Finding Higgs Boson

H→WW→lνlν : Matrix Element Method (MVA)

Based on: ATLAS-CONF-2012-060, ATLAS-CONF-2012-098

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Oct 20, 2012

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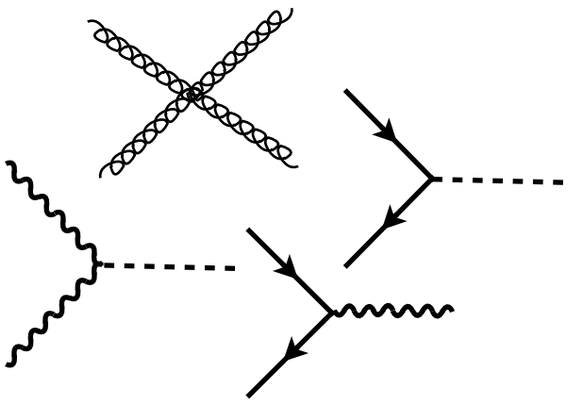
Discovery of a new particle

July 4th, 2012

Why Higgs Boson?

1. Write down the theory respecting the nature's symmetry...



2. no mass term allowed for any particle

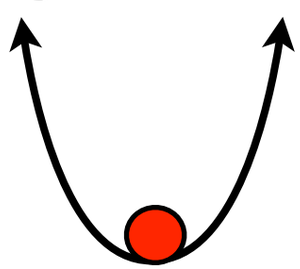
$m = 0!$

3. Higgs to the rescue!

Higgs field breaks the symmetry **spontaneously** allowing particles to have mass

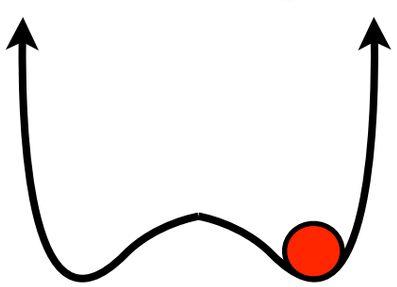
Higgs field $\Longrightarrow$ Higgs Boson

Symmetric



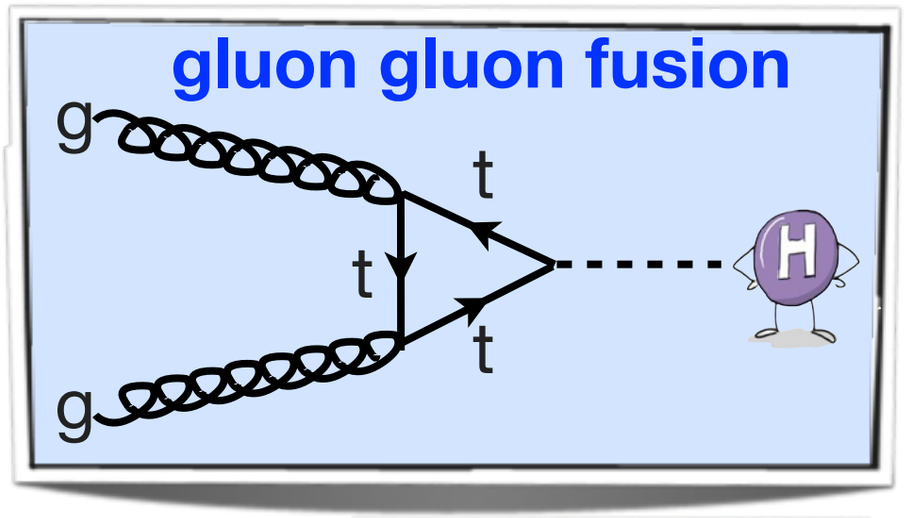
$m=0$

Spontaneously broken

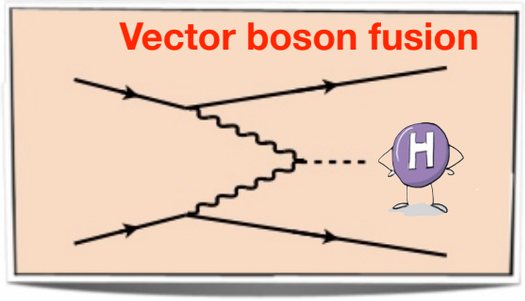


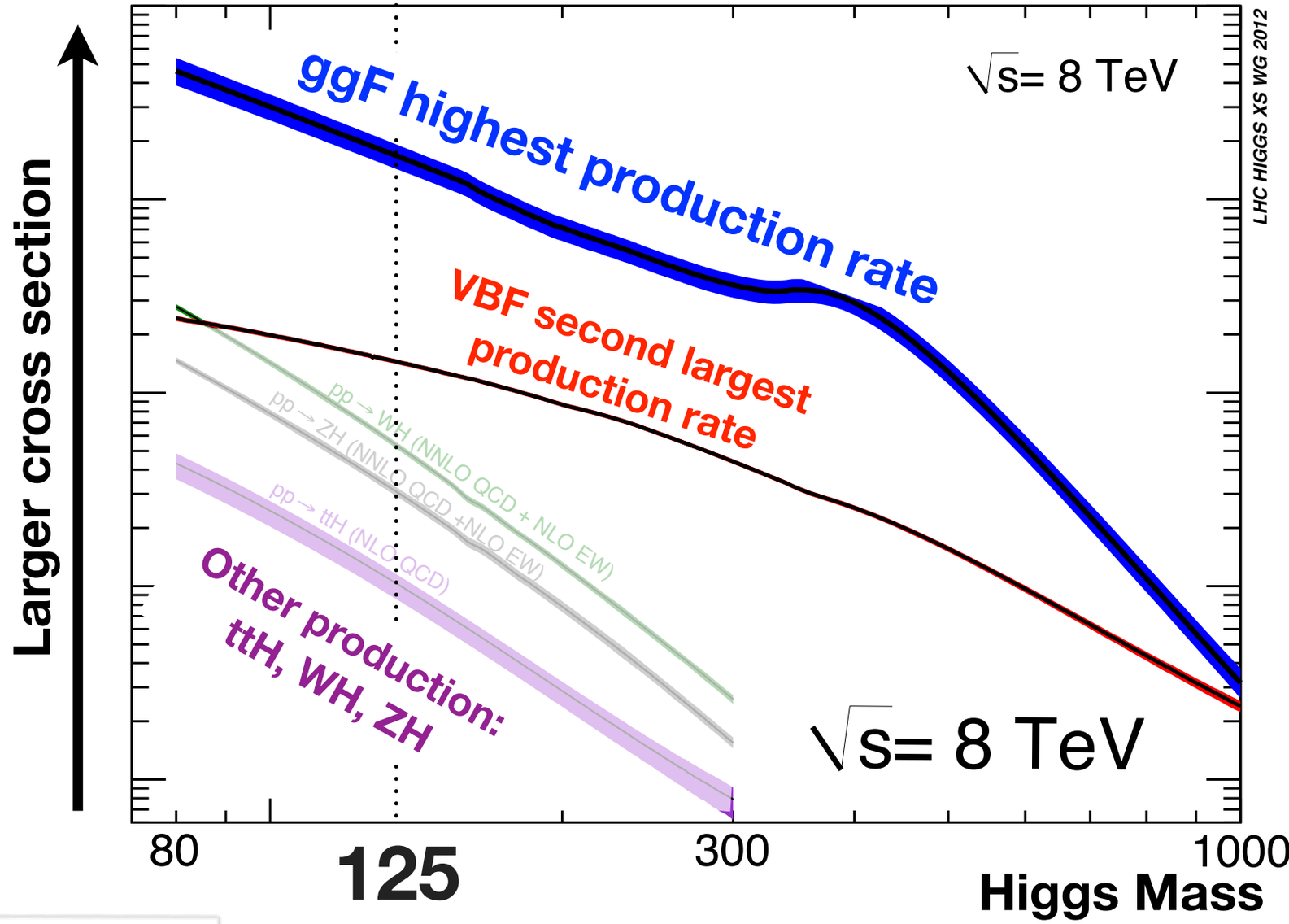
$m \neq 0$

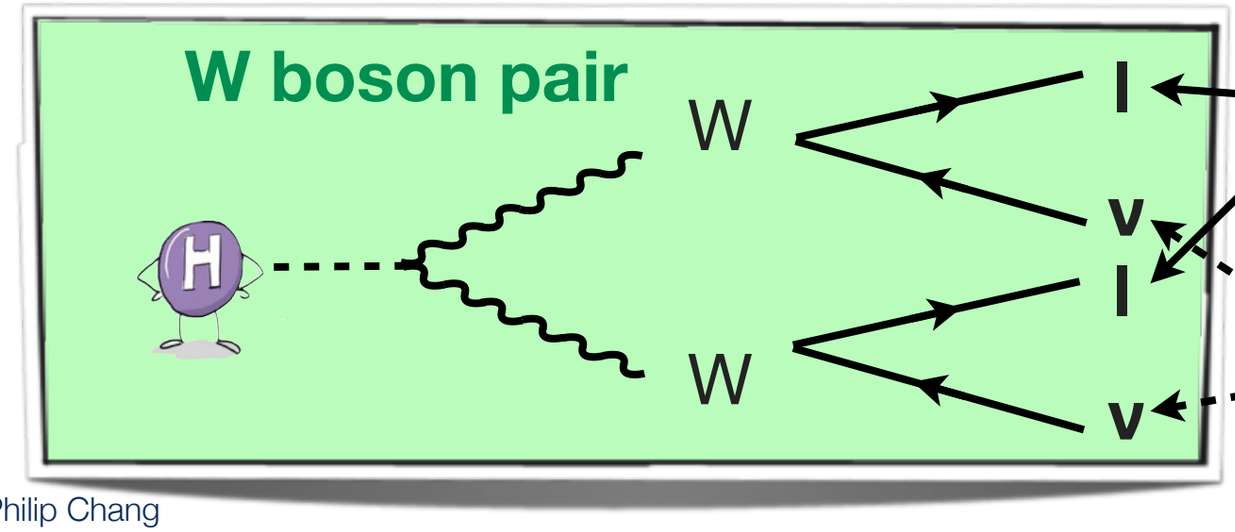
Making of Higgs boson...



Production Rate x1/10







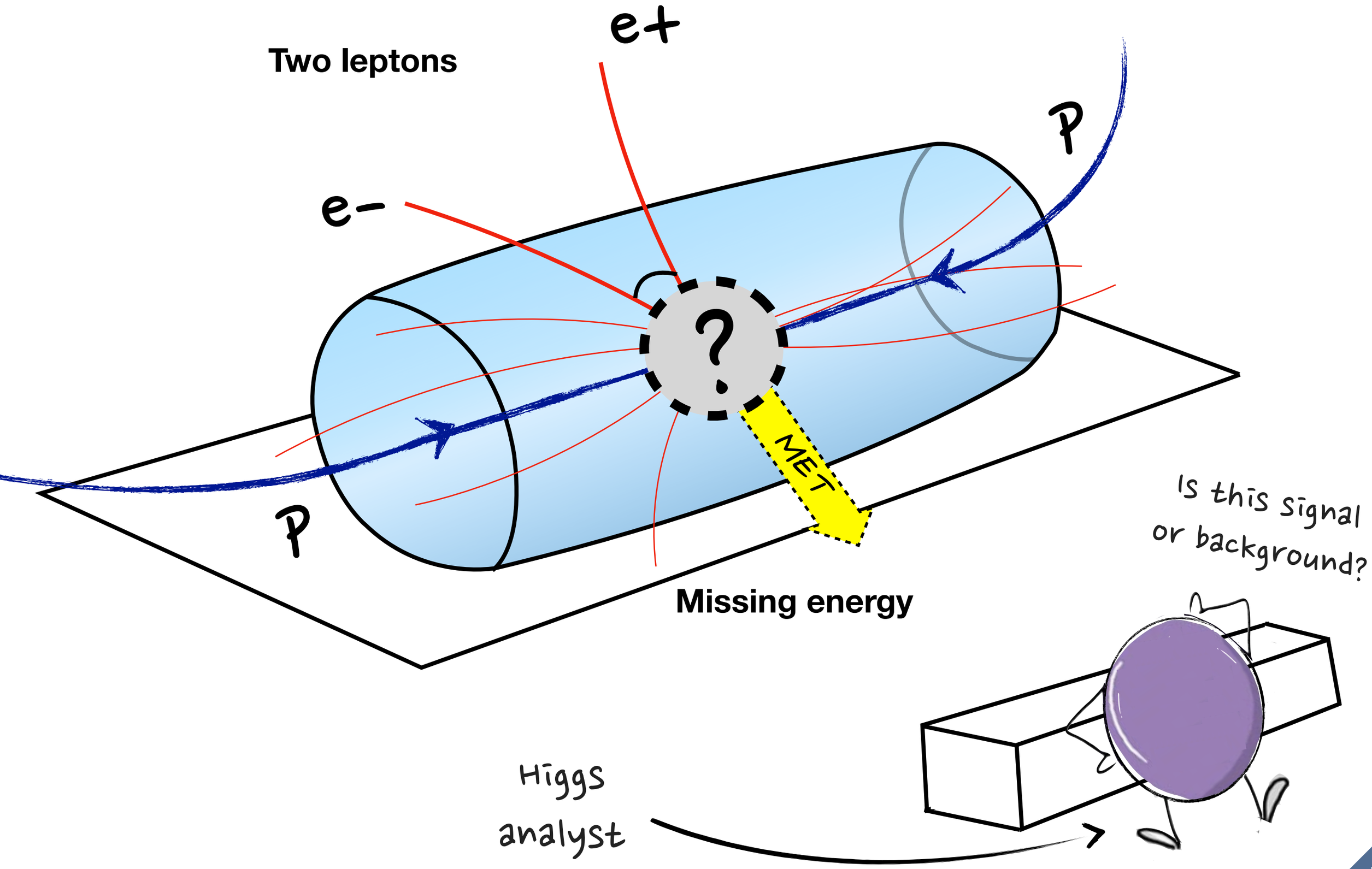
very well measured

Two leptons

Missing energy

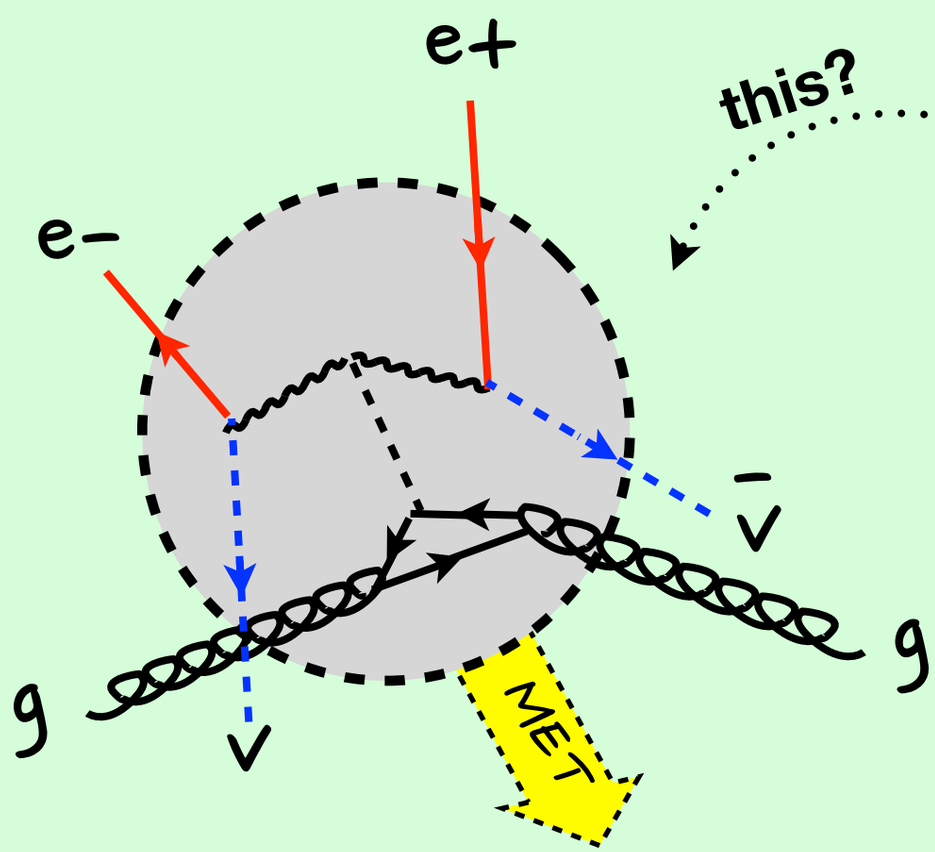
Not one but **two** neutrinos = loss of information

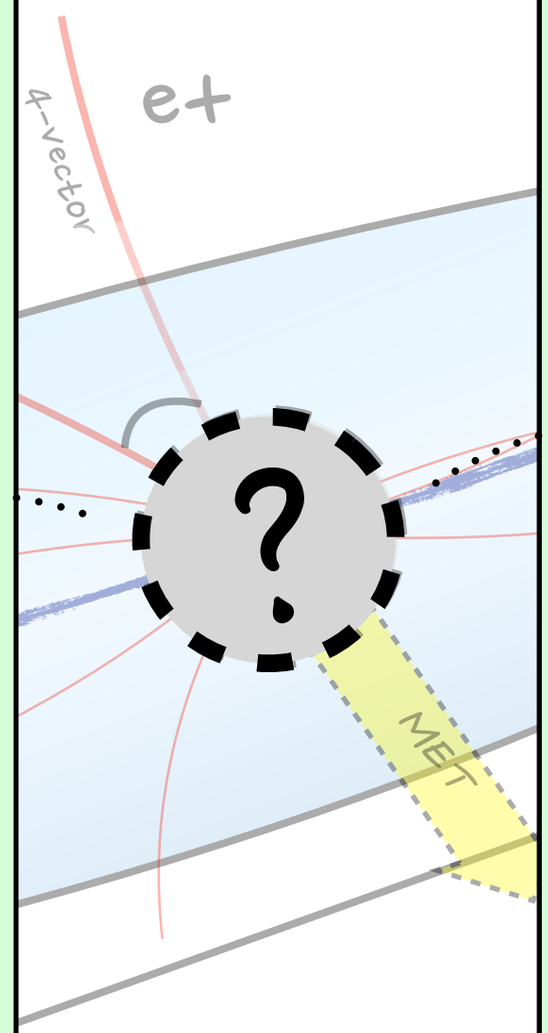
Run the experiment!



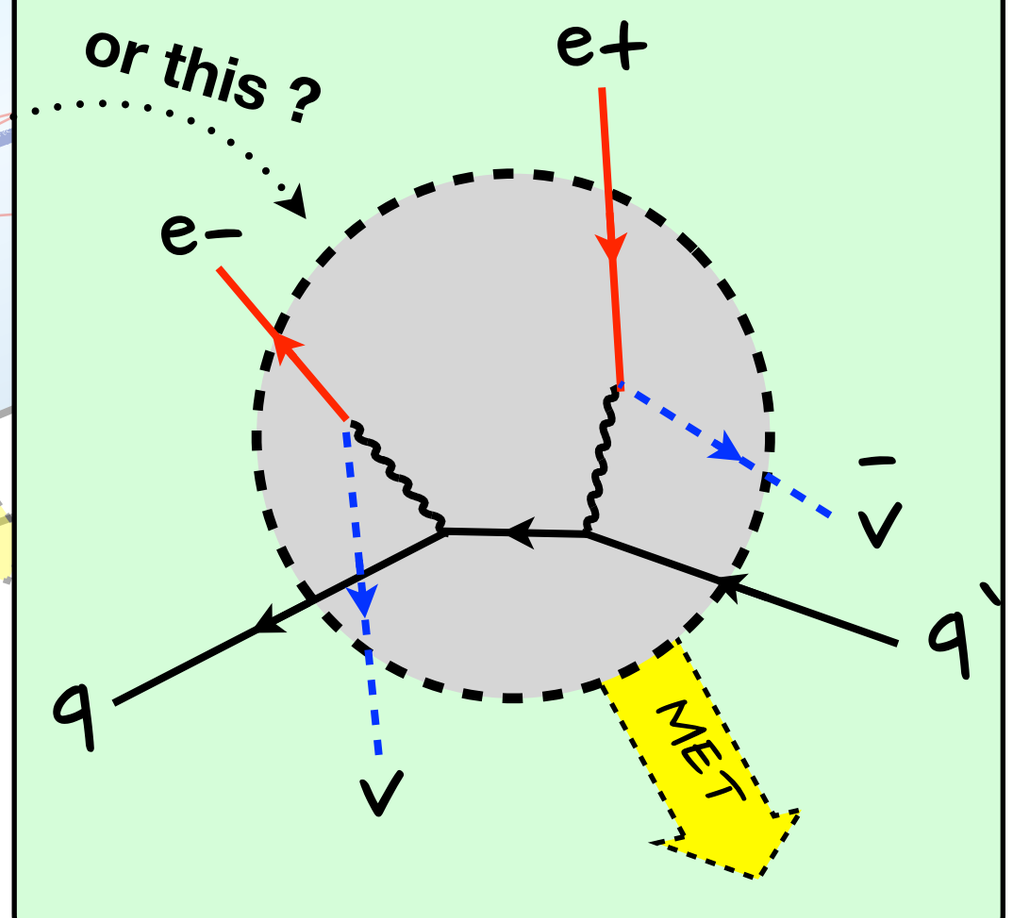
Is this our signal? or background?

Signal
Gluon Gluon Fusion To Higgs boson?





Background
W boson pair production?



Matrix element(ME) analysis uses **a priori** knowledge

1.

Fermi's golden rule:
Transition rate between initial and final state

$$P(x_{\mathrm{evt}}|H) = \int \langle \; | \mathcal{M}_H | \; \rangle d$$

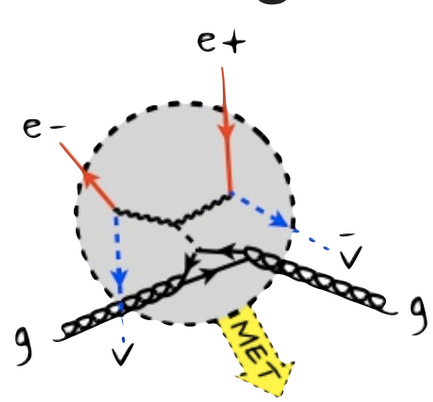
Per event weight

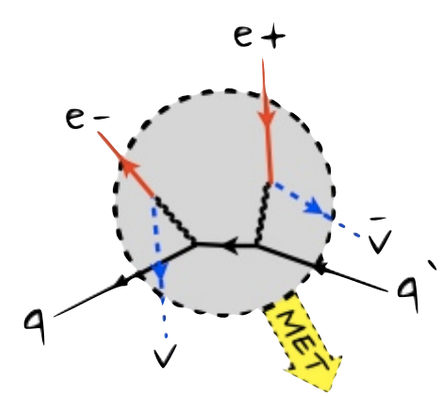
initial state

final state

integrate over unknowns

Hypothesis of interest:
Signal vs. Background





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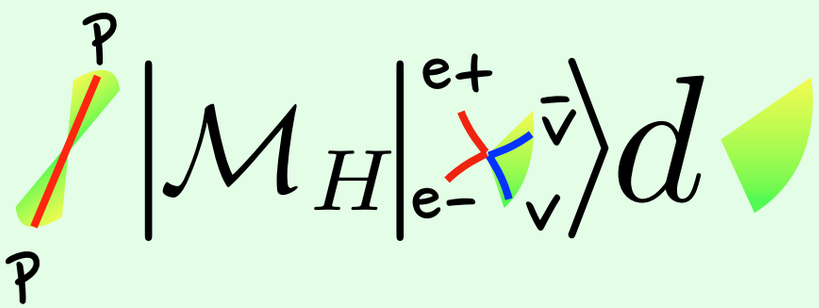
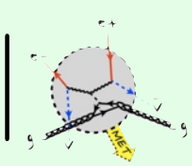


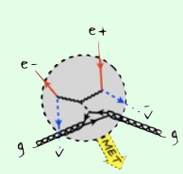
Per event weight

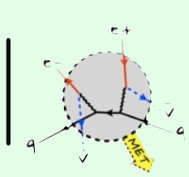
2.

Per event discriminant

$$d(x_{\mathrm{evt}}) = \frac{P(x_{\mathrm{evt}}|\;)}{P(x_{\mathrm{evt}}|\;) + P(x_{\mathrm{evt}}|\;)}$$







Signal

Signal

Background

by construct between 0 and 1

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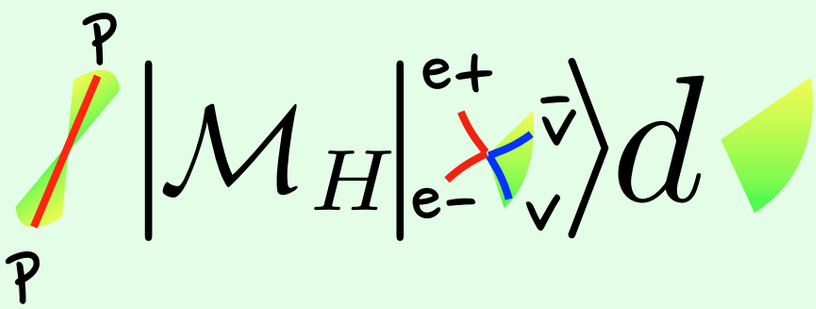

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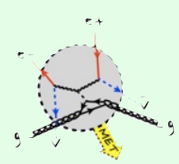
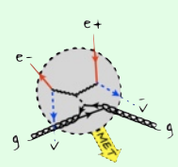
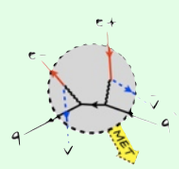




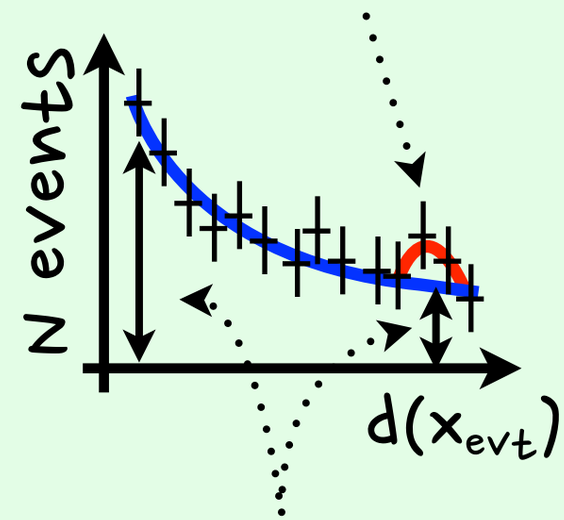


Signal **Signal** **Background**

↑ **by construct between 0 and 1**

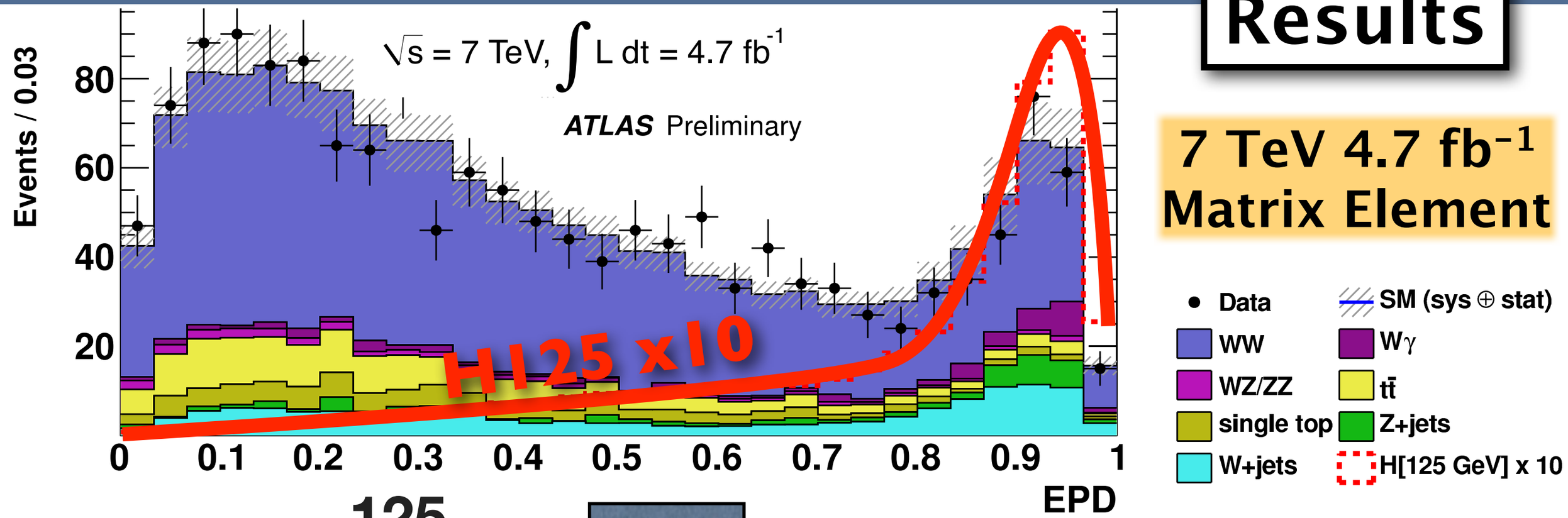
3.

Maybe Higgs?

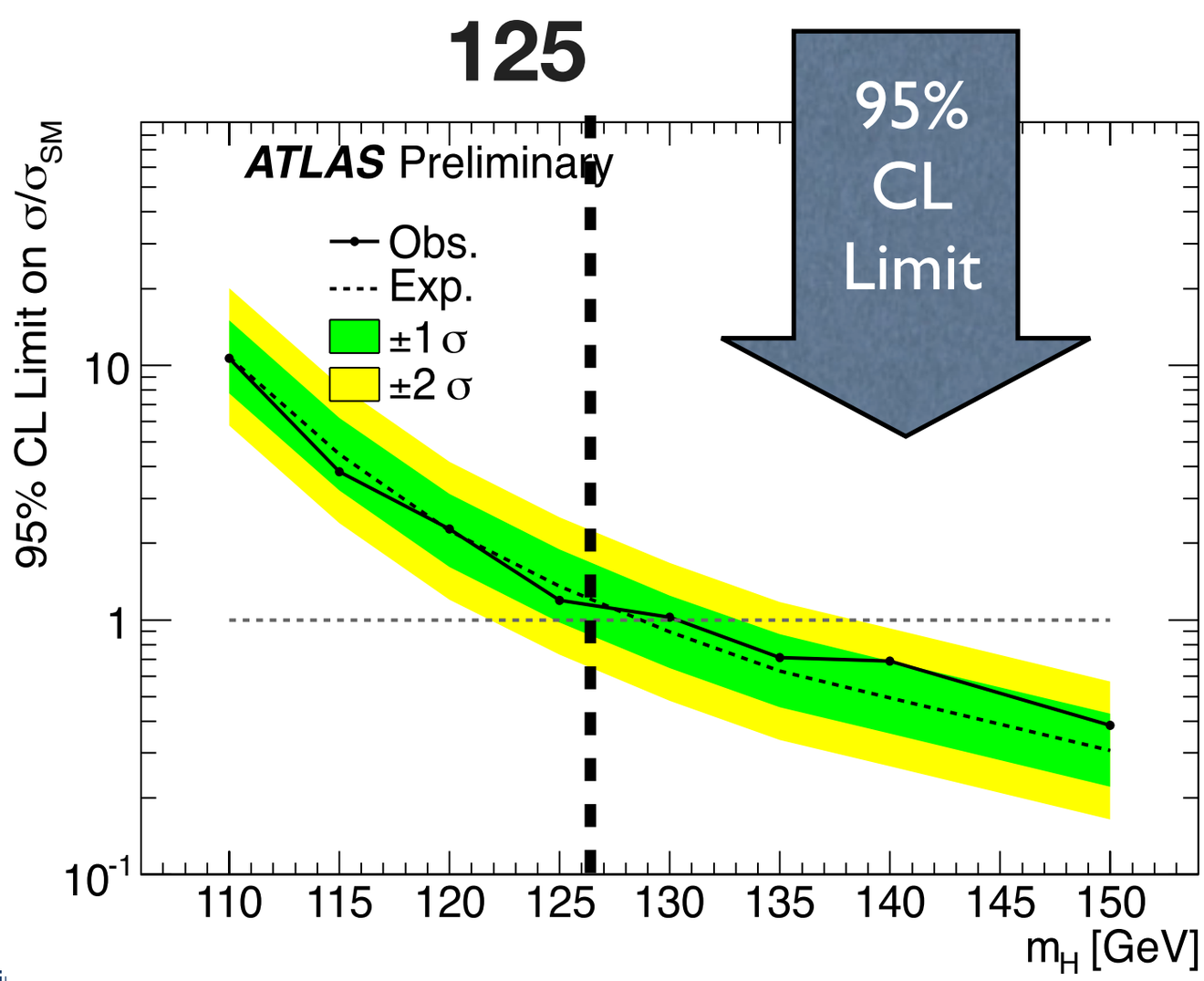


smaller background

Results



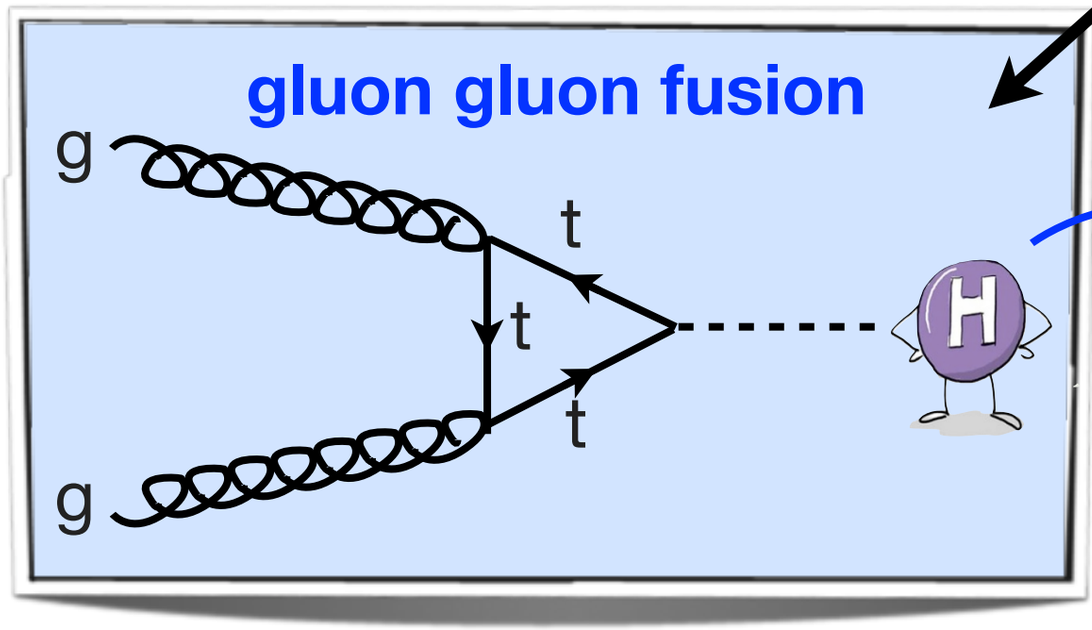
7 TeV 4.7 fb^{-1} Matrix Element



- From 7 TeV we did not see a clear excess. (Limit: 130GeV - 250GeV)
- But in 8 TeV data, the cut-based analysis sees an excess.
- We expect to see an excess in ME analysis as well

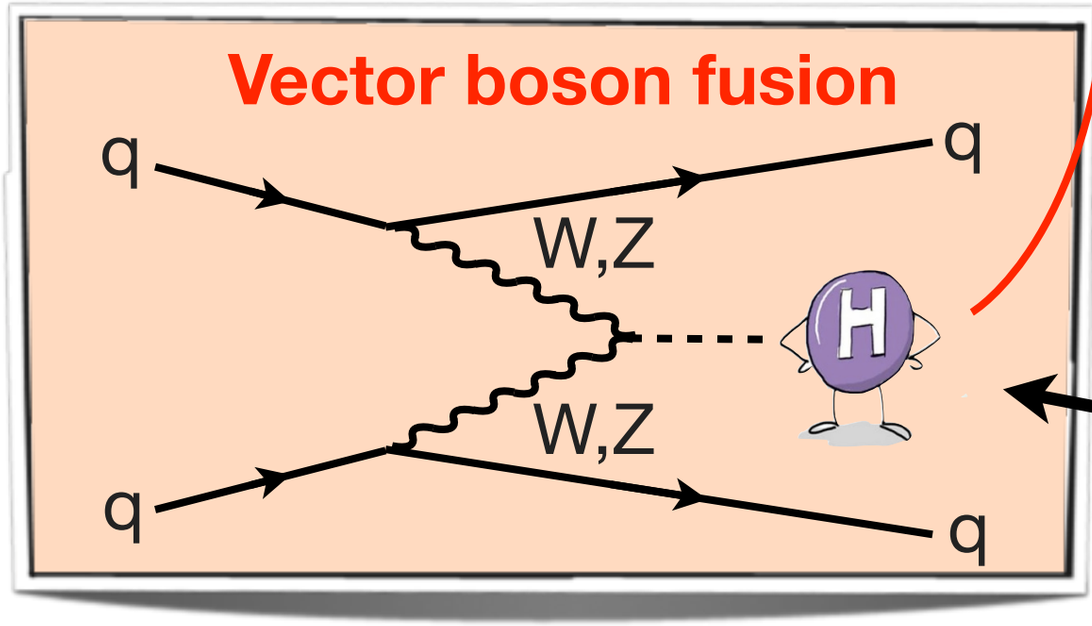
Future: There are still many ways of finding Higgs

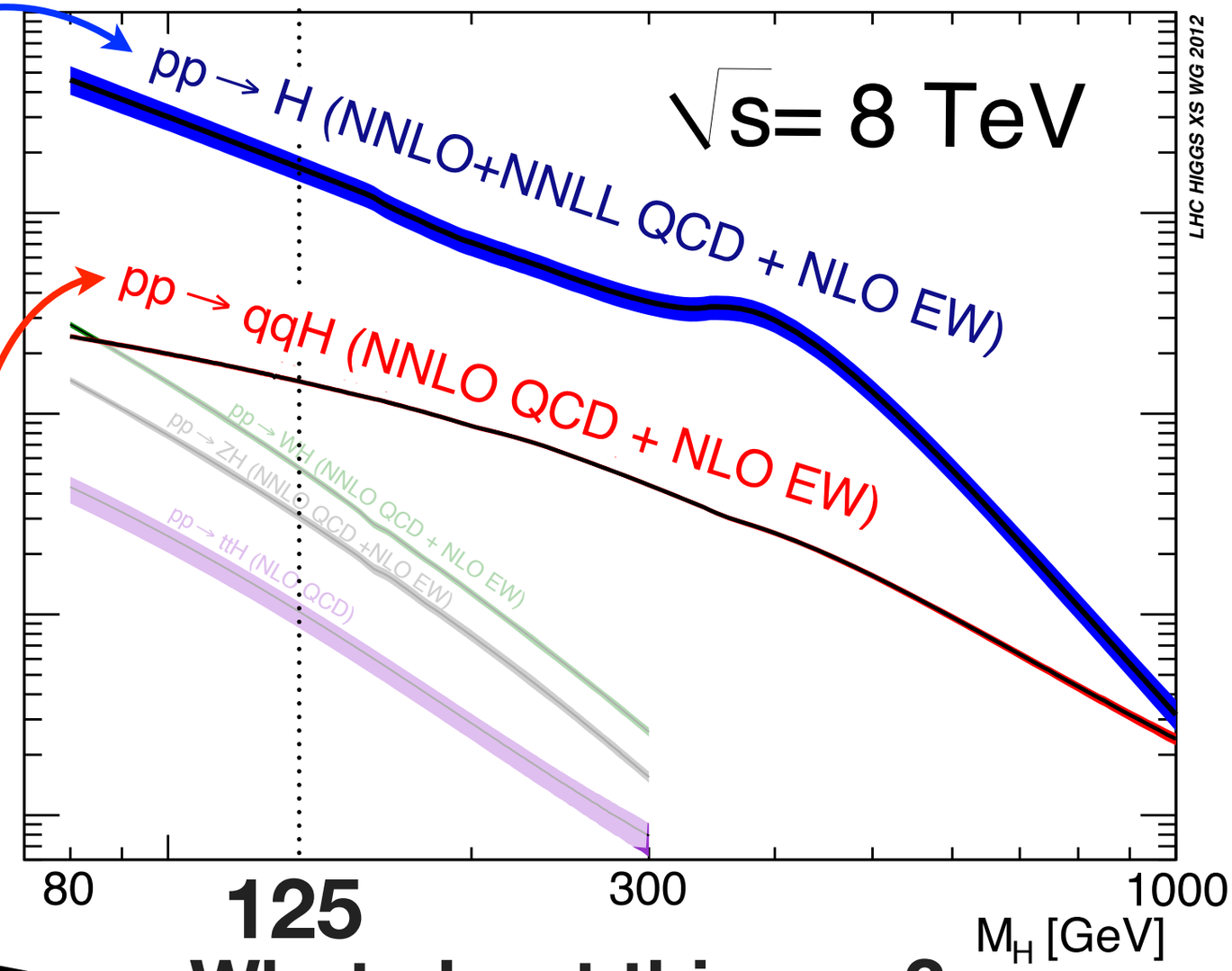
We predominantly found Higgs via this



Bye! See you again next time!

Production Rate x1/10





What about this one?

Can we find Higgs via only this?

Stay tuned...

pictures/plots

Announcement picture
http://www.csmonitor.com/Science/2012/0705/Higgs-boson-discovery-could-usher-in-new-wonderful-technologies-says-physicist-video

CMS diphoton event
http://cms.web.cern.ch/news/observation-new-particle-mass-125-gev

Diphoton ATLAS
http://www.atlas.ch/photos/atlas_photos/selected-photos/events/TwoPhoton.jpg

4 muon ATLAS
http://www.atlas.ch/photos/atlas_photos/selected-photos/events/run204769_evt71902630_VP1Base.png

Big bang
http://www.sciencephoto.com/image/334180/530wm/R9800170-Big_Bang-SPL.jpg

lagrangian
http://fc00.deviantart.net/fs71/i/2011/349/f/d/standard_model_equation_by_physicsandmore-d4j7n5b.png

atom
http://www.michaeldzjaparidze.com/images/atomtotal.png

atmoic orbital
http://wikis.lawrence.edu/download/attachments/296242/HAtomOrbitals2.png

quarks
http://www.lhc-closer.es/img/subidas/6_2_1_2.jpg

molecules
http://www.dread.demon.nl/molecules.gif

star forming nebula
http://www.universetoday.com/wp-content/uploads/2007/11/2007-1115ngc281.jpg

eagle nebula
http://nssdc.gsfc.nasa.gov/image/astro/hst_pillars_m16_close.jpg

galaxy
http://images.astronet.ru/pubd/2010/05/03/0001244907/ngc3190_hstlegacy_big.jpg

galaxy
http://1.bp.blogspot.com/-h3Md2m_v6ms/TdPepbHzLaI/AAAAAAAAAMY/OrckBRnzo_Y/s1600/spiraline+galaktika.jpg

supernova
http://www.xmtaica.gov.cn/taweb/images/attachment/3duochaixingyun/PIA03606.jpg

planet formation
http://www.nrao.edu/images/fomalhautDavidHardy510.jpg

Earth
http://fc01.deviantart.net/fs26/f/2008/143/0/c/Planet_Earth_by_sanmonku.jpg

blackhole
http://4.bp.blogspot.com/-tIUsLeiLhGQ/UC1Qnb-lwyI/AAAAAAAAArg/NJryR3emCSc/s1600/12__supermassive_black_hole.jpeg

Sun
http://www.sunorbit.net/picts/Sun_credit_The_satellite_Solar_and_Heliospheric_observatory_an_international_project_of_ESA_and_NASA_.jpg

Sun
https://a248.e.akamai.net/camo.github.com/a9bf351bfcd9e3b51a058e31ac26d49aae08aef3/687474703a2f2f692e696d6775722e636f6d2f43794478612e6a7067

mugbubble
http://www.quantumdiaries.org/wp-content/uploads/2011/06/cernmug_bubbles.jpg

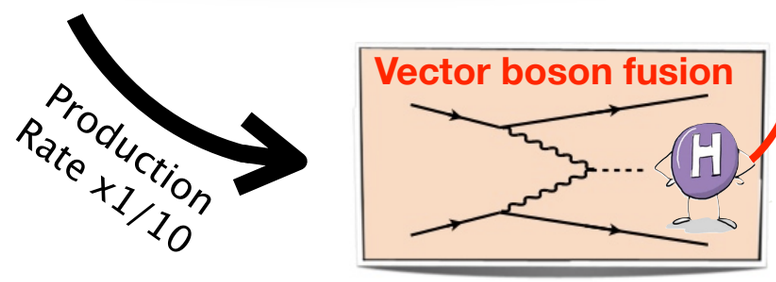
lagrangian mousepad
http://rlv.zcache.com/sticker_the_standard_model-p217001118368965322envb3_400.jpg

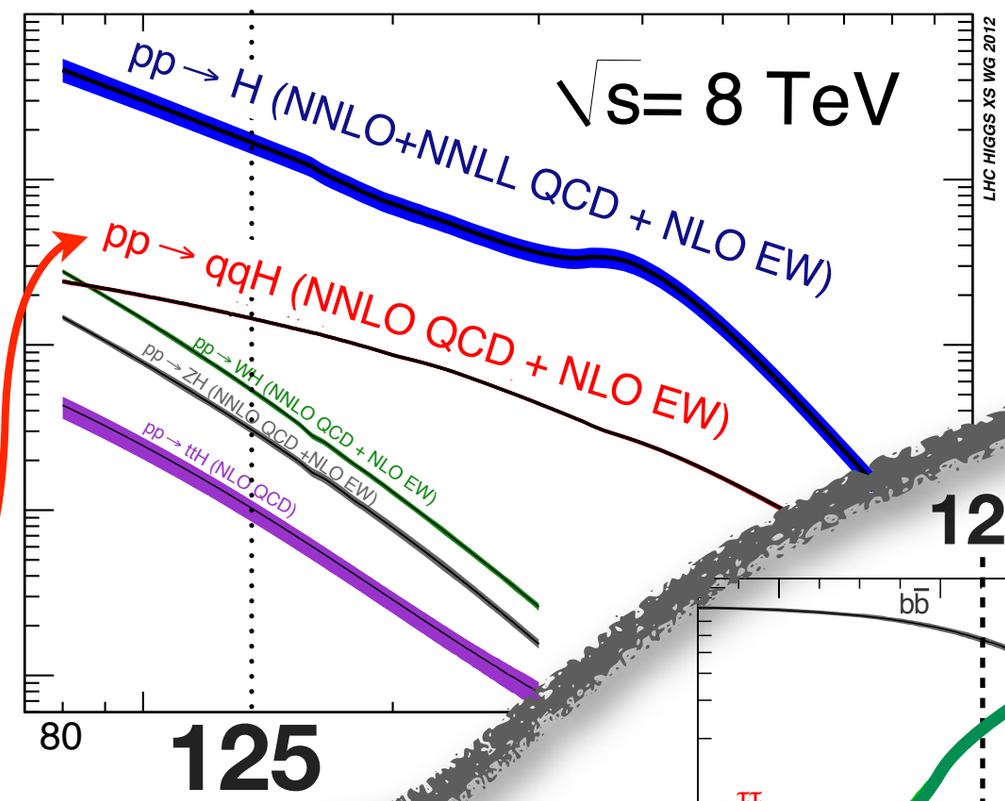
Boosted decision tree
http://tmva.sourceforge.net/docu/TMVAUsersGuide.pdf

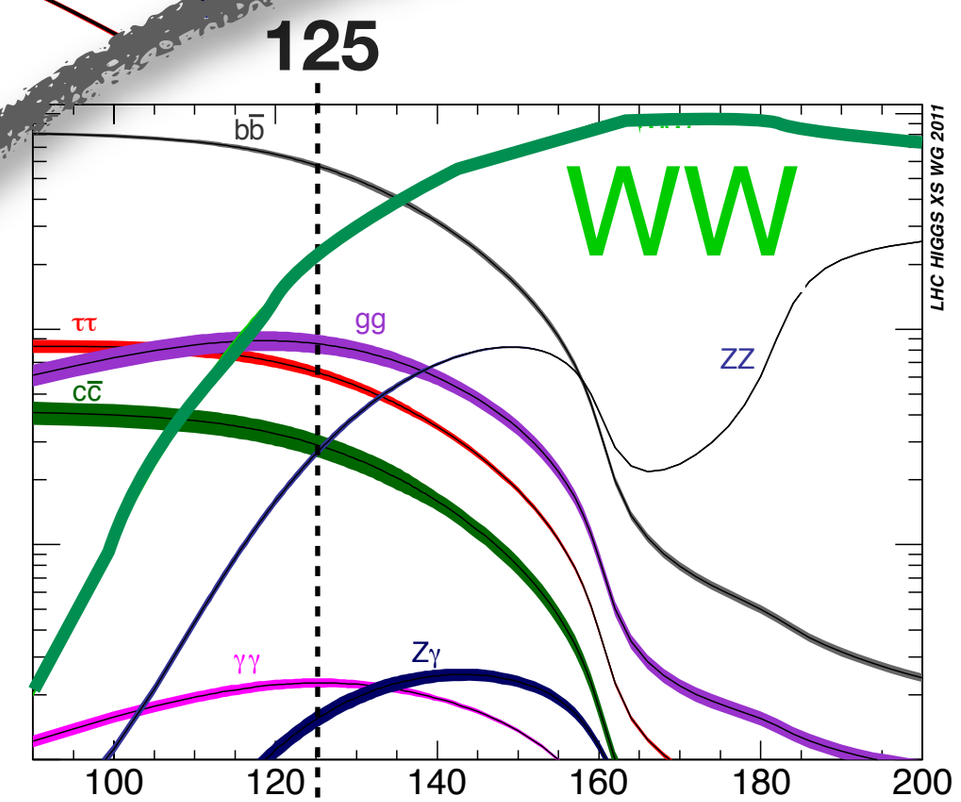
back up

Multiple production and decay mechanism

Other production mechanism will also play a significant role in the near future

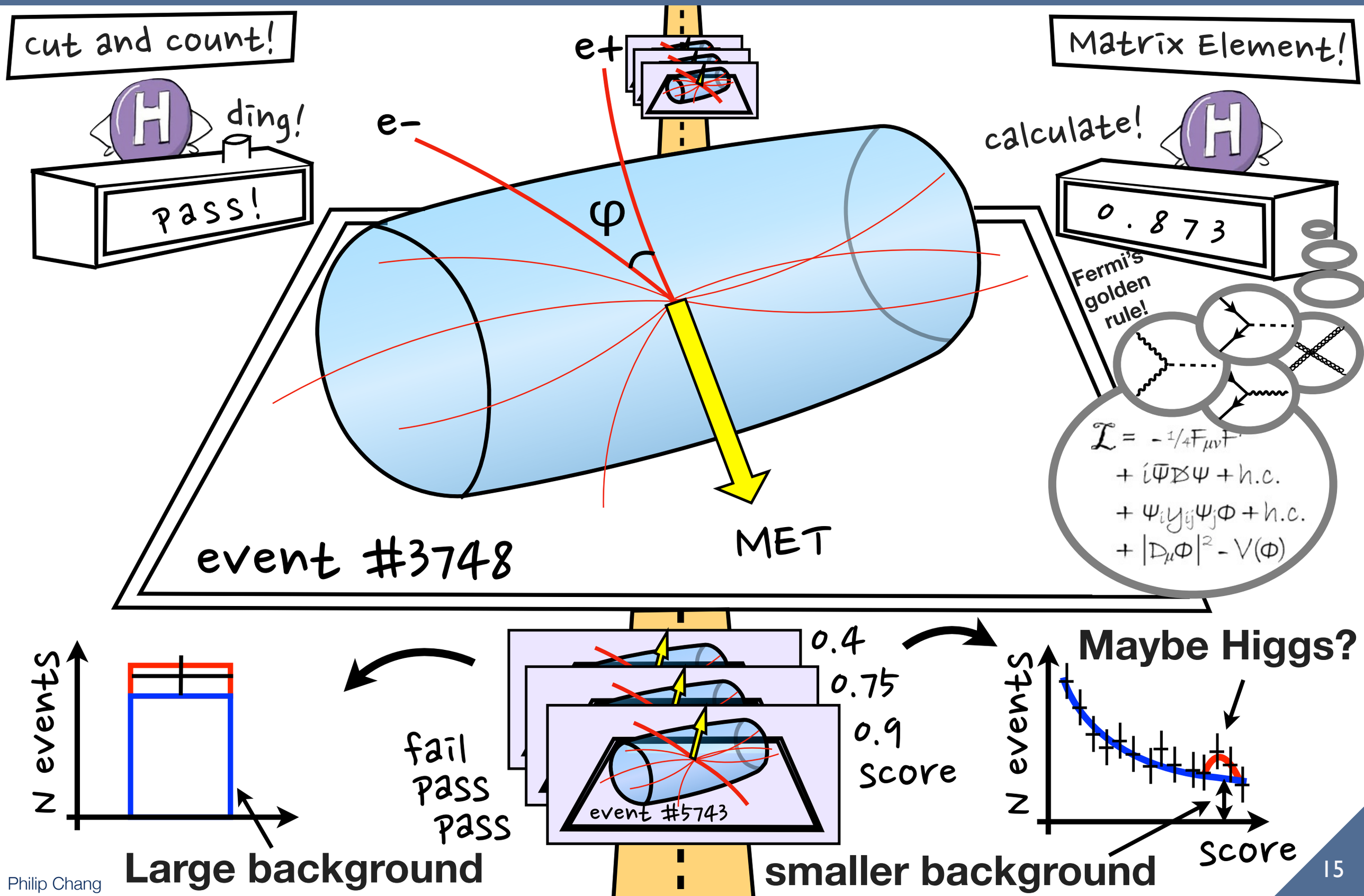






Other decay channels are also very important (maybe more) as well. And there are dozens of people working in each channel

Cut and count vs. multi-variate analysis (MVA)



Matrix element analysis uses **a priori** knowledge

Phase space points being integrated over

Transfer function to simulate detector effects

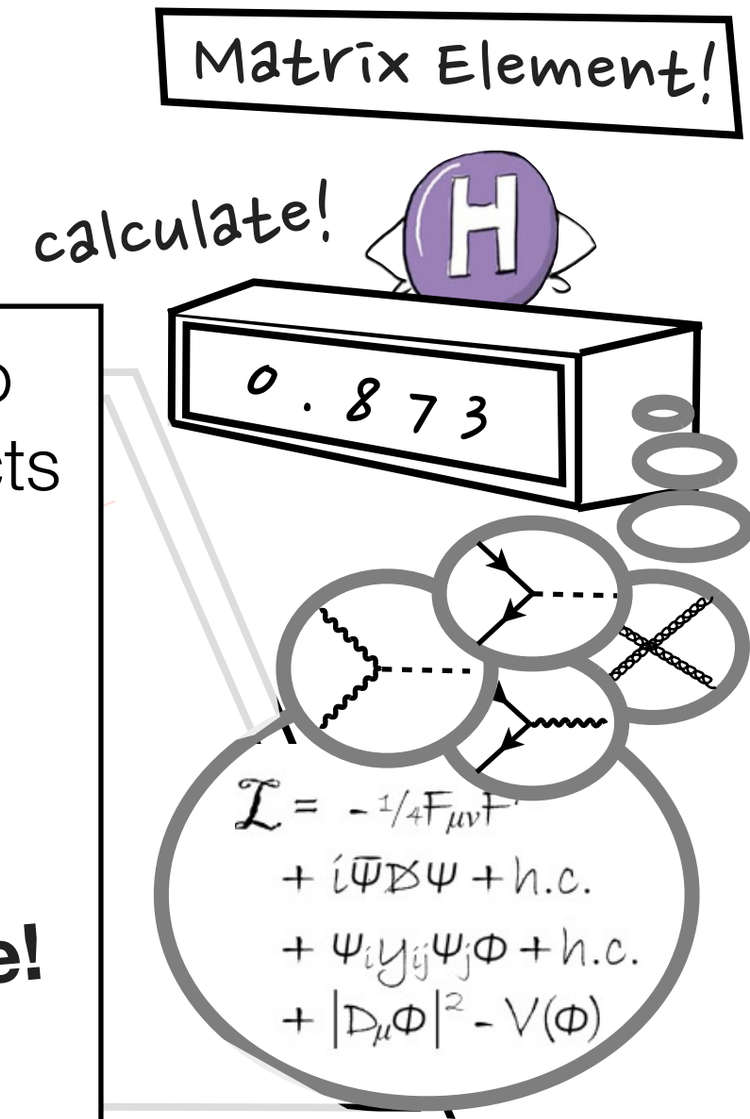
$$P(\boldsymbol{x}|\boldsymbol{\alpha}) \sim \frac{1}{\sigma_\alpha} \int d\Phi(\boldsymbol{y}) |M_\alpha|^2(\boldsymbol{y}) W(\boldsymbol{x}, \boldsymbol{y})$$

normalization

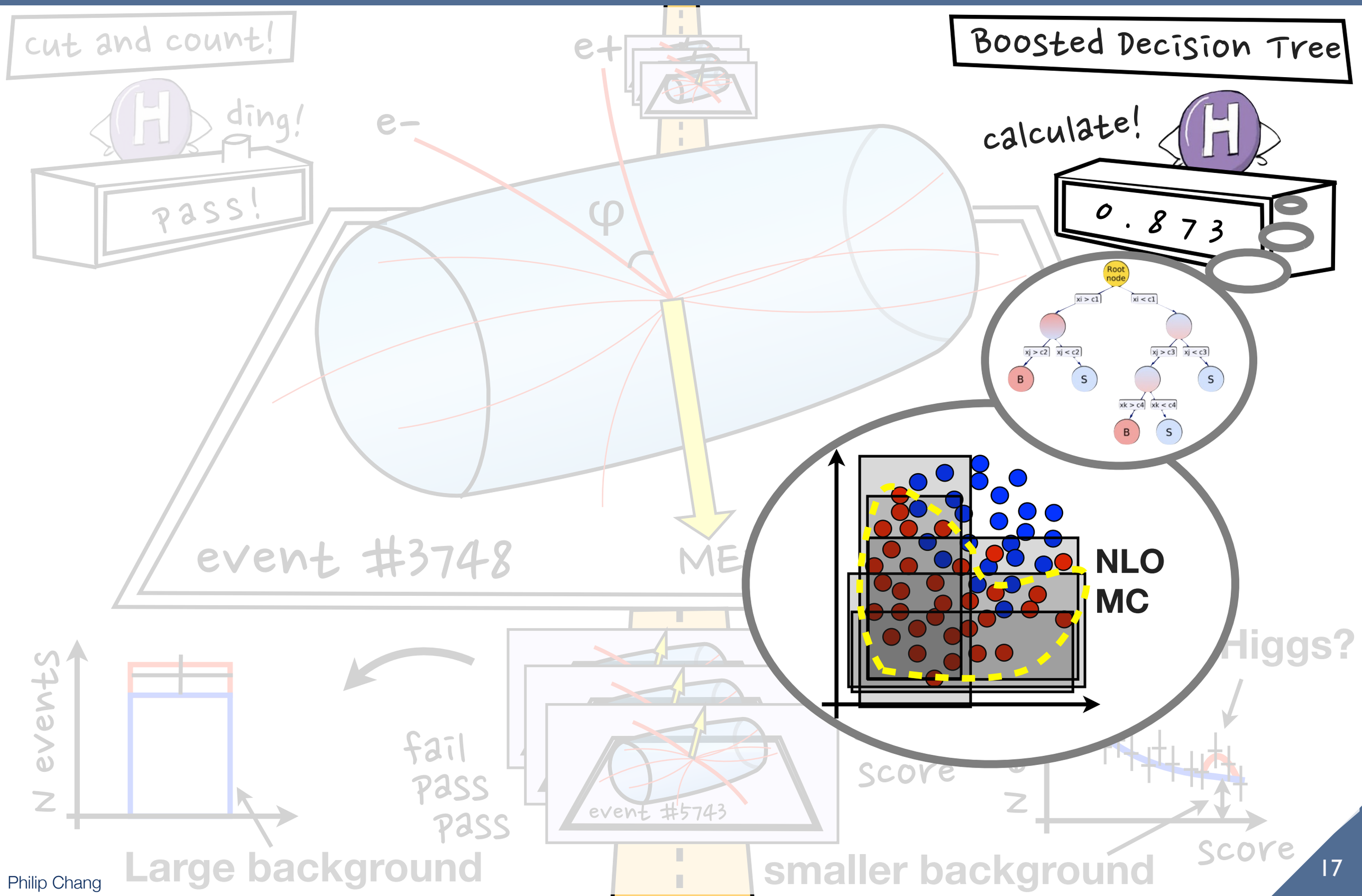
Fermi's golden rule!

Diagrams* of the process we are testing

* Leading order only: MadGraph



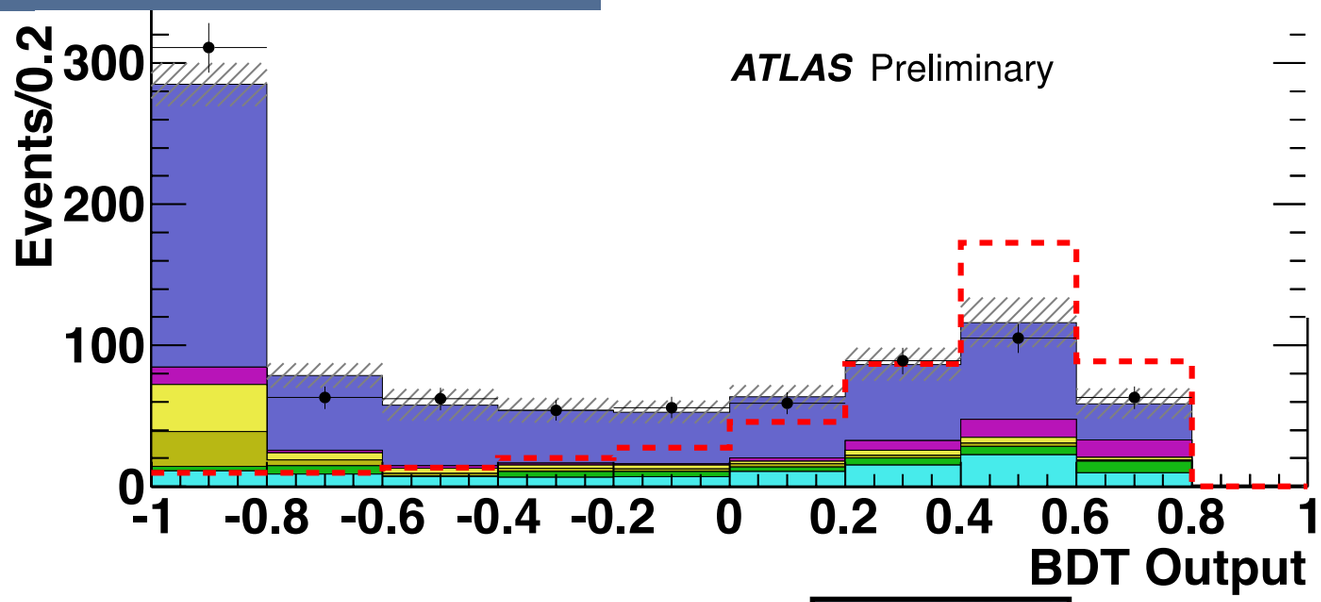
Boosted Decision Tree uses **NLO** MC knowledge

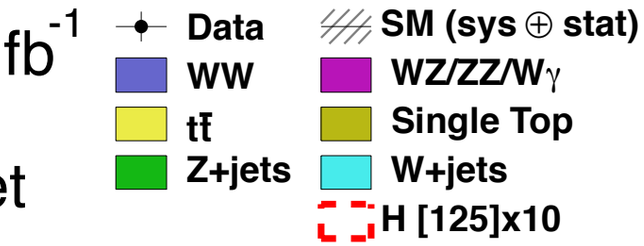


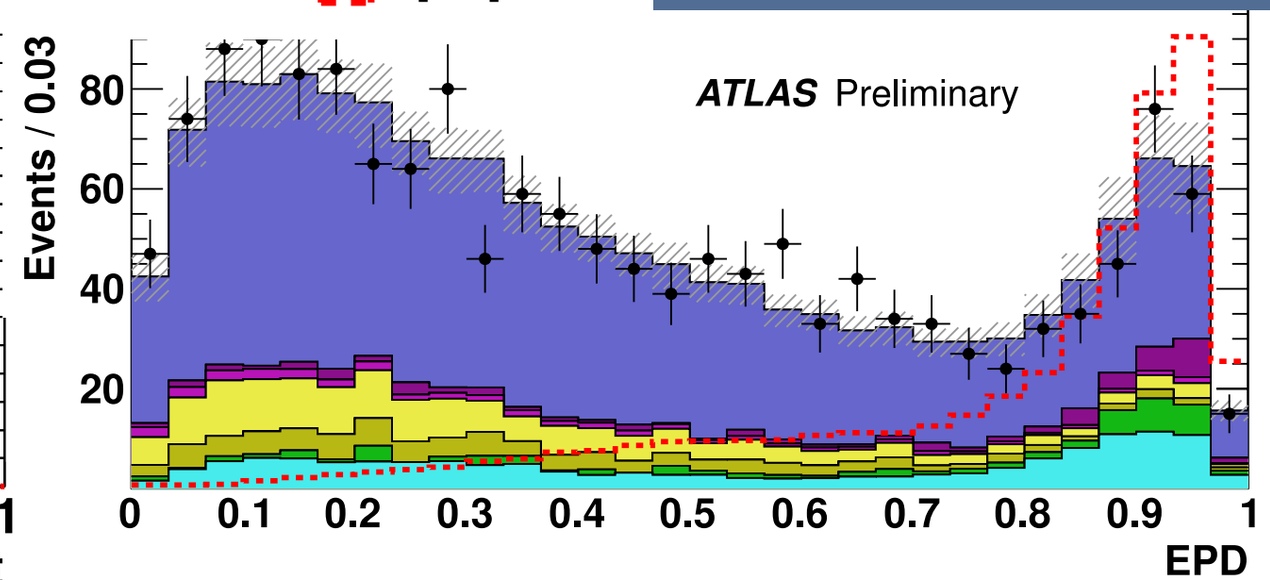
MVA

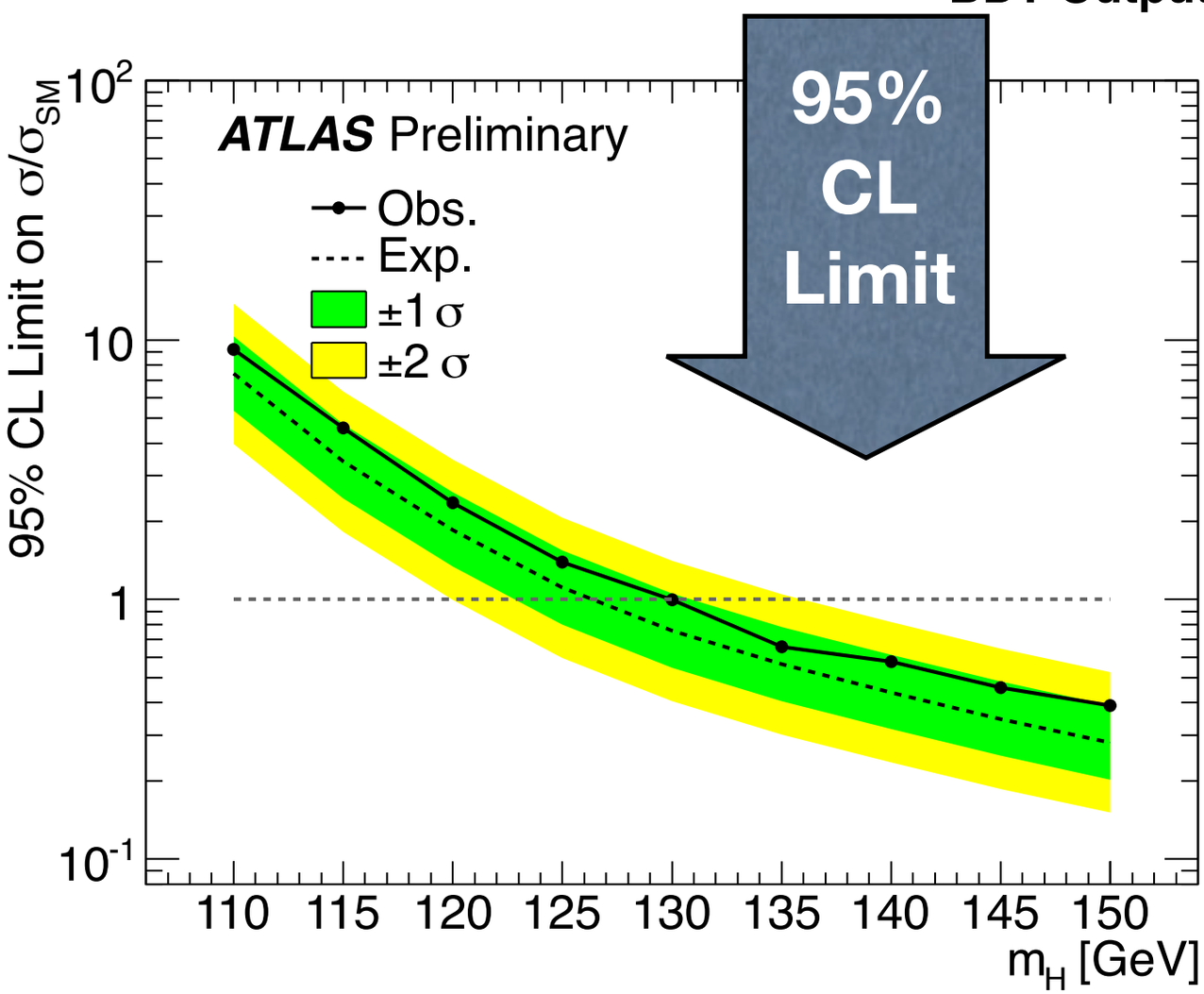
$\sqrt{s}$ = 7 TeV, $\int L\,dt = 4.7\ fb^{-1}$

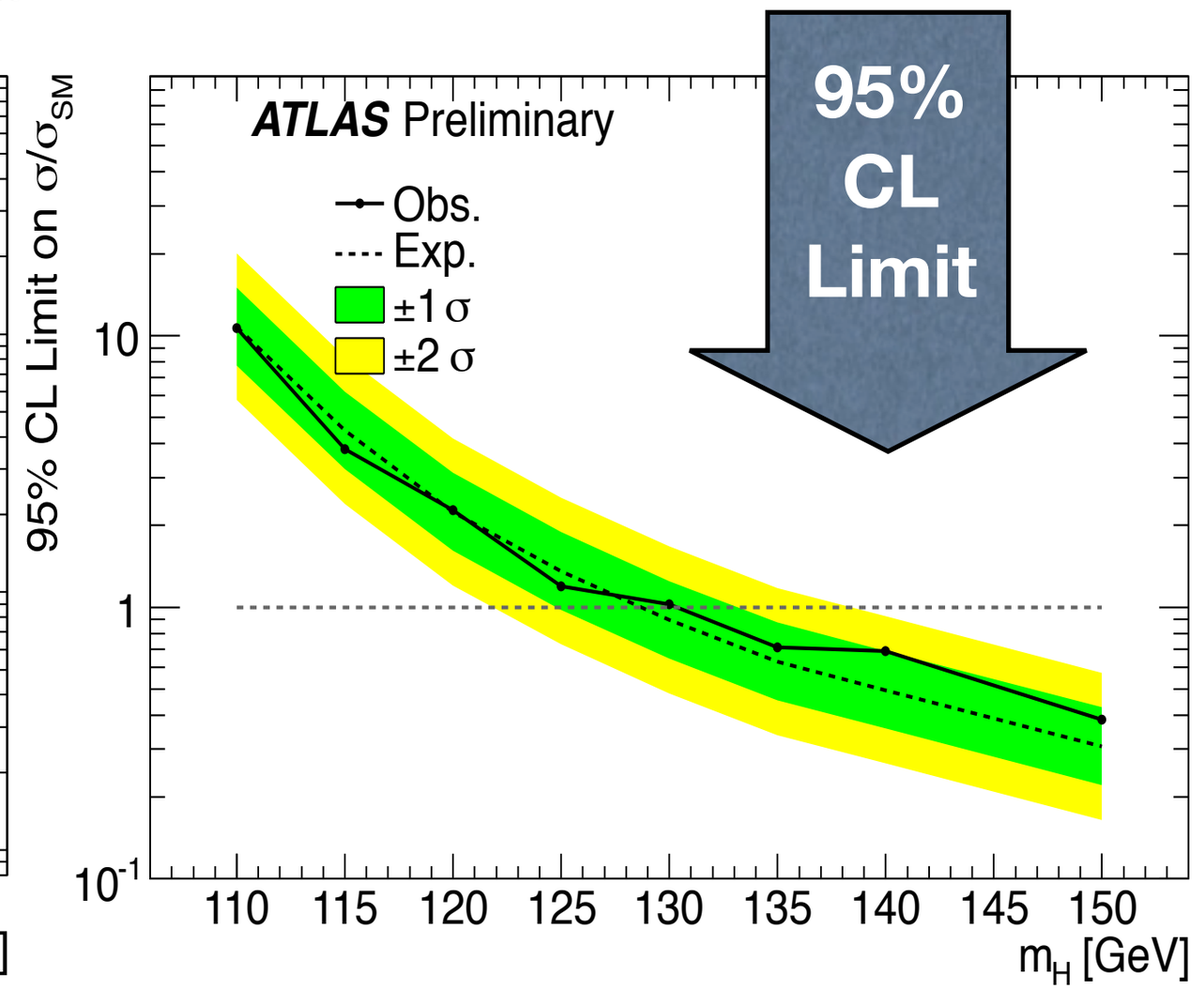
$H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$ + 0 jet



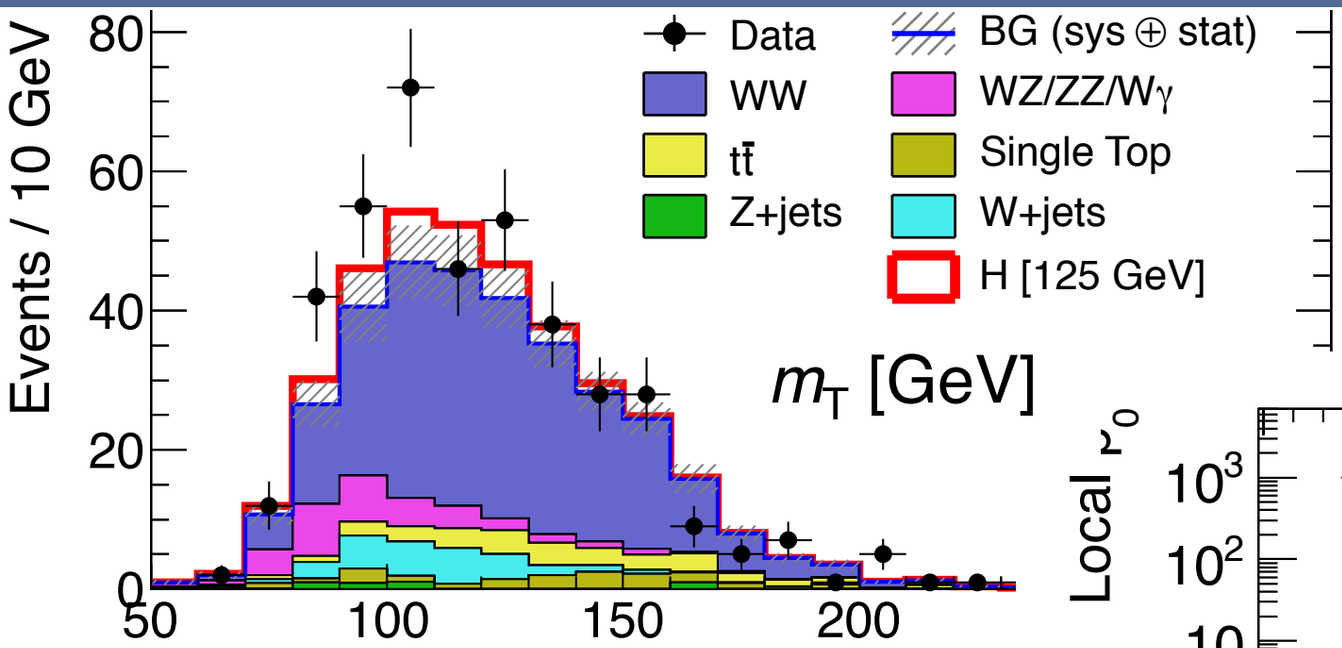






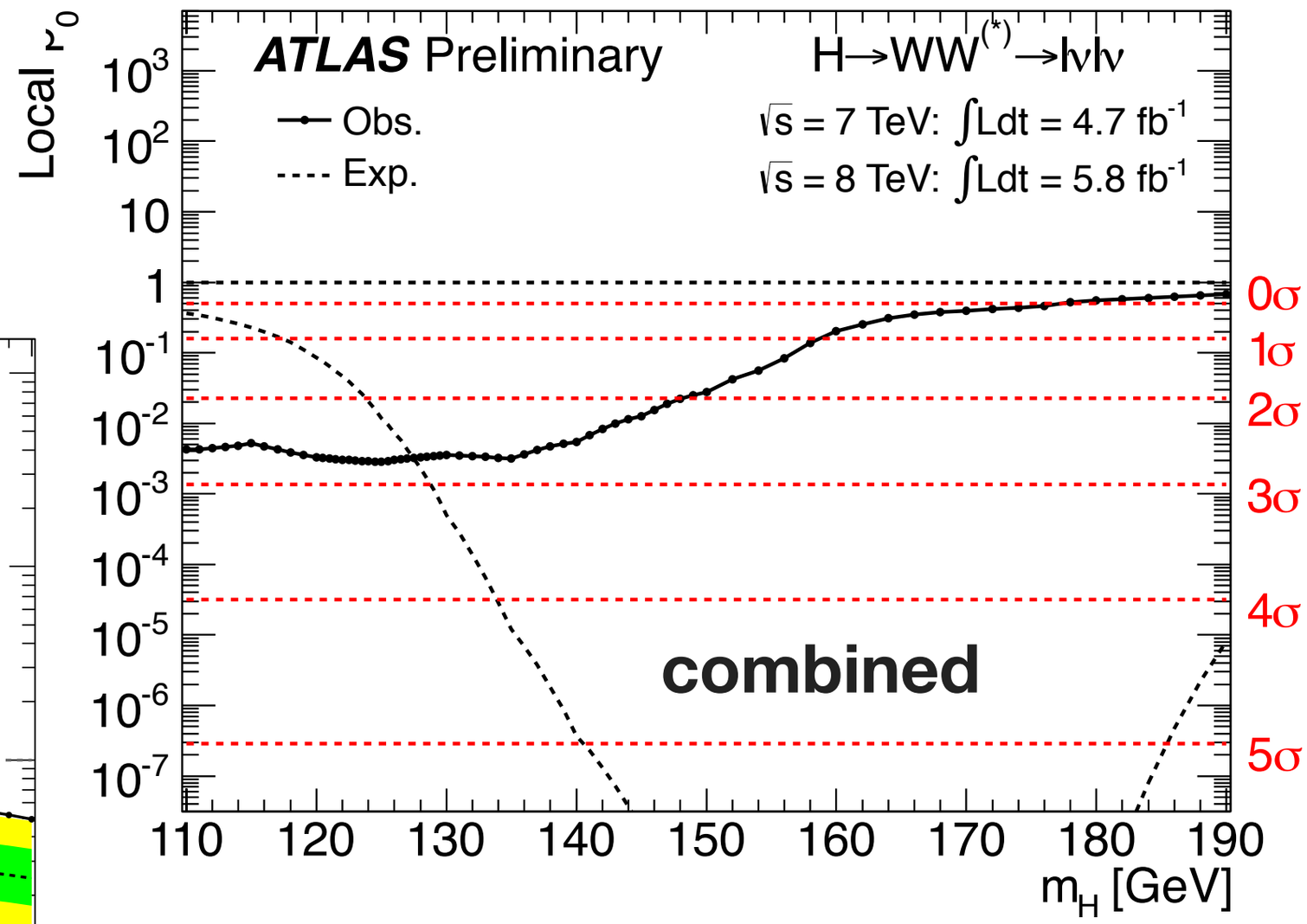


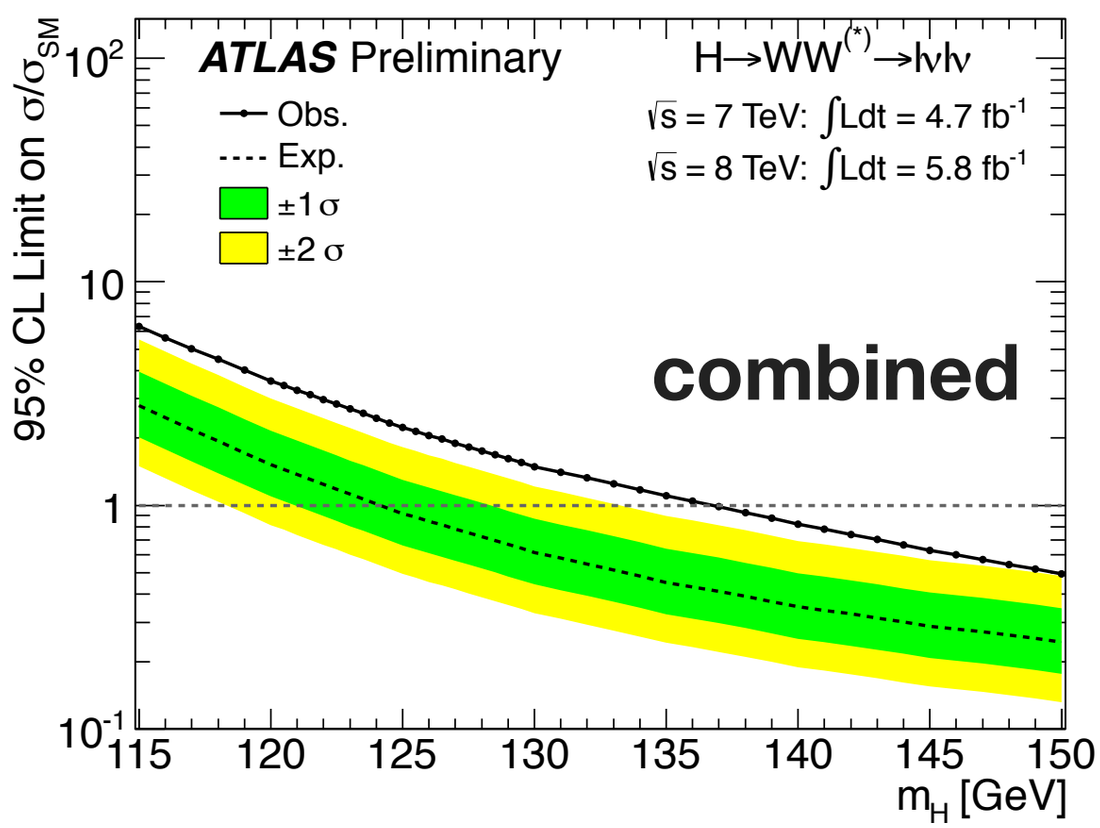
Cut-based M_T shape-fit 8 TeV (5.8 fb^{-1})



$\sqrt{s}$ = 8 TeV, $\int Ldt$ = 5.8 fb^{-1}

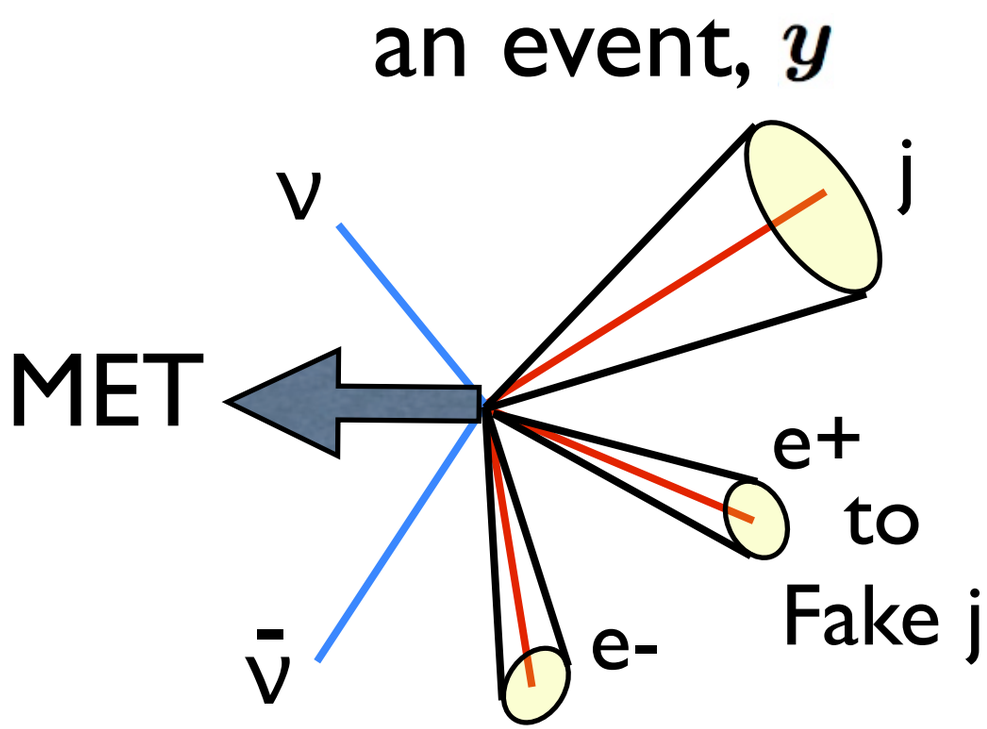
$H \to WW^{(*)} \to e\nu\mu\nu/\mu\nu e\nu$ + 0 jets





Transfer function (real life situation)

The Matrix Element, $|M_\alpha|^2(\boldsymbol{y})$ determines the probabilistic weight of an event.



Q: How likely is $\boldsymbol{y}$ from _____ process?
(fill in the blank)

A: Plug $\boldsymbol{y}$ into $|M_\alpha|^2(\boldsymbol{y})$!

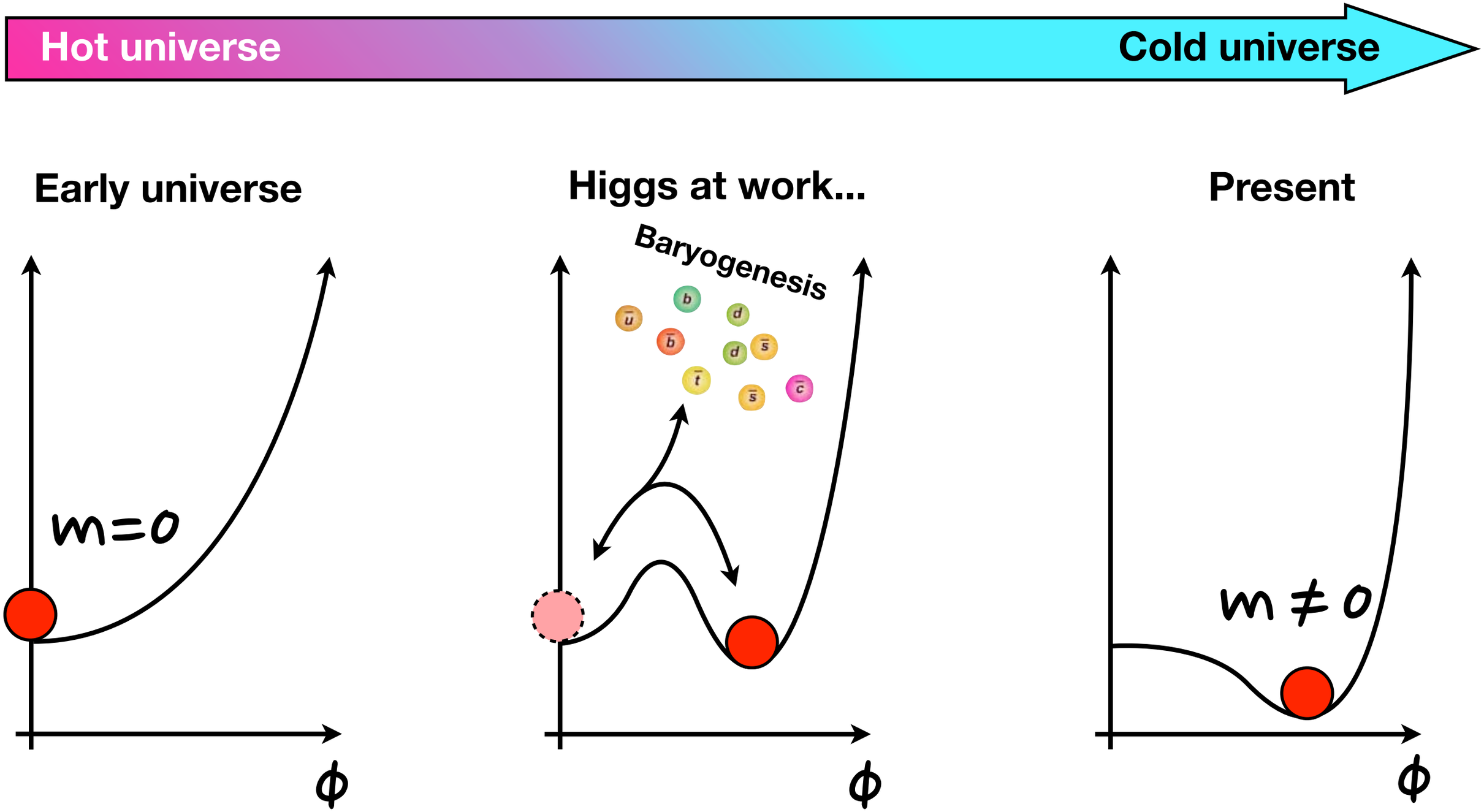
i.e. $P(\boldsymbol{y}|\boldsymbol{\alpha}) \sim |M_\alpha|^2(\boldsymbol{y})$

However, In real life situation... there are...

1. Detector effects : Use Transfer Function
2. Missing information (i.e. MET) : Integrate over them

⇒ **We can't just use** $|M_\alpha|^2(\boldsymbol{y})$

Why? To test electroweak theory



Higgs Field $\Longrightarrow$ Higgs Boson