Studying top quarks at the Fermilab Tevatron

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Texas APS, Texas A&M University
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Overview

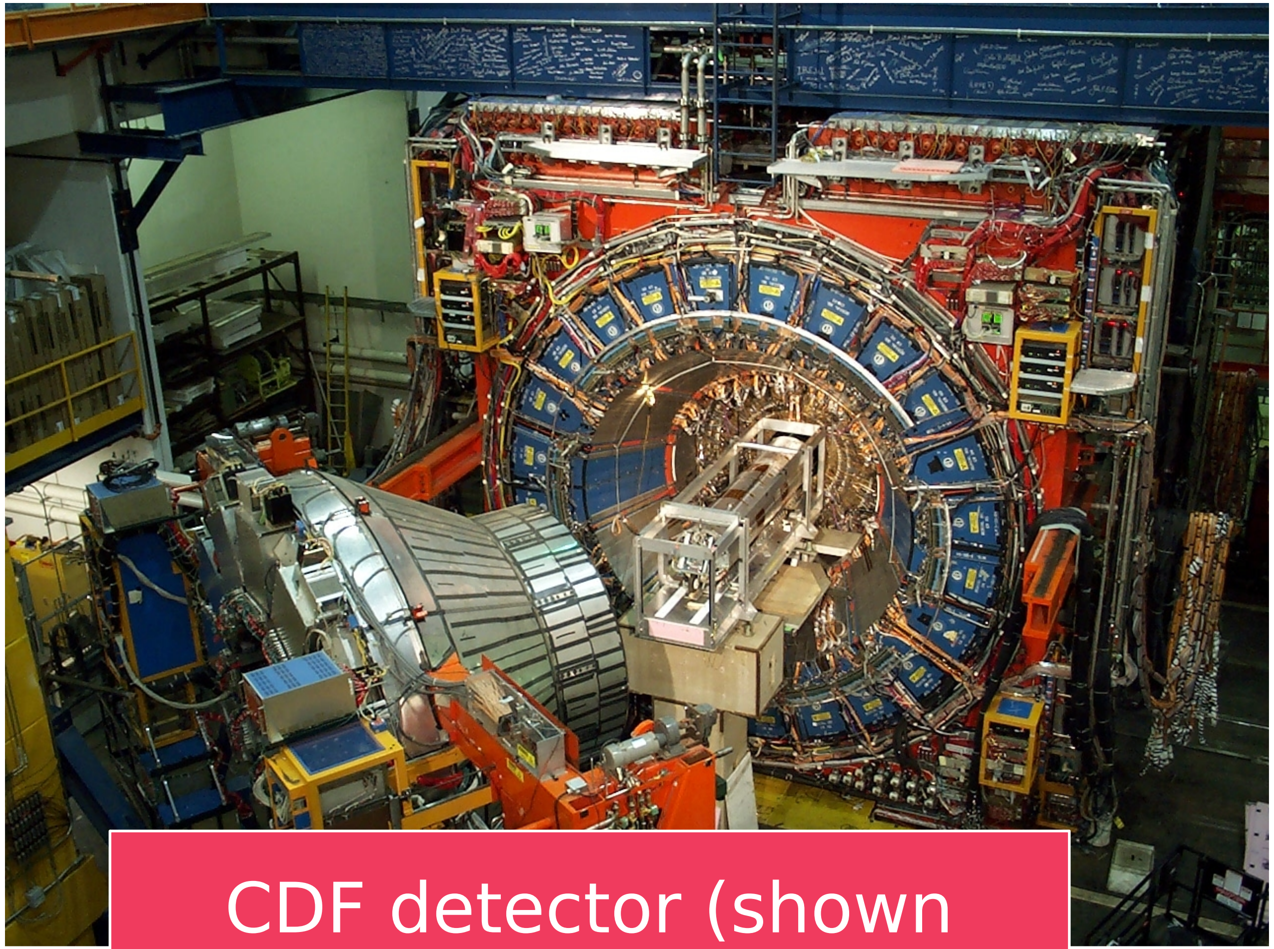
- Top quark production
- Predictions from the Standard Model
- Predictions in the case of a new particle
- Results

Collider Physics

We collide particles (protons and anti-protons) at very high speeds and when they collide sometimes top quarks are produced

This experiment was done at the Fermilab Tevatron (shown above)

Collider Physics

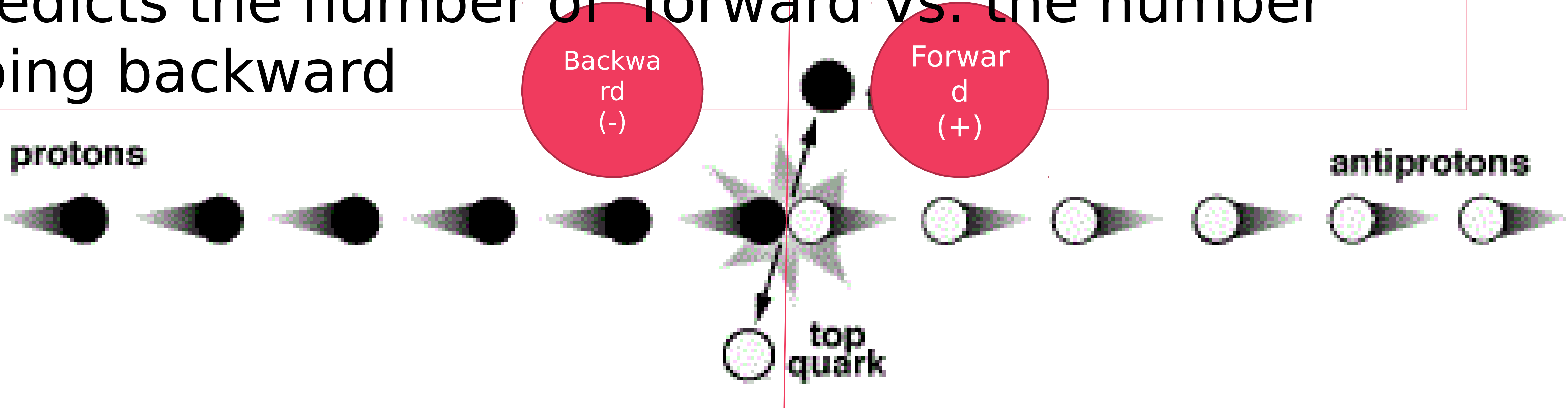


CDF detector (shown above)

With special detectors, we can identify top quarks and measure what direction they go.

Particle Physics

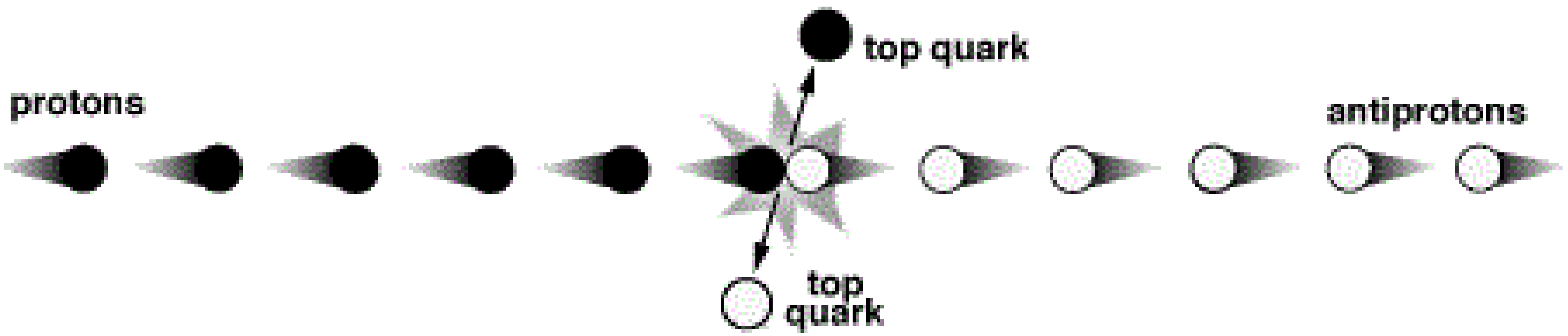
Using the detector, we can count the number of times a top quark goes along the same direction as the proton (call this “forward”) and when it goes the other way (call this “backward”). A calculation can be done, based on the known laws of physics (the standard model of particle physics), that predicts the number of forward vs. the number going backward



Theory of particle physics

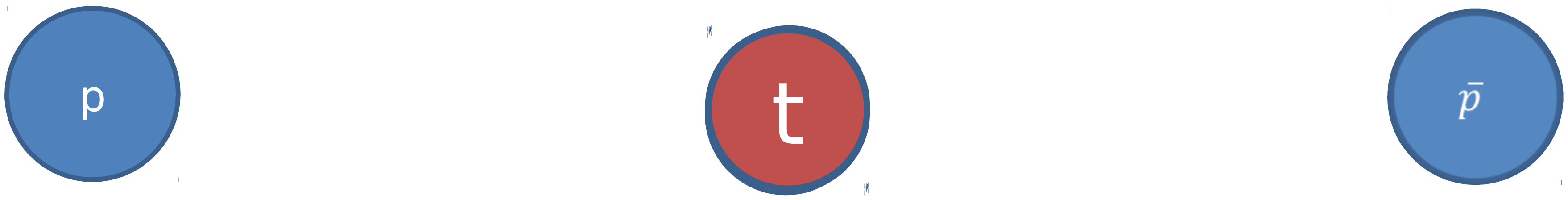
If you look at a lot of collisions, slightly more top quarks will be produced “forward” than “backward”

But not by much – not more than a few %



BACKWARD

FORWARD



$$\frac{(5\ forward\ top\ quarks) - (4\ backward\ top\ quarks)}{(5\ forward\ top\ quarks) + (4\ backward\ top\ quarks)}$$
$$= \text{Asymmetry of } 0.1$$

Predictions

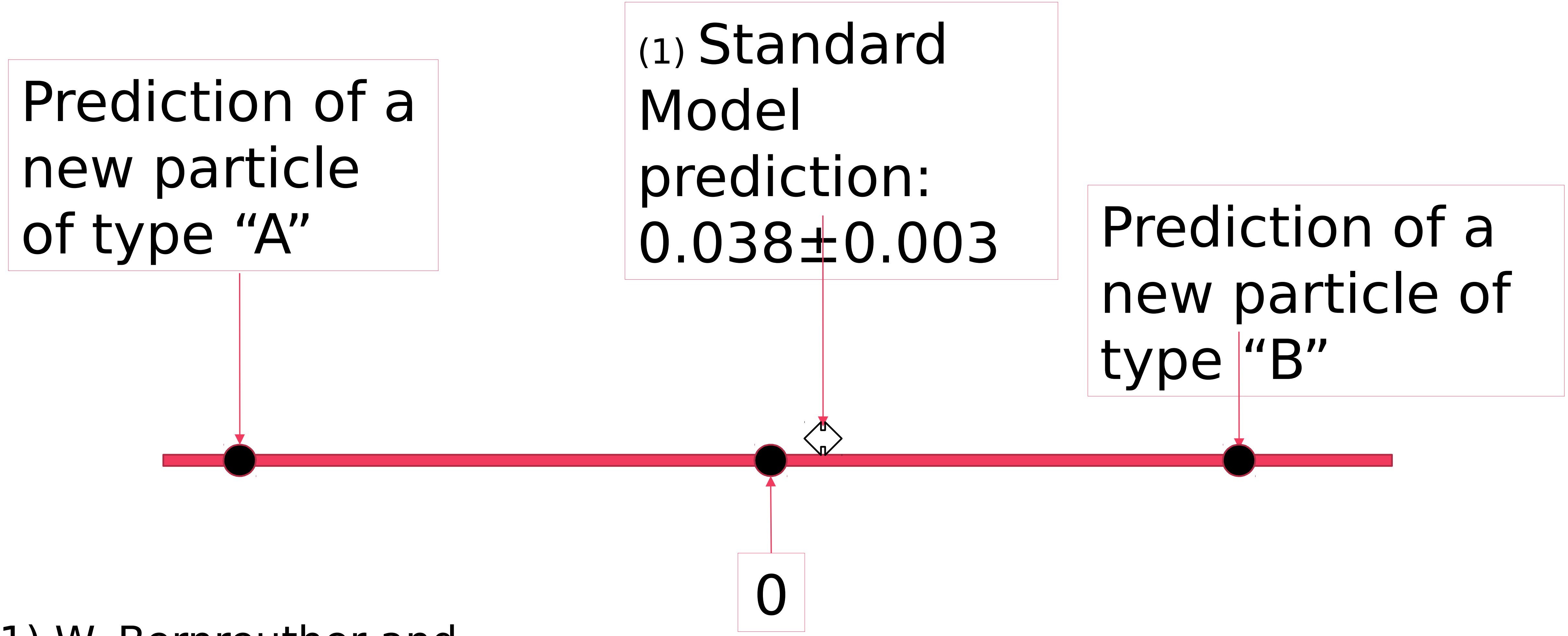
Imagine there exists another particle. What would happen in that experiment when we count the number of top quarks that go forward and the number that go backward?

An example of a new particle would be the axigluon, which is a heavy partner of the gluon

The existence of this particle could create many more OR many fewer forward-going particles than backward-going particles

We make measurements to compare different predictions of new particles.

Results with the error bar



(1) W. Bernreuther and Z.-G. Si, Phys. Rev. D 86, 034026 (2012).

Results with the error bar

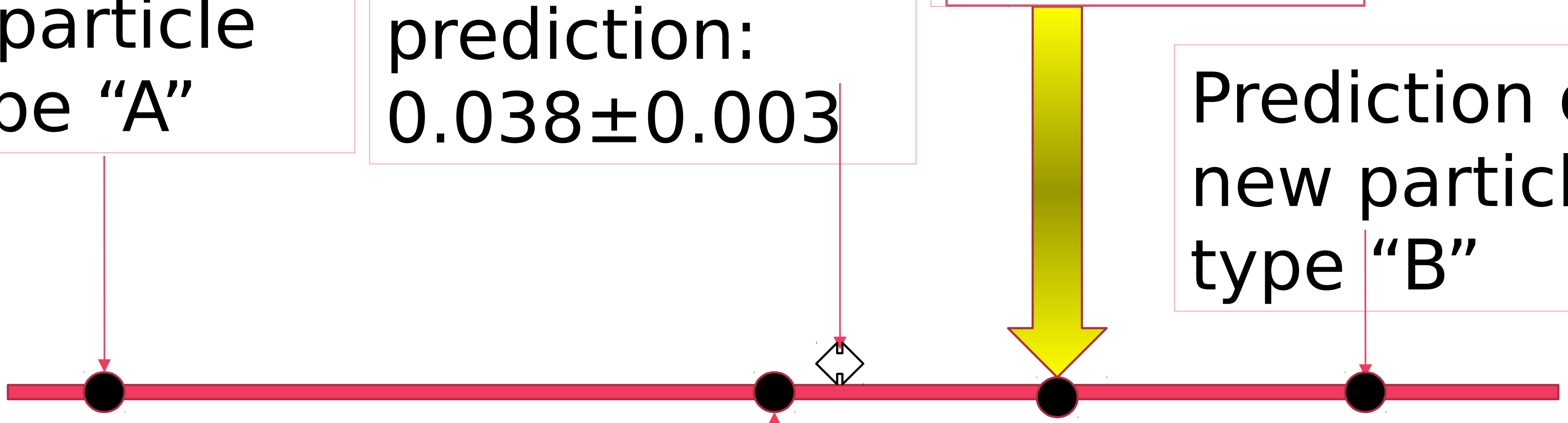
Prediction of a new particle of type “A”

Standard Model prediction: 0.038±0.003

(1) Results

$0.090\pm^{0.028}_{0.026}$

Prediction of a new particle of type “B”



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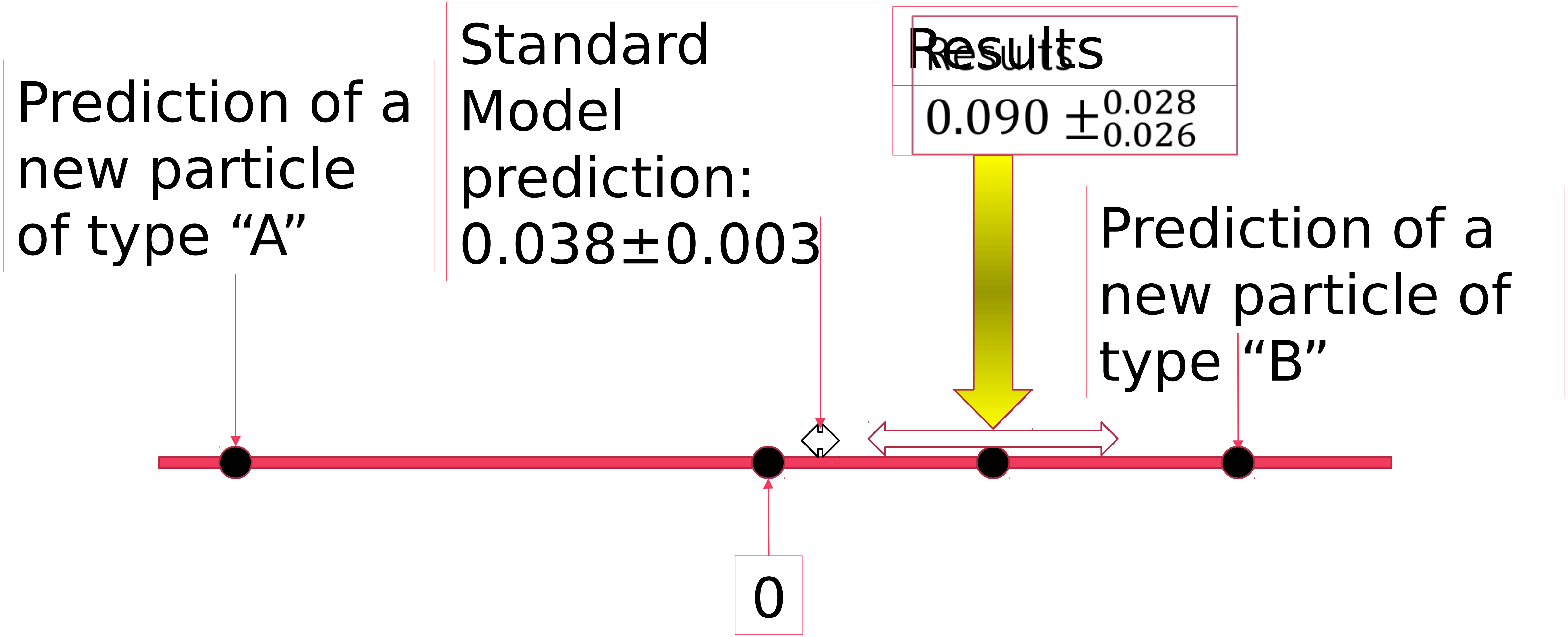
(1) Measurement of the Inclusive Leptonic Asymmetry in Top-Quark Pairs
that Decay to Two Charged Leptons at CDF. Phys. Rev.
Lett. 113, 042001

Results with the error bar

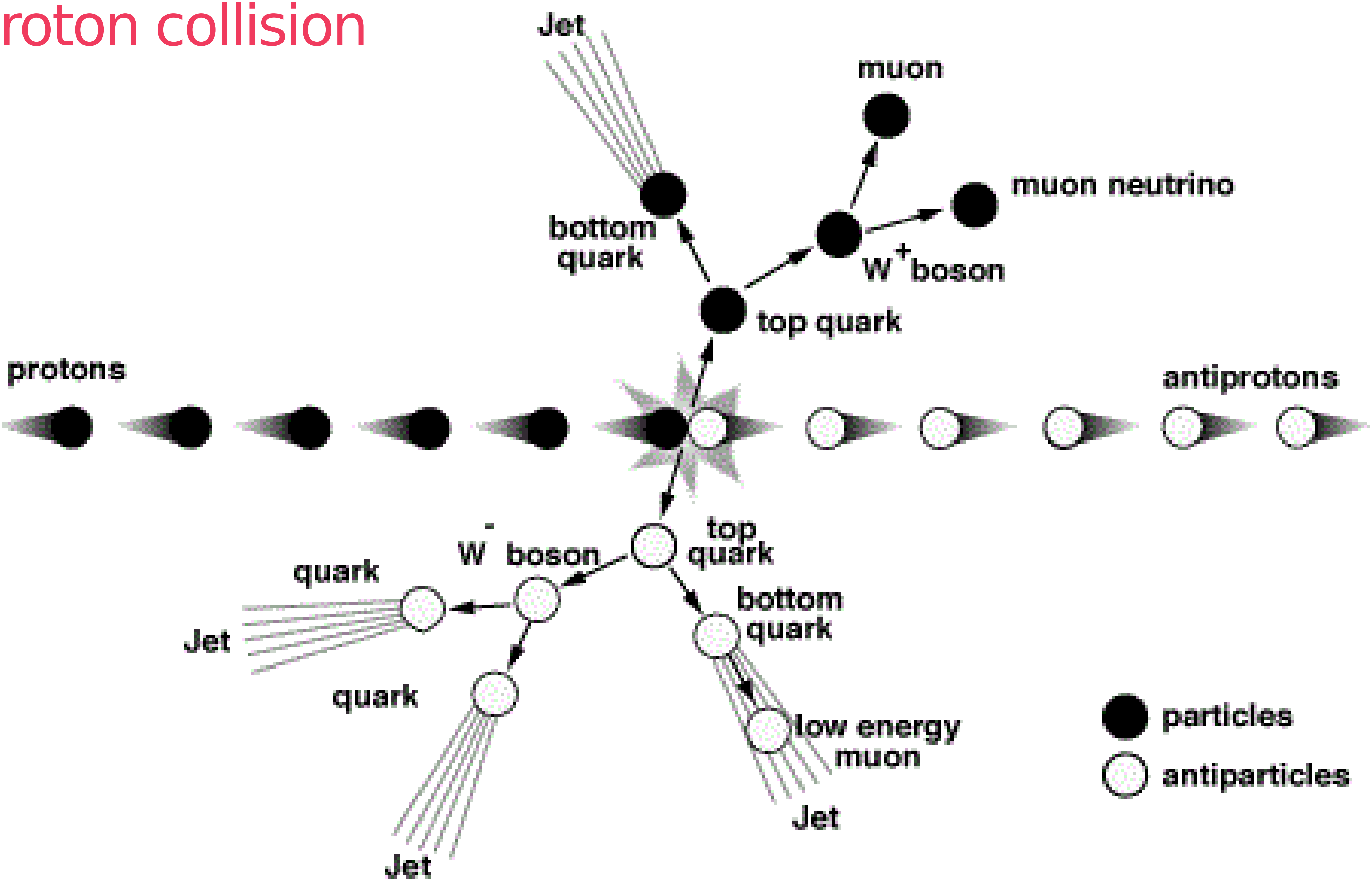


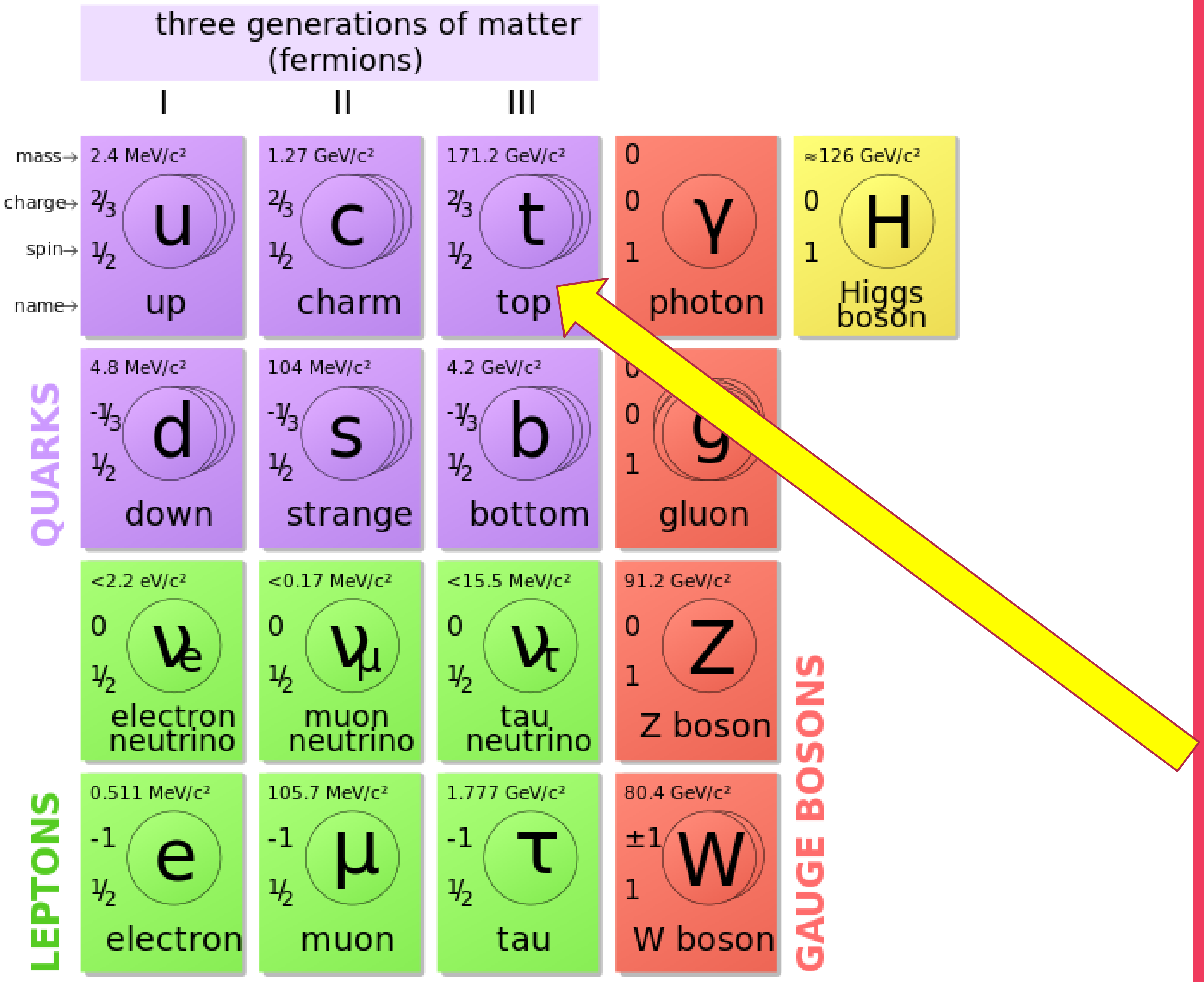
Conclusion

- We have measured the forward-backward asymmetry of top quarks produced at the Fermilab Tevatron using the CDF detector.
- The results are not completely consistent with the expectations of the Standard Model of particle physics but they are not far enough away to indicate evidence of a new particle.
- We have published these results and are looking at the rest of the data for other information that might be helpful for us to resolve this puzzle one way or another.

Stay Tuned!

Proton antiproton collision diagram





Top Quark

- The top quark is short lived and massive
- Mass of 173 GeV
- Lifetime of 10^-24 seconds

Particle Physics

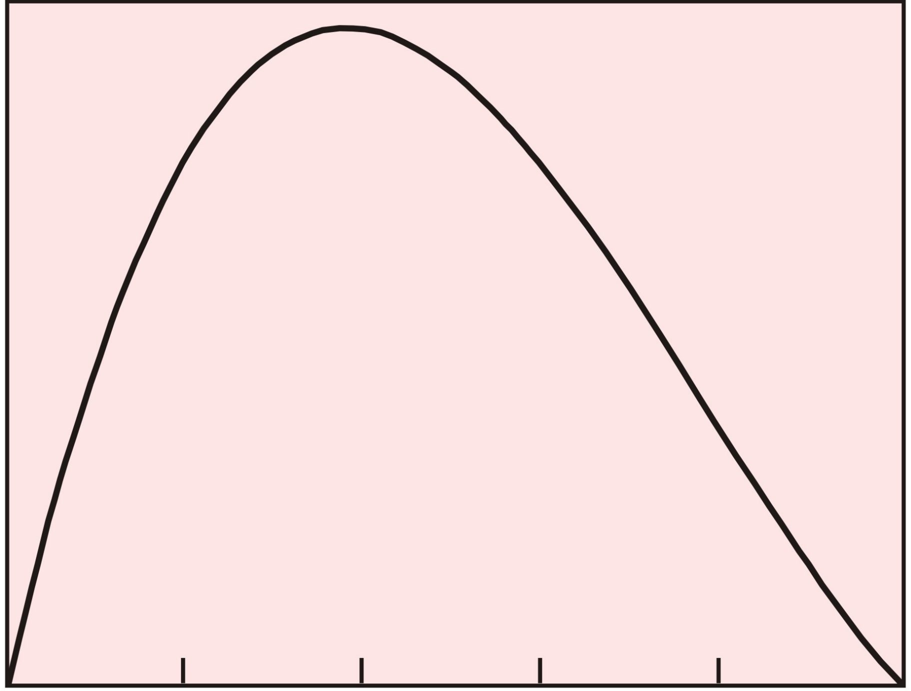
- The Fermilab Tevatron is one of only two places in the world where a particle accelerator was able to create top quarks via collision and study their properties.
- The other collider is the Large Hadron Collider (LHC)
- The difference between the two
  - Fermilab studies top quark pair production from proton antiproton
  - The LHC studies from proton

Asymmetry

Asymmetry is defined as

$$A^{l}_{FB} = \frac{N(qn>0) - N(qn<0)}{N(qn>0) + N(qn<0)}$$

For N the number of charged leptons, q the lepton charge, and n the pseudorapidity



- This asymmetry can be a helpful tool in analyzing data
  - Physicists can find an A^{l}_{FB} from the data generated at Fermilab
  - They can also find an A^{l}_{FB} value that is inclusive of additional hypothetical particles using simulation techniques
  - A comparison of these values can be made

Results

- From the Fermilab data it was found that the top quark had a asymmetry
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- As previously said this asymmetry can be compared to a simulated asymmetry value and compared

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- Theoretical physicists have come up with a particle called an axigluon. Though we may not know much about this particle we can give feedback on whether their axigluon model holds a possibility of existing
  - 200 GeV AxiL -0.063 (left handed axigluon)
  - 200 GeV AxiF – 0.151 (right handed axigluon)
  - 200 GeV Axi0 – 0.050 (pure axigluon)