SciFi Tracker LHCb

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By Joost van Dijk

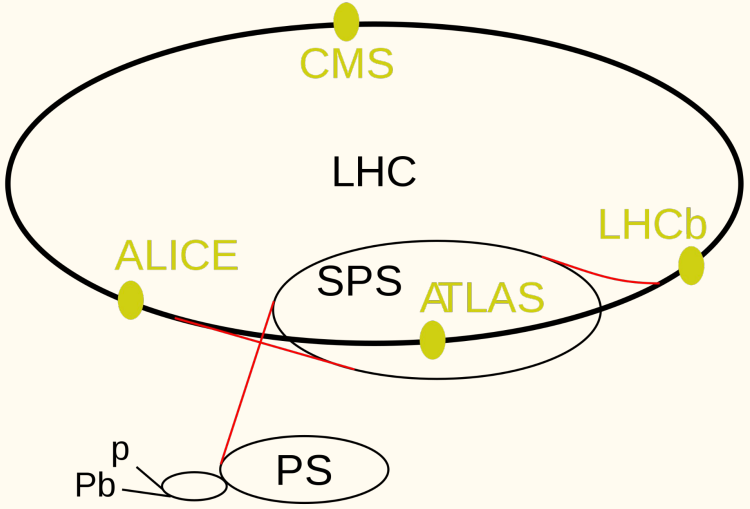
Outline

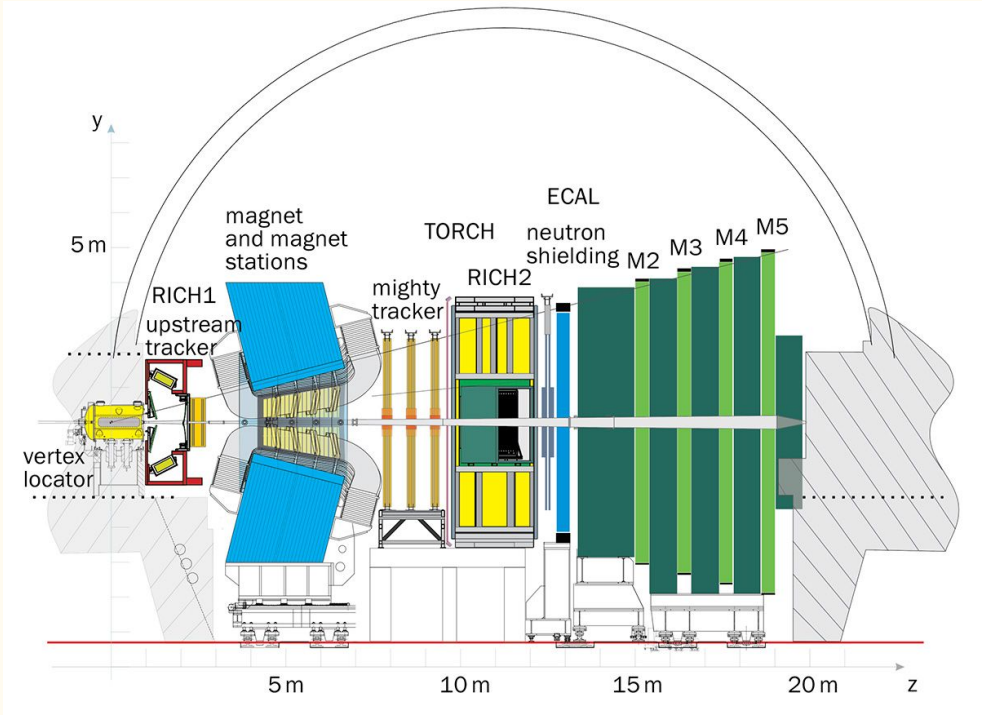
- LHCb
- SciFi Tracking Detector
- Fiber and SiPM
- CP (violation)
- Why look for CPV

LHCb

https://commons.wikimedia.org/wiki/File:Lhcb-logo-new.svg

Large Hadron Collider Beauty



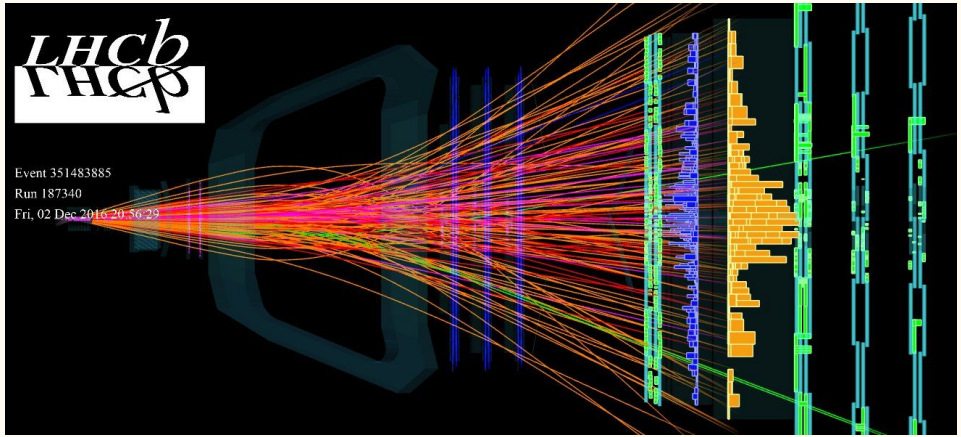


https://en.wikipedia.org/wiki/LHCb_experiment#/media/File:LHC.svg

https://cerncourier.com/a/lhcb-looks-forward-to-the-2030s/

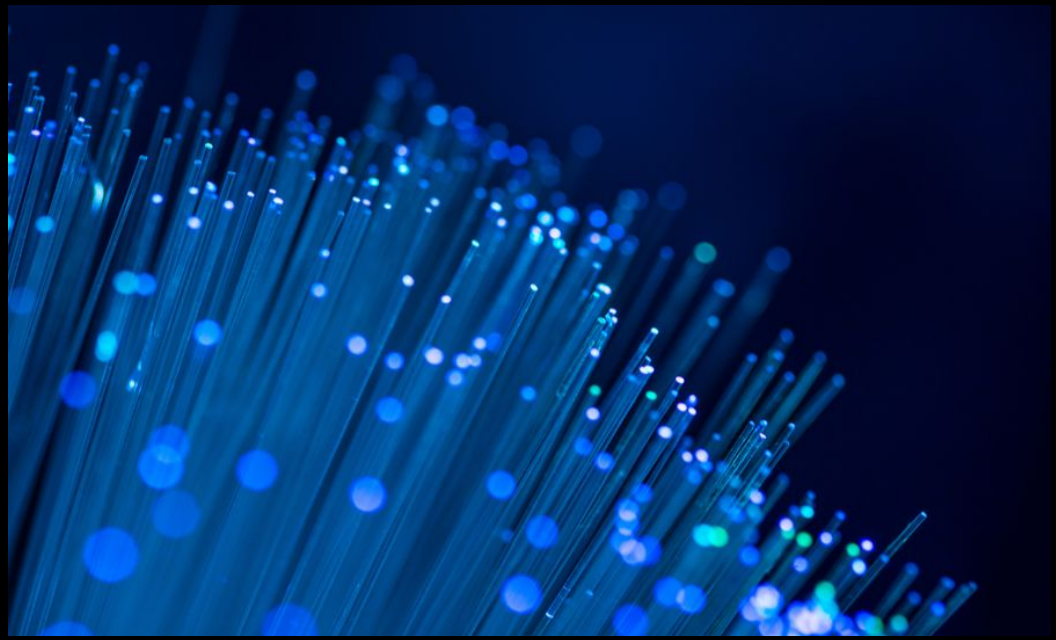
LHCb

- B-physics
- CP violation
- Forward Geometry (heavy quarks)
- Precision Measurements
- Rare decay (new physics?)



https://twitter.com/LHCbExperiment/status/805890561156808704/photo/1

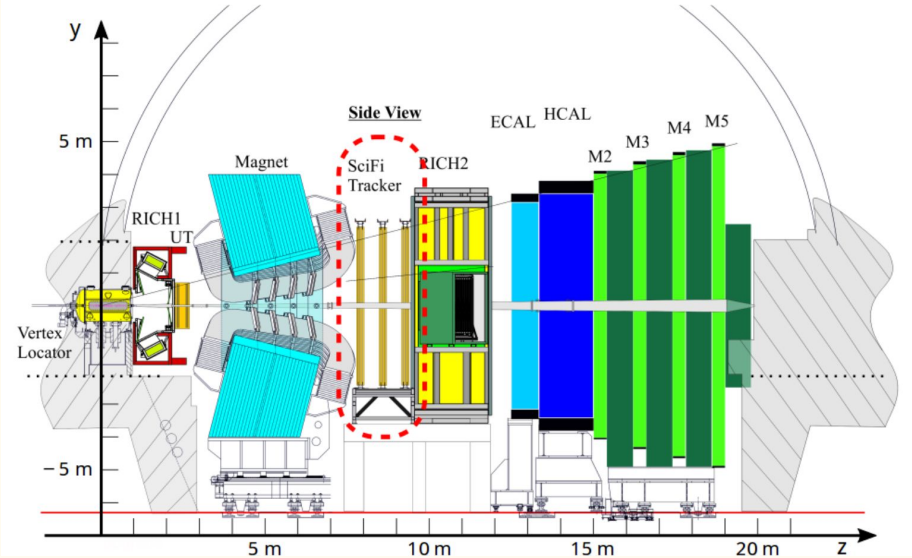
Scifi



https://resources.altium.com/p/semiconductor-fibers-could-replace-fiber-optic-cable-transmission-lines

Scifi tracker

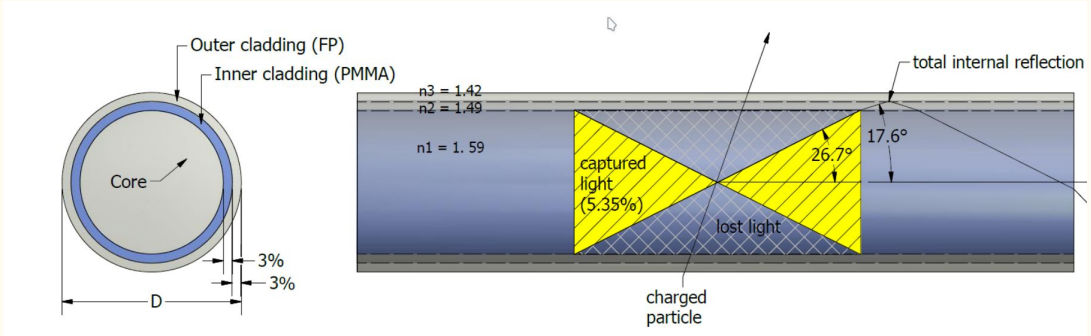
- 3 stations, 8 fiber mats, mirror in between
- Each mat has 6 layers of densely packed scintillating fibres
- 5 degrees angle
- Total of approx. 2500 fibers, 340 m2
- 250 μm fiber
- Scintillation recorded by SiPM
- Spacial 100 μm resolution
- Read-out of 40MHz
- Radiation (up to 35 kGy)
- Cooled to -40◦ C

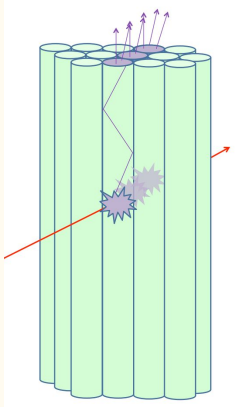


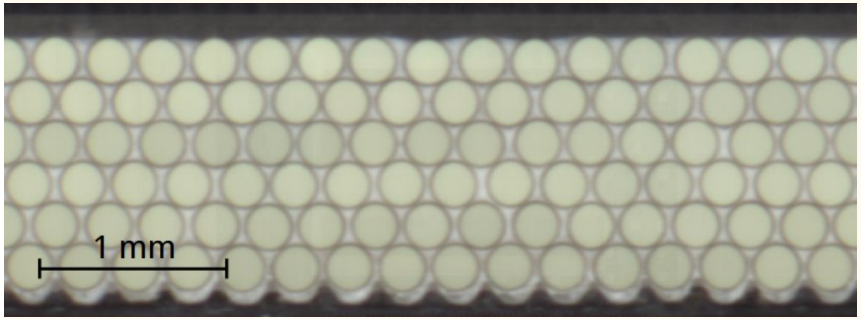
https://arxiv.org/pdf/1710.08325.pdf

Scintillating fibers

- SCSF-78MJ polystyrene
- ~2.8ns decay time
- Several thousands photons per MeV
- Wavelength shifting with activator
- 450 nm wavelength
- Replacement modules due to Radiation
- 40% loss of transmitted light after 10 years of radiation

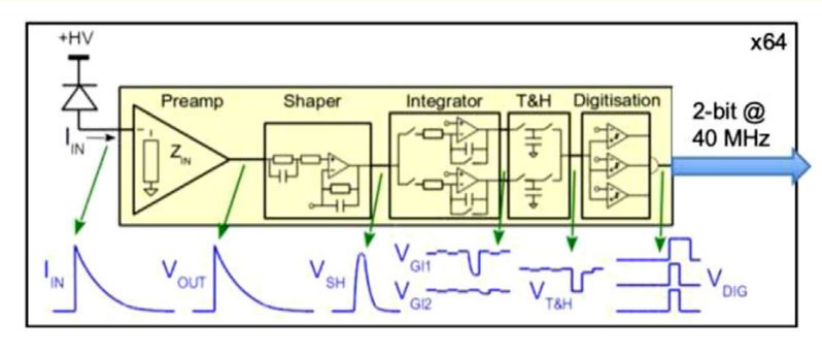




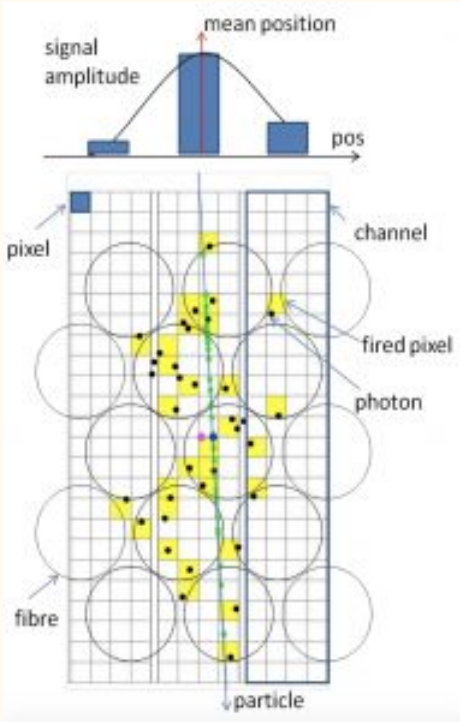


SiPM

- 45% photon detection efficiency
- Cooled to suppress dark noise



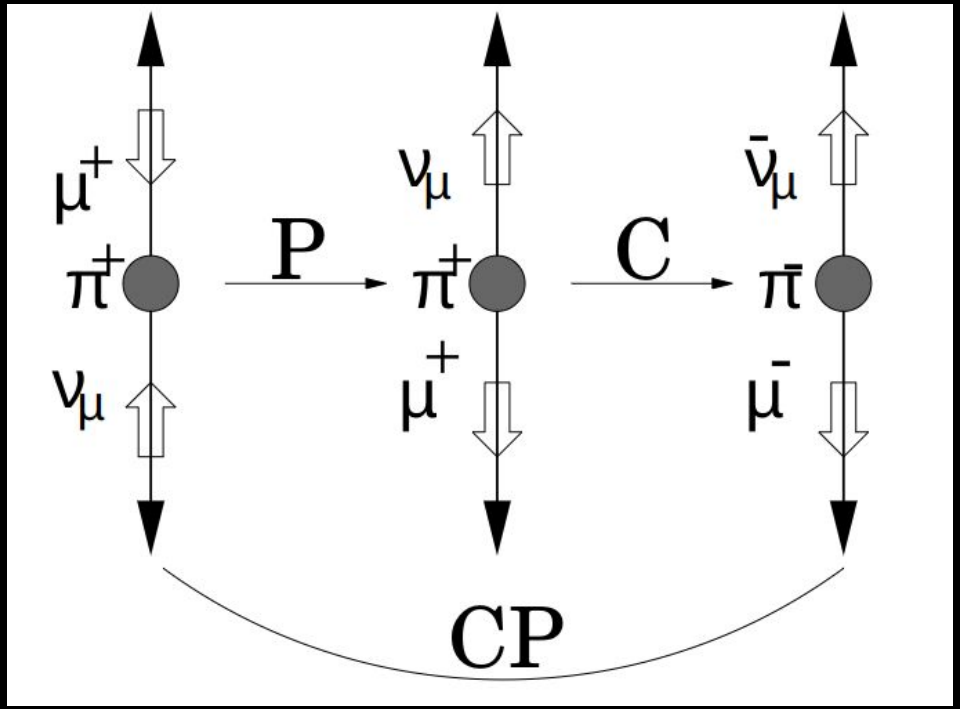
https://www.sciencedirect.com/science/article/pii/S016890021930422X



https://www.epfl.ch/labs/lphe/en/lhcb/sipm/

Image: Lecture notes on CP violation from N. Tuning

CP



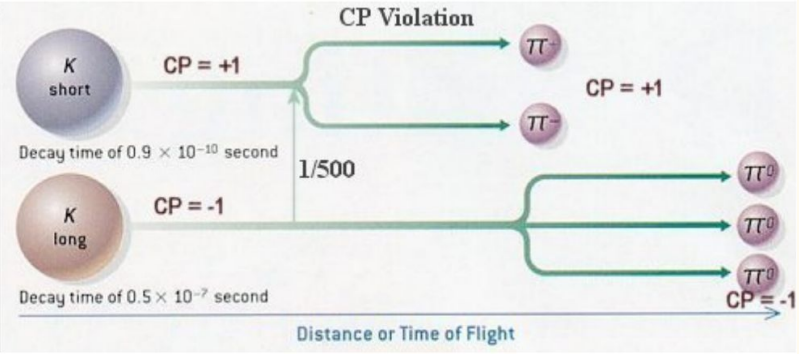
$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

$$=$$

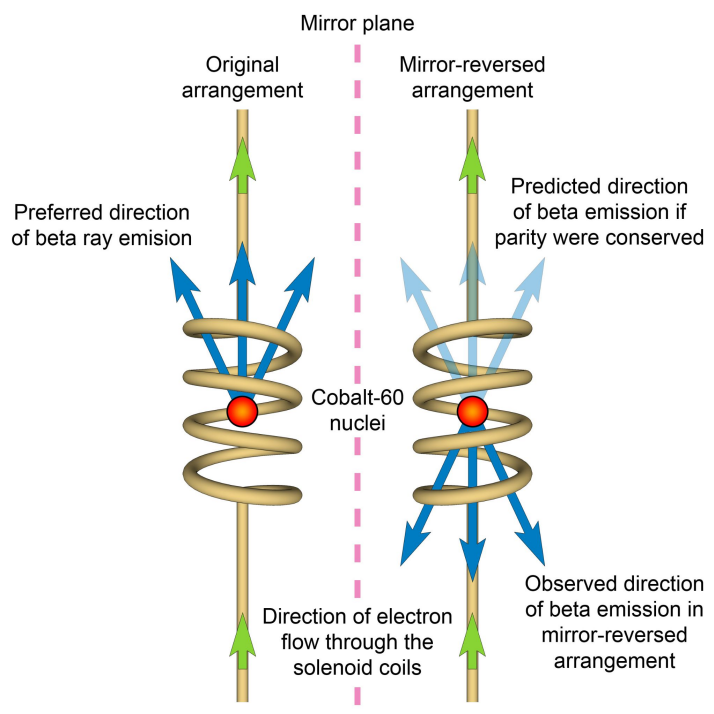
$$\pi^- \rightarrow \mu^- + \bar{\nu_\mu}$$

CP violation

- 1956 Wu's experiment
- 1957 Lee and Yang "for their penetrating investigation of the so-called parity laws which has led to important discoveries regarding the elementary particles"
- 1964 Cronin and Fitch



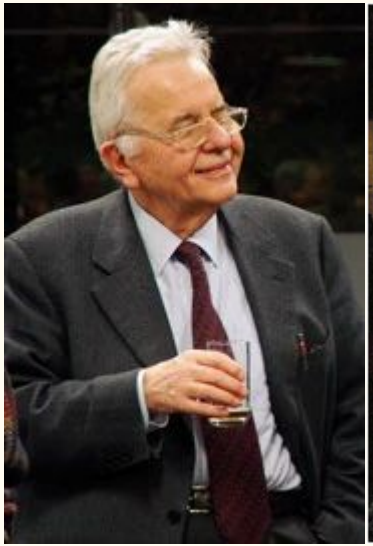
https://www.physi.uni-heidelberg.de/~reygers/seminars/2015/nobel_prizes_in_particle_physics/talks/paul_cp_violation.pdf



https://en.m.wikipedia.org/wiki/File:Parity_violation_principle_Wu_experiment_%28English%29.jpg

Cabibbo-Kobayashi-Maskawa

CP in Standard model



https://www.nature.com/articles/nphys1791

https://www.researchgate.net/figure/Makoto-Kobayashi-and-Toshihide-Maskawa-display-their-Nobel-Prize-Medals-after-the-awards_fig15_310428923

$$\begin{bmatrix} d' \\ s' \\ b' \end{bmatrix} = \begin{bmatrix} V_{\mathrm{ud}} & V_{\mathrm{us}} & V_{\mathrm{ub}} \\ V_{\mathrm{cd}} & V_{\mathrm{cs}} & V_{\mathrm{cb}} \\ V_{\mathrm{td}} & V_{\mathrm{ts}} & V_{\mathrm{tb}} \end{bmatrix} \begin{bmatrix} d \\ s \\ b \end{bmatrix}.$$

Unitary triangle and wolfenstein parametrization

$$V^\dagger V = V V^\dagger = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} V_{ud}^* & V_{cd}^* & V_{td}^* \\ V_{us}^* & V_{cs}^* & V_{ts}^* \\ V_{ub}^* & V_{cb}^* & V_{tb}^* \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$

$$V_{CKM} = \begin{pmatrix} 1 - \frac{1}{2}\lambda^2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1 - \frac{1}{2}\lambda^2 & A\lambda^2 \\ A\lambda^3(1 - \rho - i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \delta V$$

Image: Lecture notes on CP violation from N. Tuning

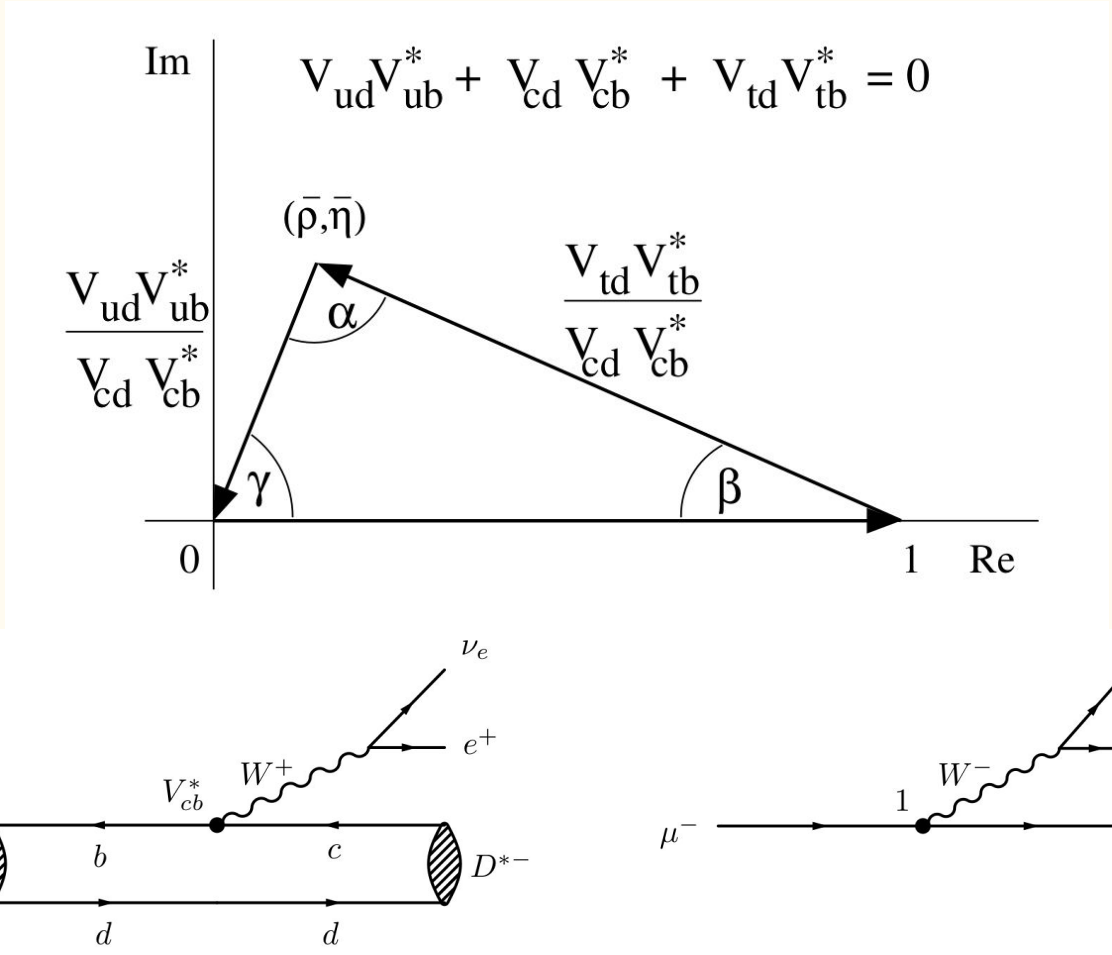
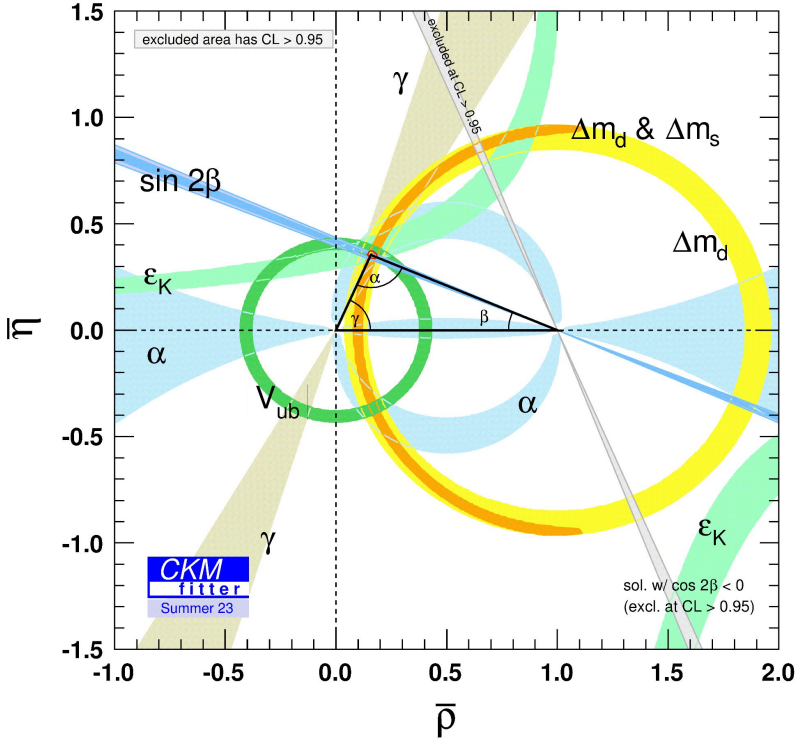


Image: Lecture notes on CP violation from N. Tuning

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

$$\begin{bmatrix} 0.97373 \pm 0.00031 & 0.2243 \pm 0.0008 & 0.00382 \pm 0.00020 \\ 0.221 \pm 0.004 & 0.975 \pm 0.006 & 0.0408 \pm 0.0014 \\ 0.0086 \pm 0.0002 & 0.0415 \pm 0.0009 & 1.014 \pm 0.029 \end{bmatrix}$$



http://ckmfitter.in2p3.fr/www/results/plots_summer23/png/rhoeta_large.png

Why look for CPV?

Questions?

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- Authors not listed. "The LHCb Scintillating Fiber Tracker," Nuclear Instruments and Methods in Physics Research Section A, 2019. DOI: https://doi.org/10.1016/j.nima.2019.03.042. Available at: https://www.sciencedirect.com/science/article/abs/pii/S016890021930422X?via%3Dihub
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