GITHUB TUTORIALS

12/10/2020

Branch → edit by adding "commits" → pull request to discuss commits & review, → deploy from branch to test → merge w/ main

Distributed version control system → see all edits & changes
→ view history
→ split by user

commits = file history, edits.

Git commands → git clone = create a local copy of an existing project.

WHERE TO START?

- ~~Analyse example code & make notes~~
- ~~Data format → root pages~~

Measure W & Z production cross sections
→ these constrain PDFs
PDF – how likely is it to find an up quark w/ a particular momentum fraction when you probe the proton at a particular energy scale

Dataset never looked at → low energy run @ $\sqrt{s} = 5$ TeV
→ unique sensitivity to proton structure at larger momentum fractions

Split between as – measurement of x-sections
– calculation of the "hypothesis" theory predictions of x-sections

Next step: Search for Z boson in the dataset
to familiarise w/ helper functions for 4-momentum vectors

- Method on comment, one do python, one C

15/10/2020

MIKA MEETING

- Initial set up on top level read me (ESSENTIAL)

  ALWAYS:

  module use /warwick/epp/Modules
  module load linuxbrew

- ROOT is CERN project
  ROOT trees are the data format
  ∴ use to extract data & can create histograms.

- Issues 2 & 3 → ROOT TBrowser
  → pythonic event loop in ROOT

- Rule of thumb python x100 slower than C by TTree is a lot faster

- Going through TTree & TBrowser

  root [0] → can type C into this
  → useful to inspect file

  quicker if add "root -l /shor"

  see says "attaching files as _file0"

  _file0 → ls()

  Better: gdirectory → ls() lists files

Written up better in project notes doc.

~~pdf for report~~

INVARIANT MASS CALCULATION

$$Z \rightarrow \mu^+ \mu^-$$

"In the labframe, the charged particle has 3 degrees of freedom" - Mihai

- → Cartesian, p_x p_y p_z
- → Cylindrical (spherical) → p_T transverse momentum (MeV)
  - → η pseudorapidity (polar angle)
  - → ϕ azimuthal angle.

see diagrams overleaf

Use muon mass $M = 0.105$ GeV

Particles are relativistic ⇒ 4 momentum

(I'm assuming natural units)

Standard Model notes, L4

$$p^\mu = (E, \underline{p}) \qquad p \cdot p = p^\mu p_\mu = E^2 - |\underline{p}|^2 = m^2$$

$$M^2 = \left(\sum^N E_i\right)^2 - \left(\sum^N \underline{p}_i\right)^2 \text{ for N particle system}$$

↳ invariant mass of system

$$p_Z^\alpha = p_{\mu^+}^\alpha + p_{\mu^-}^\alpha$$

$$M^2 = (p_{\mu^+} + p_{\mu^-})_\alpha^2 = (p_{\mu^+} + p_{\mu^-})^\alpha \cdot (p_{\mu^+} + p_{\mu^-})_\alpha$$

$$= p_{\mu^+} p_{\mu^+}{}^\alpha + p_{\mu^-} p_{\mu^-\alpha} + 2 p_{\mu^+} \cdot p_{\mu^-}$$

$$= m_{\mu^+}^2 + m_{\mu^-}^2 + 2(E_{\mu^+} E_{\mu^-} - \underline{p}_{\mu^+} \cdot \underline{p}_{\mu^-})$$

$$m_{\mu^+} = m_{\mu^-} = 0.105 \text{ GeV}$$

$$\Rightarrow M^2 = 2 m_\mu + 2 E_{\mu^+} E_{\mu^-} - 2 \underline{p}_{\mu^+} \cdot \underline{p}_{\mu^-}$$

Spherical polars → cartesian

$x = r\sin\theta\cos\varphi$ where $r = p$

$y = r\sin\theta\sin\varphi$ $\quad \theta = \theta_{cm}$

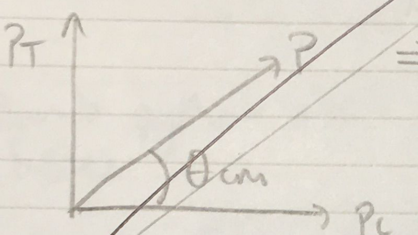
$z = r\cos\theta$ $\quad \varphi = \phi$

$$\eta = -\ln\left[\tan\left(\frac{\theta}{2}\right)\right] \qquad \theta = 2\arctan(e^{-\eta})$$

$$z = r\cos\left[2\arctan(e^{-\eta})\right]$$

$$\cos 2\theta = \frac{1-\tan^2\theta}{1+\tan^2\theta} \Rightarrow \frac{1-e^{-2\eta}}{1+e^{-2\eta}} = \frac{e^{\eta}-e^{-\eta}}{e^{\eta}+e^{-\eta}} = \tanh(\eta)$$

$$\Rightarrow z = p\tanh(\eta)$$



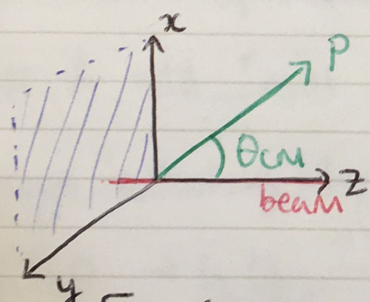
$$\Rightarrow p = p_T\sin\theta_{cm}$$

$$p = p_T\sin\left[2\arctan e^{-\eta}\right]$$

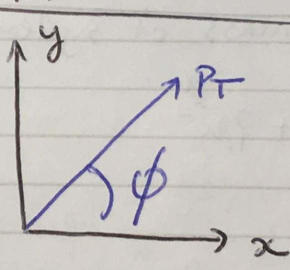
$$p = p_T\frac{2e^{-\eta}}{1-e^{-2\eta}} = \operatorname{csch}(\eta) = \frac{1}{\sinh(\eta)}$$

$$z = p_T\frac{\tanh(\eta)}{\sinh(\eta)} = \frac{p_T}{\cosh(\eta)} = p_T\operatorname{sech}(\eta)$$

COORDINATE SYSTEM



→ Transverse x-y plane



ϕ = Azimuthal scattering angle

$$\eta = -\ln\left[\tan\left(\frac{\theta_{cm}}{2}\right)\right]$$

$p_T = p\sin\theta_{cm}$

θ_{cm} = Centre of mass scattering angle.

$$\Rightarrow p_x = p_T\cos\phi$$

$$p_y = p_T\sin\phi$$

~~$p_z = p\sin\theta_{cm}$~~

$$p_z = p\cos\theta_{cm} \rightarrow p = \frac{p_T}{\sin\theta_{cm}} \Rightarrow p_z = p_T\frac{\cos\theta_{cm}}{\sin\theta_{cm}}$$

$$p_z = p_T\cot\theta_{cm}$$

$$\theta_{cm} = 2\arctan(e^{-\eta})$$

~~sin~~ $\frac{\cos 2\theta}{\sin 2\theta} = \frac{1-\tan^2\theta}{1+\tan^2\theta} \times \frac{1+\tan^2\theta}{2\tan\theta}$

$= \frac{1-\tan^2\theta}{2\tan\theta}$

$\Rightarrow p_z = p_T \, \frac{1-e^{-2\eta}}{2e^{-\eta}} = p_T \sinh(\eta)$

$p_z = p_T \sinh(\eta)$

- $M^2 = 2m_\mu + 2E_{\mu^+}E_{\mu^-} - 2\vec{p}_{\mu^+}\cdot\vec{p}_{\mu^-}$

$\vec{p}_{\mu^+}\cdot\vec{p}_{\mu^-} = p_{T_1}p_{T_2}\cos\phi_1\cos\phi_2 + p_{T_1}p_{T_2}\sin\phi_1\sin\phi_2$

$+ p_{T_1}p_{T_2}\sinh(\eta_1)\sinh(\eta_2)$

$= p_{T_1}p_{T_2}\left[\cos(\phi_1-\phi_2) + \sinh(\eta_1)\sinh(\eta_2)\right]$

(ROOT: TLorentzVector)

$E^2 = m^2 + |p|^2 \Rightarrow E_{\mu^+}^2 = m_\mu^2 + |p_{\mu^+}|^2$

$E_\mu^2 = m_\mu^2 + p_x^2 + p_y^2 + p_z^2$

$E_\mu^2 = m_\mu^2 + p_T^2\cos^2\phi + p_T^2\sin^2\phi + p_T^2\sinh^2(\eta)$

$= m_\mu^2 + p_T^2 + p_T^2\sinh^2\eta$

$= m_\mu^2 + p_T^2\cosh^2\eta$

$M^2 = 2m_\mu + 2\sqrt{m_\mu^2 + p_{T_1}^2\cosh^2\eta_1}\sqrt{m_\mu^2 + p_{T_2}^2\cosh^2\eta_2} - 2p_{T_1}p_{T_2}\left[\cos(\phi_1-\phi_2) + \sinh(\eta_1)\sinh(\eta_2)\right]$

~~$M^2 = 2[\ ]$~~

16/10/20 & 15/10/20 evening

- Coded manually ~~using R~~ & by using ROOT in python
- REMEMBER to square root M^2! → Gave ~~factor~~ 10^2 higher
- Gets expected Z mass ~91 GeV
- Originally bins 0 – 150 GeV
  reduced to 30–120 GeV → 40 – 120 GeV

- Used mix of Spyder & emacs -nw