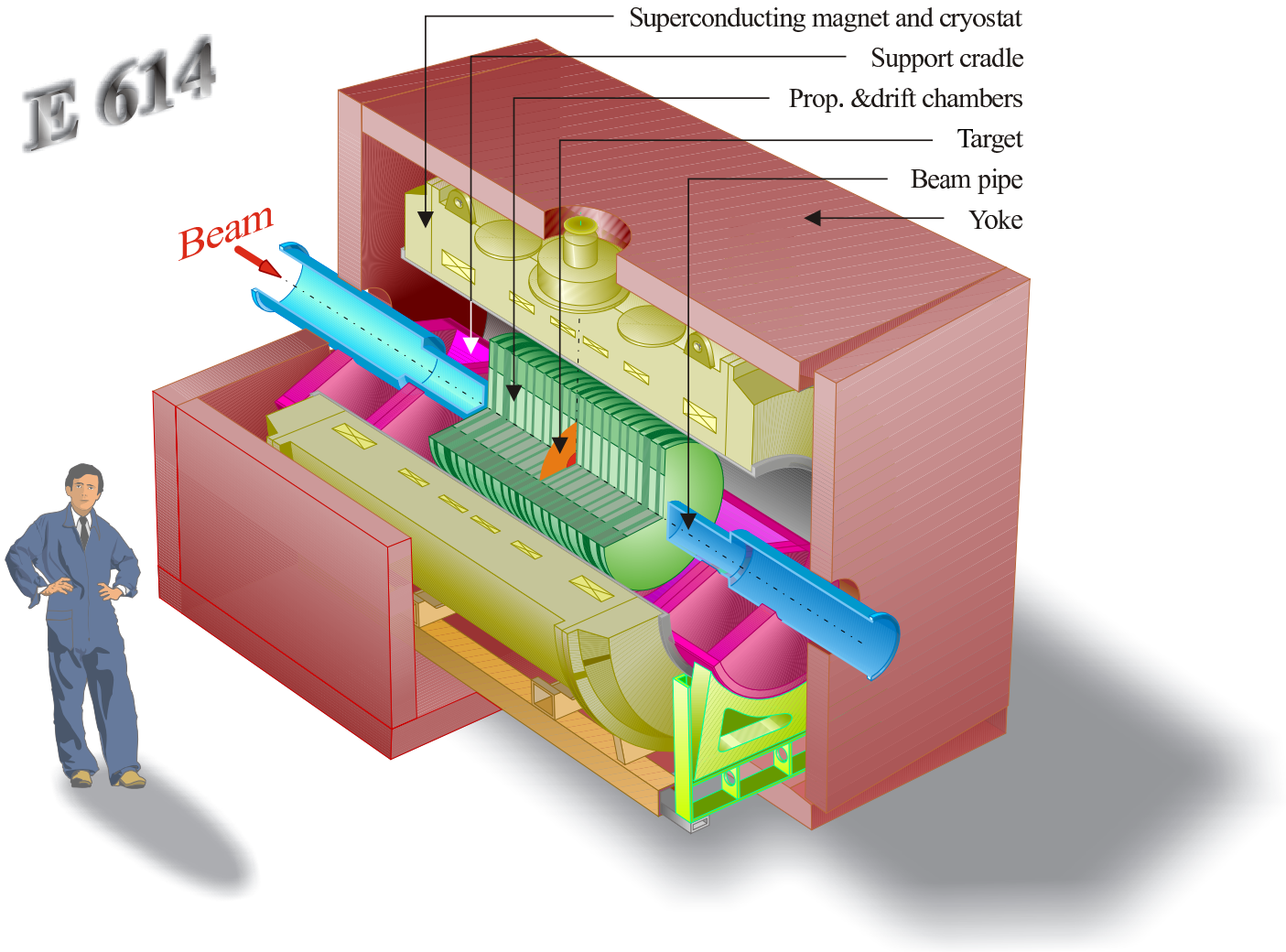
- Extra dimensions?
  - ▷ Split fermions: $\eta \neq 0$.

The experiment: beamline

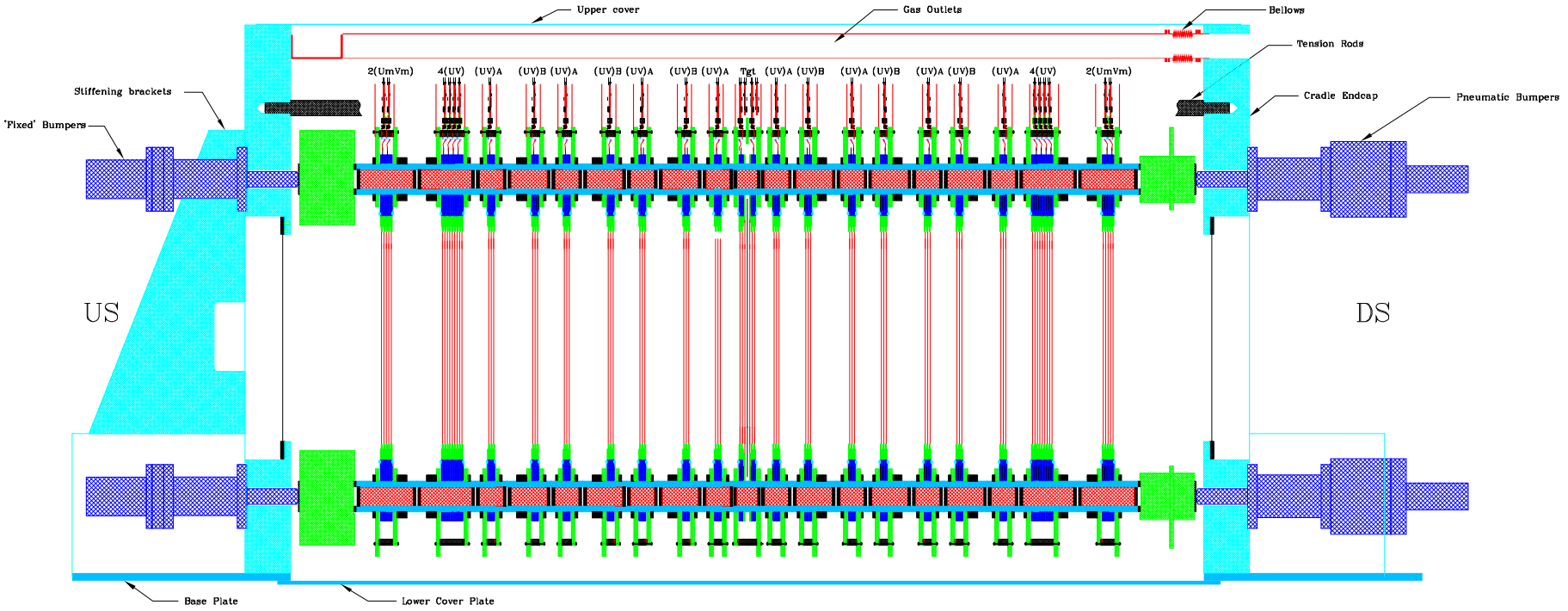




The experiment: *TWIST* detector—I



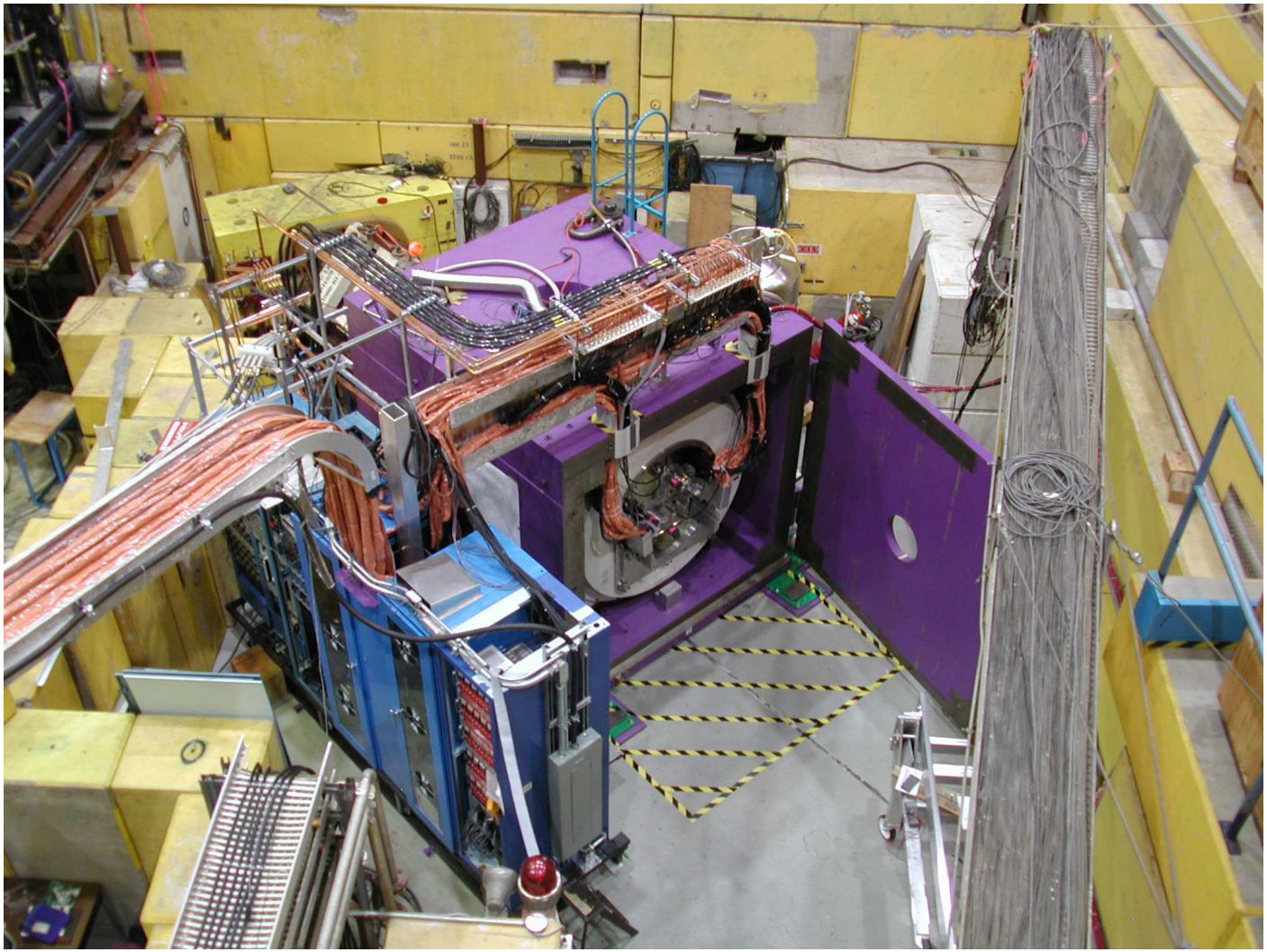
The experiment: *TWIST* detector—II



TWIST Spectrometer

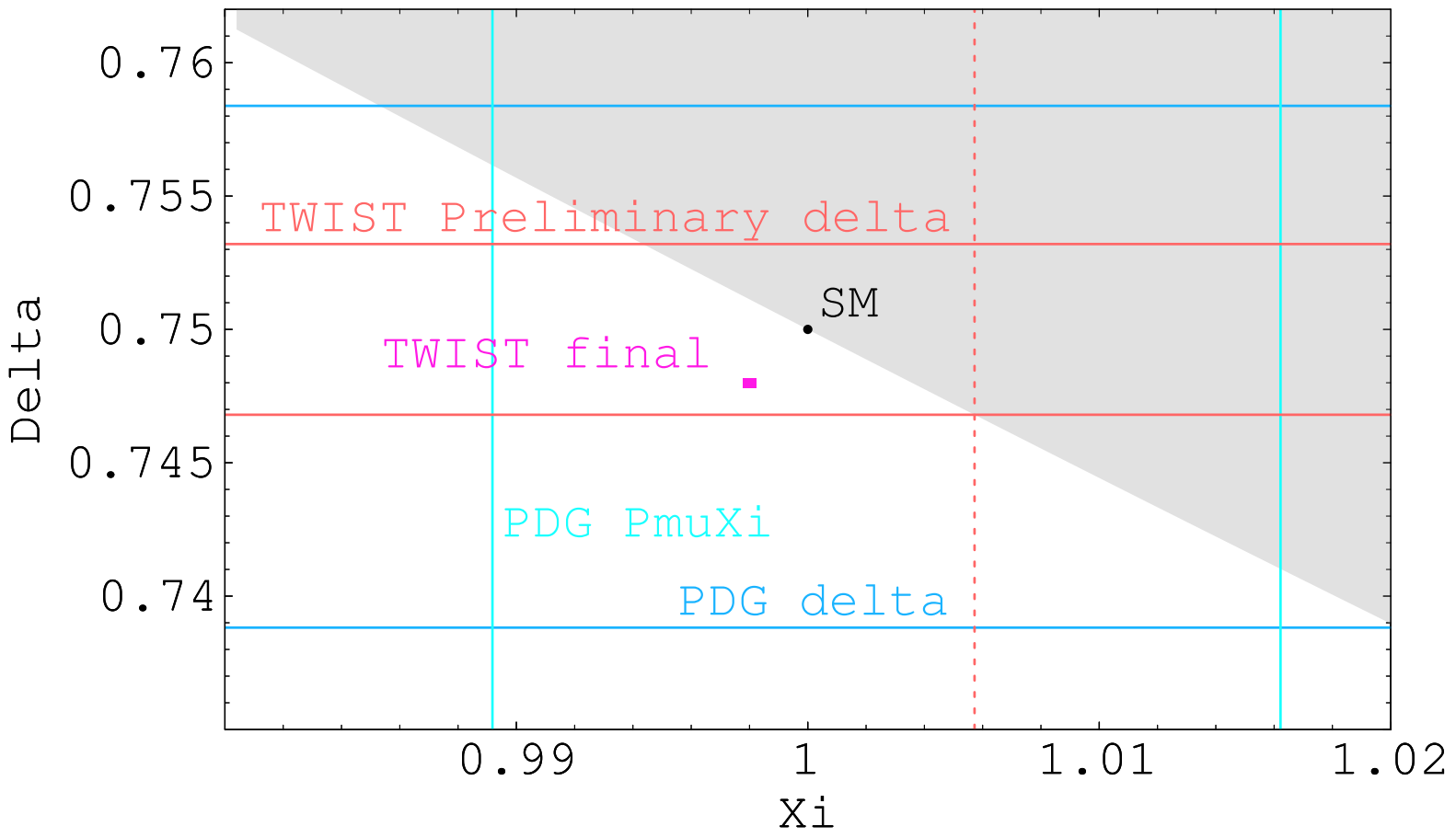
The experiment: *TWIST* detector—III

The experiment: *TWIST* detector—IV



Summary

- $\mathcal{TWIST}$ sensitivity to physics beyond the Standard Model:
  - ▷ model-independent sensitivity to right-handed interactions,
  - ▷ data on Left-Right symmetric models complementary to collider experiments.
- Stimulated theoretical work on muon decay.
- 6×10^9 events on tape.
- Analysis is in progress.
- Aiming for ρ and δ at 10^{-3} by Christmas.



$\mathcal{TWIST}$ data on this plot show anticipated precision, the central values are arbitrary.