# Terascale ISTP 2010: $Z'$ reconstruction with ROOT/C++

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# Introduction

- Tutorial for this afternoon: Reconstruction of $Z'$
- $Z'$: neutral, heavy particle (most generally)
  $\longrightarrow$ here: Additional gauge boson (very similar to $Z^0$)
- Look for decay $Z' \longrightarrow t\bar{t} \Rightarrow$ Mostly $t\bar{t}$ background!
- Therefore: $Z'$ **reconstruction is basically** $t\bar{t}$ **reconstruction**
- Choose semi–leptonic $t\bar{t}$ decays ("Golden channel")

Detailed instructions (handout) in `./docs` directory!

# The analysis package

- $Z'$ reconstruction + exercises already prepared:

```
/afs/desy.de/group/school/tut_Zprime_2010/
```

- Important objects (jets, $W$ bosons, etc.) organized in `structs` (Refer to handout for detailed description or see `typedefs.cc`)
- Event selection (cuts) already defined (`bool isGoodEvent(Event)`)
- MC datasets (signal+background) from official ATLAS samples
- Changes to source code: First compile (`make`), then execute (`./main`)

# Reconstruction of the hadronic top quark

1. Reconstruct hadronic $W$ boson:
   - Look for the two light flavor (LF) jets ($p_T > 40\,\text{GeV}$) with invariant mass nearest to $M_W$
2. Associated $b$ jet:
   - Choose $b$ jet (i.e. jet with tag weight$> 6.0$) closest to $W$ boson (minimum $\Delta R$)

- Additional exercises: Fit Tschebyschoff polynomial to reconstruct $W$ and top mass (exercise 3+4)

# Reconstruction of the leptonic top quark

1. Reconstruct leptonic data $W$ boson:
   - Recover neutrino kinematically using $W$ mass constraint:

     $$M_W{}^2 = m_\ell{}^2 - 2(p_x^\ell p_x^\nu + p_y^\ell p_y^\nu) + 2E_\ell \sqrt{\not{E}_T{}^2 + p_z^{\nu\,2}} - 2(p_z^\ell p_z^\nu)$$

     Take $\not{E}_T$ as $p_T(\nu) \rightarrow$ decrease $p_T(\nu)$ iterativelly $\rightarrow p_z$
     $\Rightarrow$ two solutions (quadratic equation)
   - $p_x^\nu$, $p_y^\nu$ can be calculated from $\varphi(\not{E}_T)$ and $p_T(\nu)$
   - Choose the solution so that leptonic top mass is closest to hadronic top mass!
2. Associated $b$ jet:
   Just take the one remaining $b$ jet!
   (Event selection: exactly two jets with tag weight$>$ 6.0 required)

# Reconstruction of the $Z'$

- Invariant $t\bar{t}$ mass is $Z'$ mass
  $\longrightarrow$ should peak at $M_{Z'}$!
- Problem: Lot of $t\bar{t}$ background (BG)
- Choose $\Delta R$ cut between $W$ and $b$ to reduce BG
  (top quarks from $Z'$ should be more boosted)
- Still too much BG, only calculate discovery potential and upper bound for cross section!
- Analyze "fake" $Z'$ sample: Different particle with much higher cross section
  $\Rightarrow$ signal extraction possible
  $\longrightarrow$ determine cross section and mass (exercise 10)

# Final remarks

- Try to comprehend all exercises (source code and handout!)
- Play around with histogram binning, colors, legends, etc.
- But: We are very limited in time!
  $\longrightarrow$ maybe you won't be able to finish