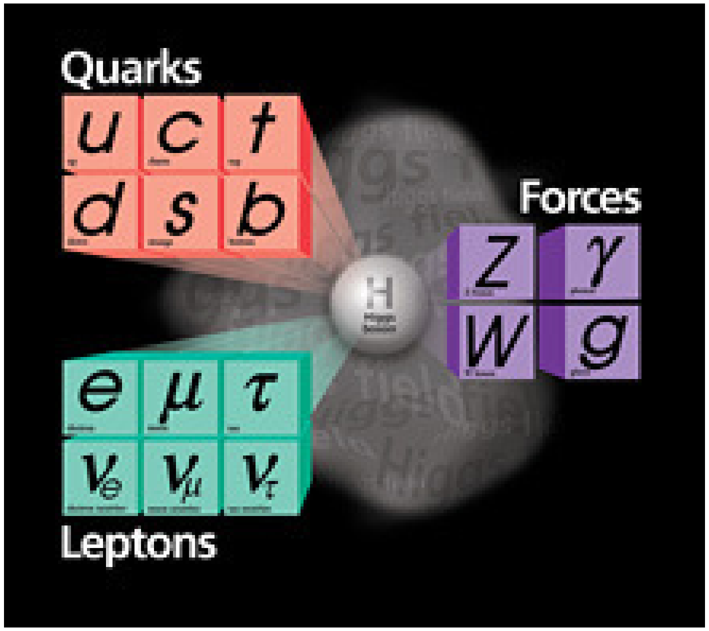
Search for the Standard Model Higgs Boson produced in Association With a W boson

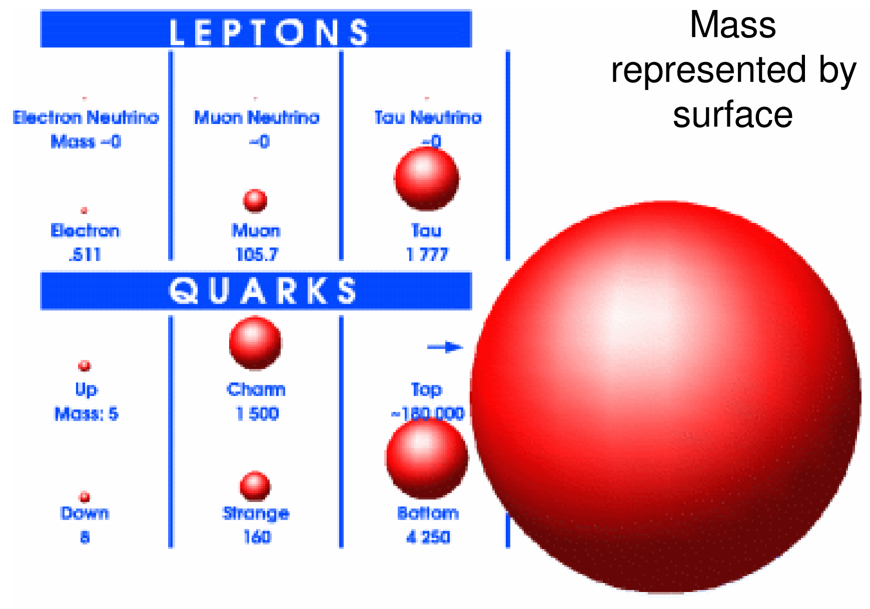
Adrian Buzatu, PhD Candidate

McGill University, Montreal, Canada

Collider Detector At Fermilab

The Missing Ingredient

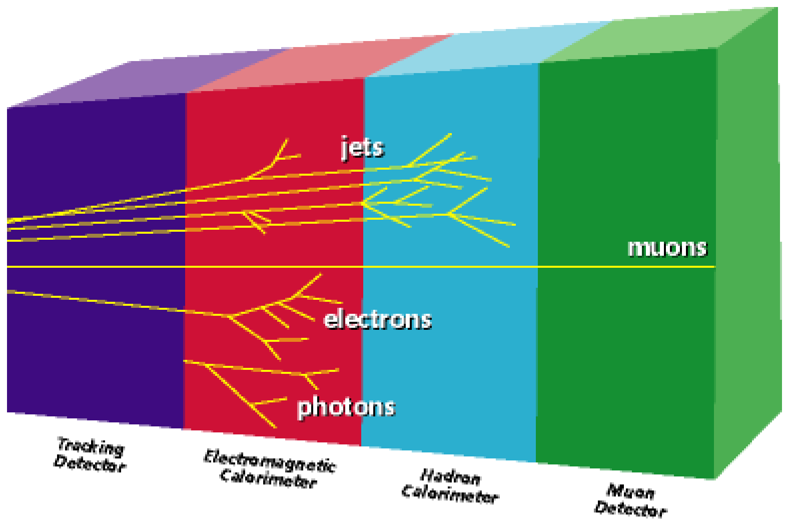


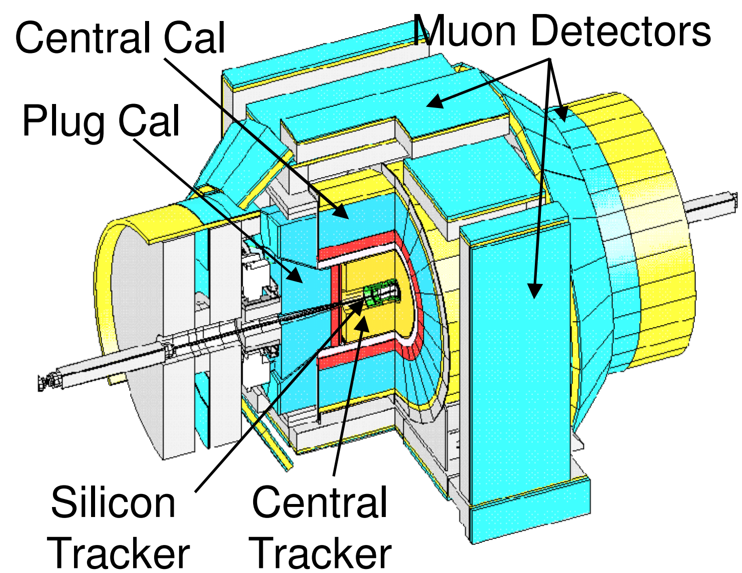


The origin of mass for elementary particles?

Suspect an extra recipe: the Higgs mechanism
Suspect an extra elementary particle: the Higgs boson

Collider Detector at Fermilab



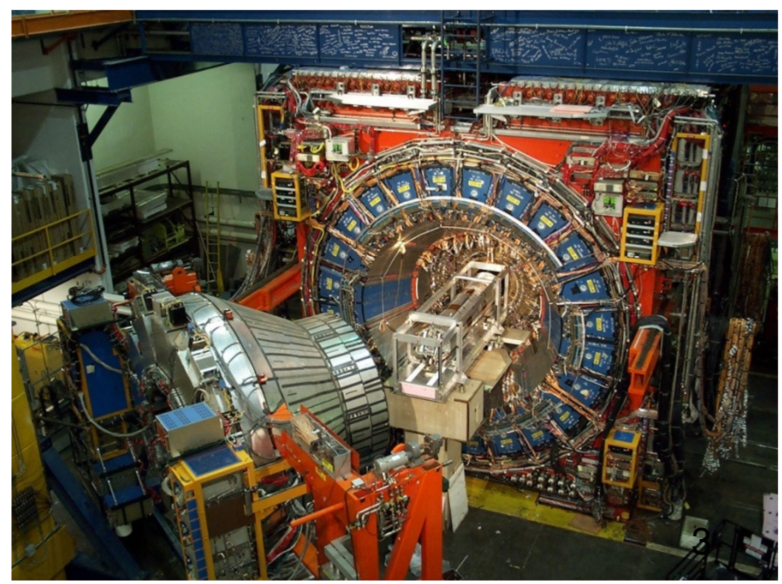


A particle detector (3D digital camera)

As big as a huge room

Layers of subdetectors

Measuring particle type, direction of movement, energy and momentum



As Heavy as Heavy Atoms!

PERIODIC TABLE OF THE ELEMENTS

1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 H Hydrogen 1.00794																	2 He Helium 4.002602
3 Li Lithium 6.941	4 Be Beryllium 9.012182											5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
11 Na Sodium 22.98976928	12 Mg Magnesium 24.3050											13 Al Aluminum 26.9815386	14 Si Silicon 28.0855	15 P Phosph. 30.973762	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955912	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938045	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge German. 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybd. 95.96	43 Tc Technet. (97.90722)	44 Ru Ruthen. 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.293
55 Cs Cesium 132.9054519	56 Ba Barium 137.327	57–71 Lantha-nides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.966569	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98040	84 Po Polonium (208.98243)	85 At Astatine (209.98715)	86 Rn Radon (222.01758)
87 Fr Francium (223.01974)	88 Ra Radium (226.02541)	89–103 Actinides	104 Rf Rutherford (267.122)	105 Db Dubnium (268.125)	106 Sg Seaborg. (271.133)	107 Bh Bohrium (270.134)	108 Hs Hassium (269.134)	109 Mt Meitner. (276.151)	110 Ds Darmstadt. (281.162)	111 Rg Roentgen. (280.164)	112 (285.174)						

Series															
Lanthanide series	57 La Lanthan. 138.90547	58 Ce Cerium 140.116	59 Pr Praseodym. 140.90765	60 Nd Neodym. 144.242	61 Pm Prometh. (144.91275)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolin. 157.25	65 Tb Terbium 158.92535	66 Dy Dyspros. 162.500	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.9668
Actinide series	89 Ac Actinium (227.02775)	90 Th Thorium 232.03806	91 Pa Protactin. 231.03588	92 U Uranium 238.02891	93 Np Neptunium (237.04817)	94 Pu Plutonium (244.06420)	95 Am Americ. (243.06138)	96 Cm Curium (247.07035)	97 Bk Berkelium (247.07031)	98 Cf Californ. (251.07959)	99 Es Einstein. (252.0830)	100 Fm Fermium (257.09510)	101 Md Mendelev. (258.09843)	102 No Nobelium (259.1010)	103 Lr Lawrenc. (262.110)

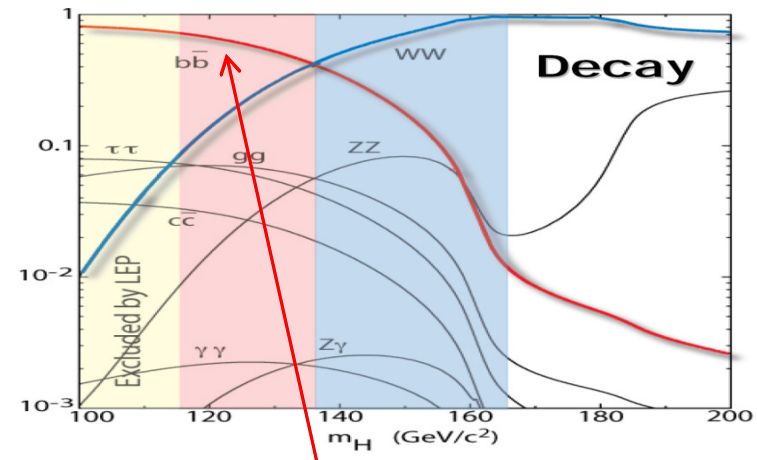
Higgs boson is characterized only by its mass,
However, its mass is not predicted by the theory!
Allowed mass interval
In atomic mass units: 123 – 199, in GeV/c^2: 115 – 185!

The WH Associated Production

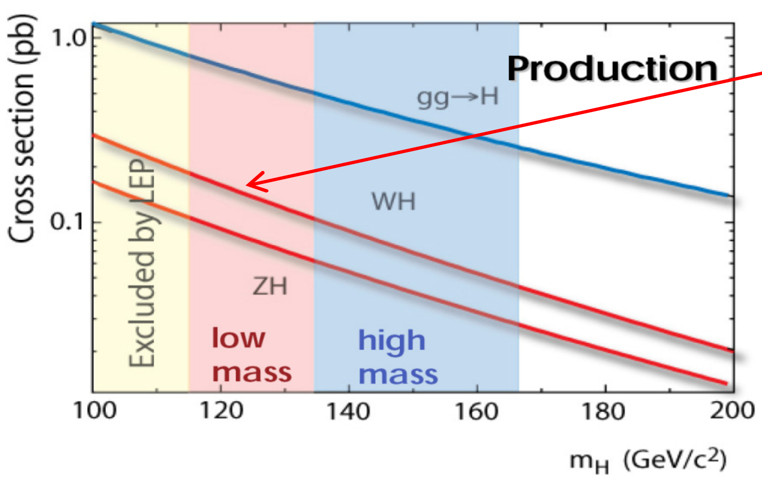
Our search: a W boson + a Higgs boson

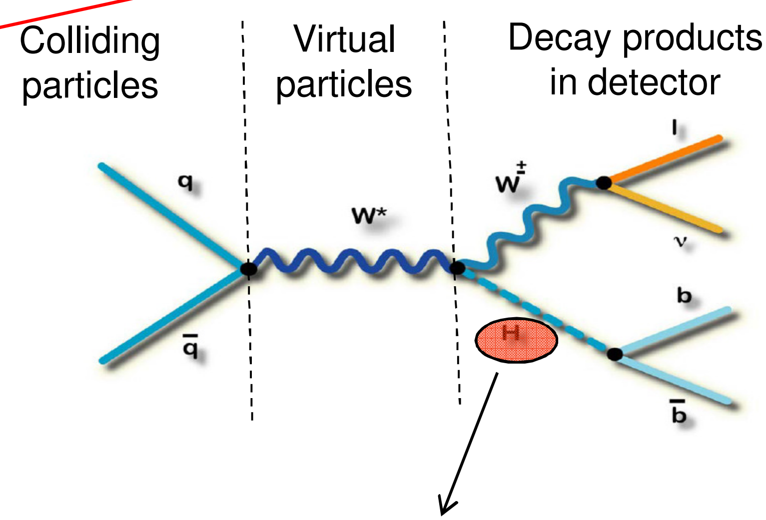
The W boson decays to an electron (muon) + neutrino

It helps us a lot that we can indentify well electrons and muons in the detector



Our search (WH)





Higgs Particle (H)
Elementary particle as massive as heavy atoms

Our Improvement

Charged lepton (Electron or Muon)

Our contribution to improve the search:

More charged leptons, which means

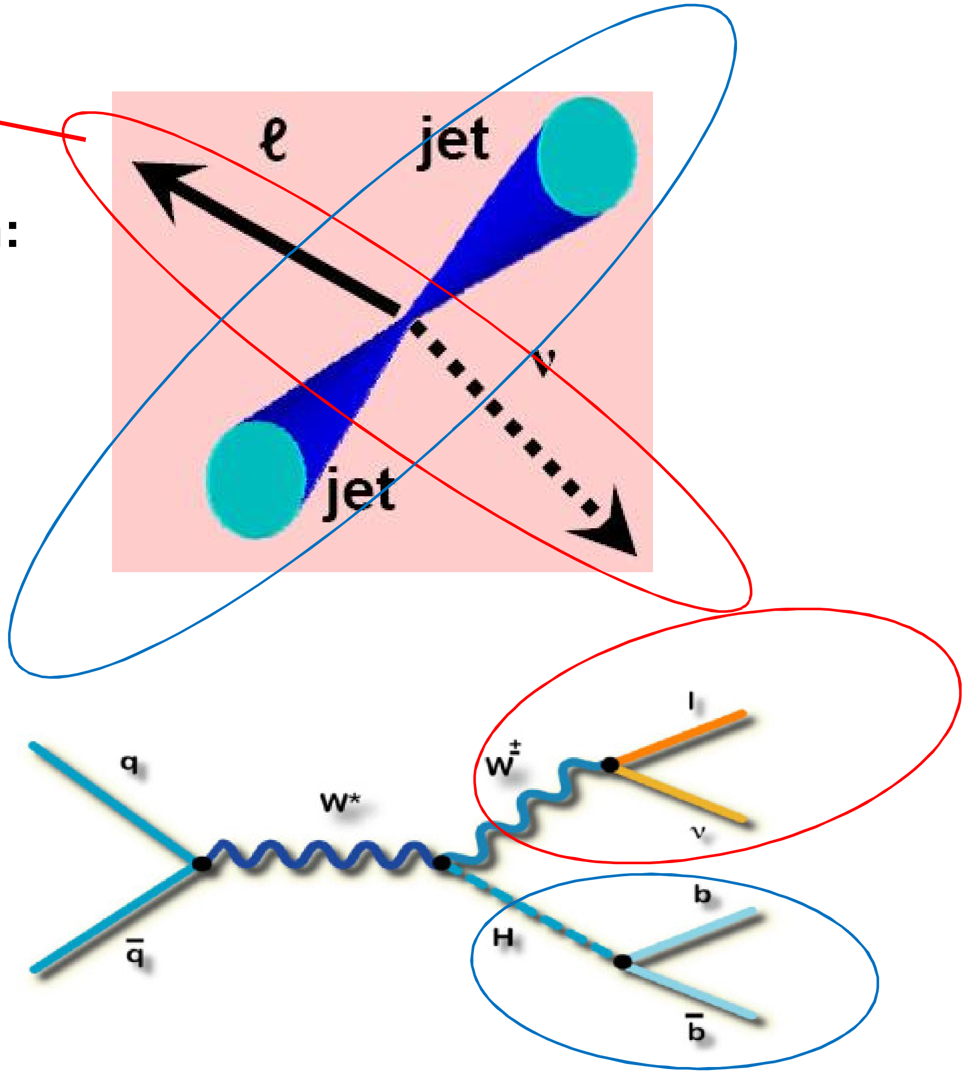
More W bosons, which means

More WH events, which means

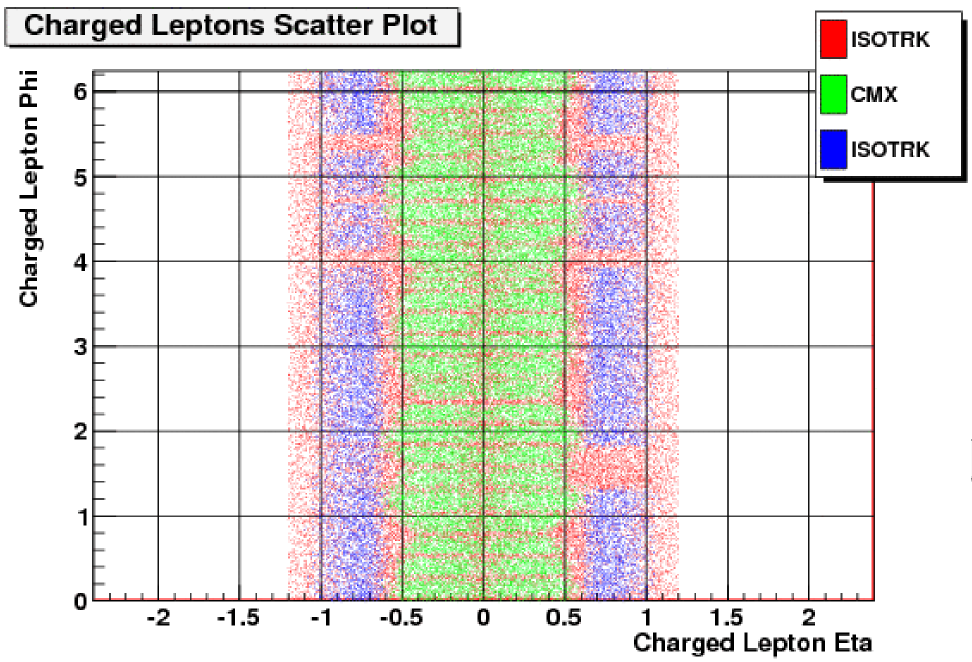
More signal selected, which means

More precise “microscope”!

We introduce a new method to reconstruct electrons and muons that would normally be lost in the non instrumented regions of the detector

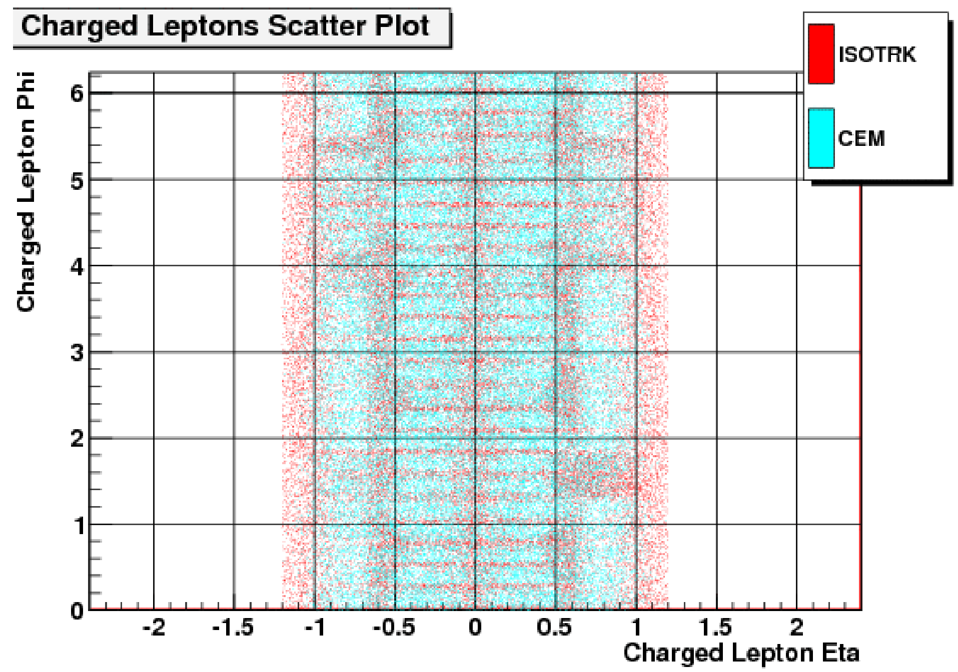


Charged Lepton Improvement



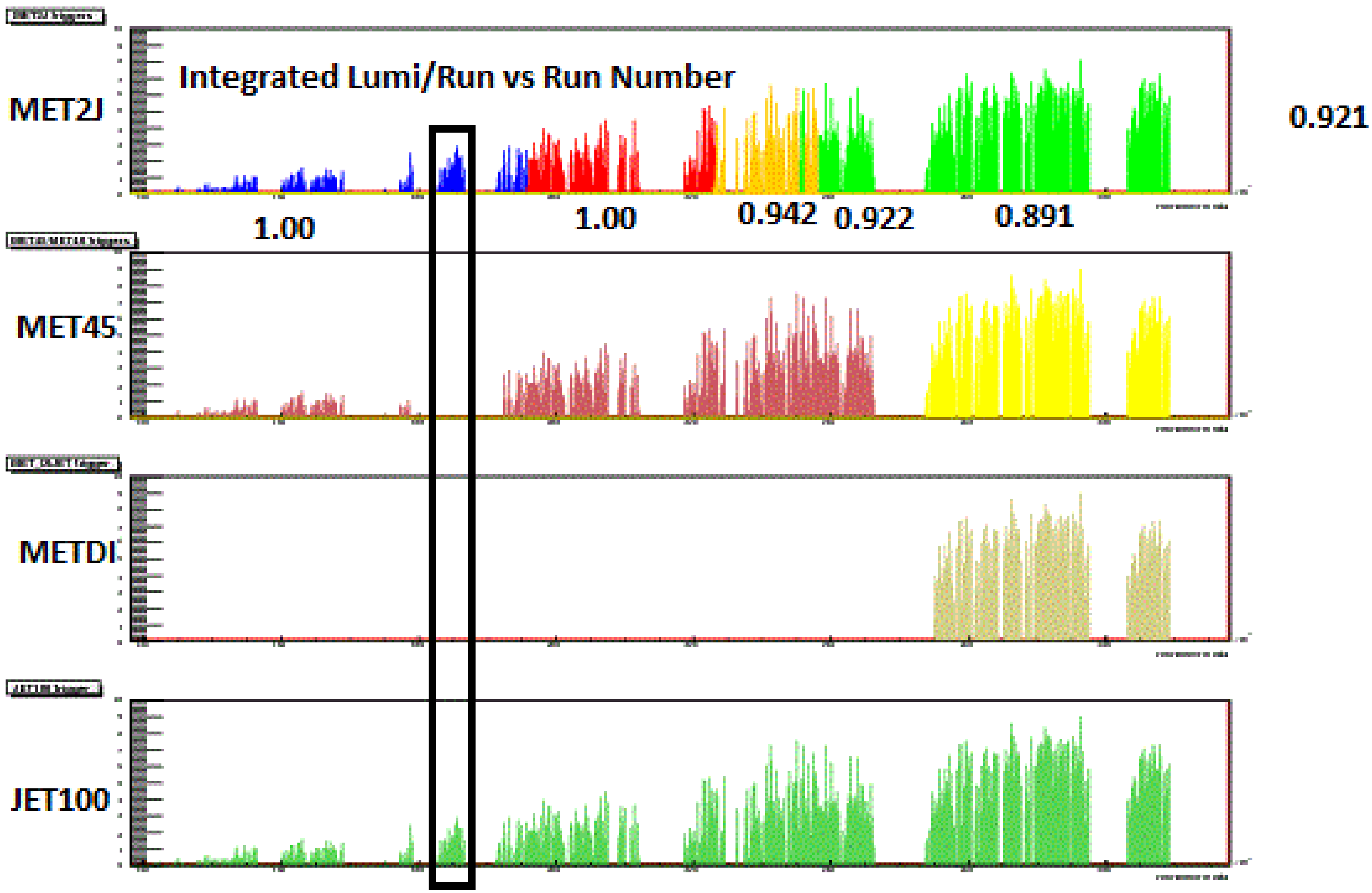
Cylindrical detector rolled on a plane

Y axis: 0-2Pi
X axis – 0 for half height



Dark blue, Green – muons
Light blue – electrons
Red – muons or electrons that would be lost in the non instrumented regions of the detector, but we recover

3 MET + jets triggers



Trigger specific jet selection

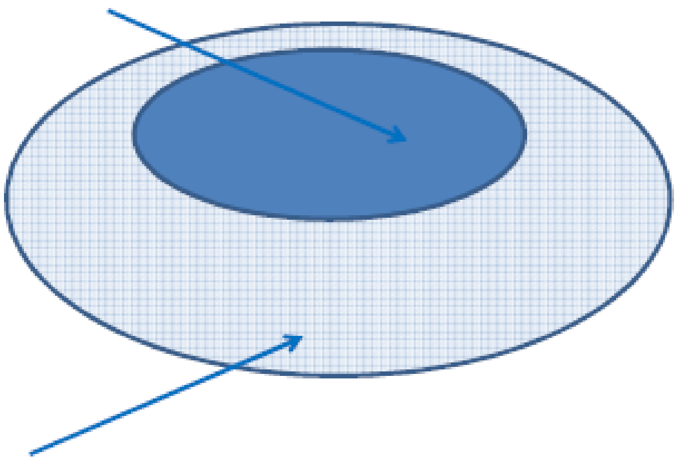
MET-based triggers

- **MET2J (MET+2Jets)**
  - Trigger: MET>35 GeV, 2 jets, one of them central
  - Offline: et1>25 GeV, et2>25 GeV, dR>1, |eta1|<0.9 or |eta2|<0.9
- **MET45 (MET45/MET40)**
  - Trigger: MET>45 GeV, then MET>40 GeV, no jet requirement
  - Offline: et1>20 GeV, et2>20 GeV, dR>0
- **METDI (MET_DIJET)**
  - Trigger: MET>30 GeV, one jet tower > 10 GeV
  - Offline: et1>40 GeV, et2>25 GeV, dR>0
- **History at WH NN at CDF**
  - 2.7fb-1, MET2J +25% signal over central leptons (Jason Slaunwhite)
  - 4.3fb-1, MET2J & MET45 in orthogonal kinematic regions +20% signal over MET2J (Yoshikazu Nagai)
  - 5.7fb-1, MET2J & MET45 in orthogonal kinematic regions +20% signal over MET2J (Yoshikazu Nagai)
- **Our plan: MET2J & MET45 in a better way, than add METDI the same way**

Novel method to combine triggers

Old vs new method

Tight jet selection: et1>25 GeV, et2>25 GeV, dR>1, |eta1|<0.9 or |eta2|<0.9
Old – DATA: check if MET2J fired; MC: assign MET2J trigger weight
New – DATA: pick trigger with largest weight and check if that trigger fired;
MC: assign as trigger weight the largest of the two

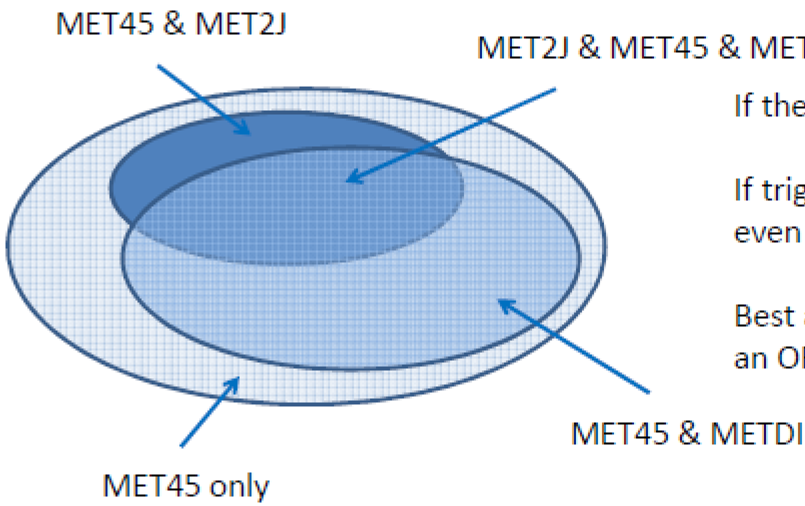


Tight jet selection fails and loose selection is true: et1>20 GeV, et2>20 GeV, dR>0
Old and New are the same here:
DATA: check if MET45 fired
MC: assign trigger weight corresponding to MET45

Our analysis: 3 triggers

New method: adding METDI

In jet kinematic regions where triggers overlap, let them “fight” each other: the one with best weight wins and is picked in order for that trigger to be checked it if has fired



If the trigger has fired, event is kept.

If trigger has not fired, event is rejected, even if other triggers have fired.

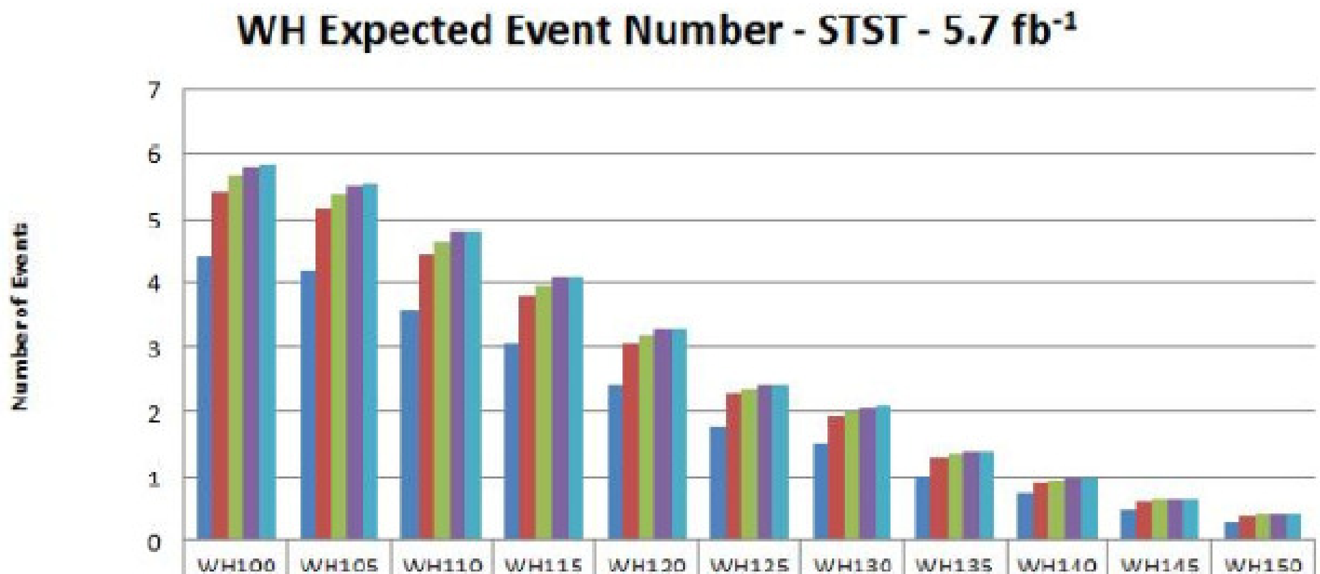
Best acceptance possible short of making an OR between the triggers

To every event corresponds only one trigger

Method generalizable to N triggers

This allows for easy systematic uncertainty measurement (not shown here)

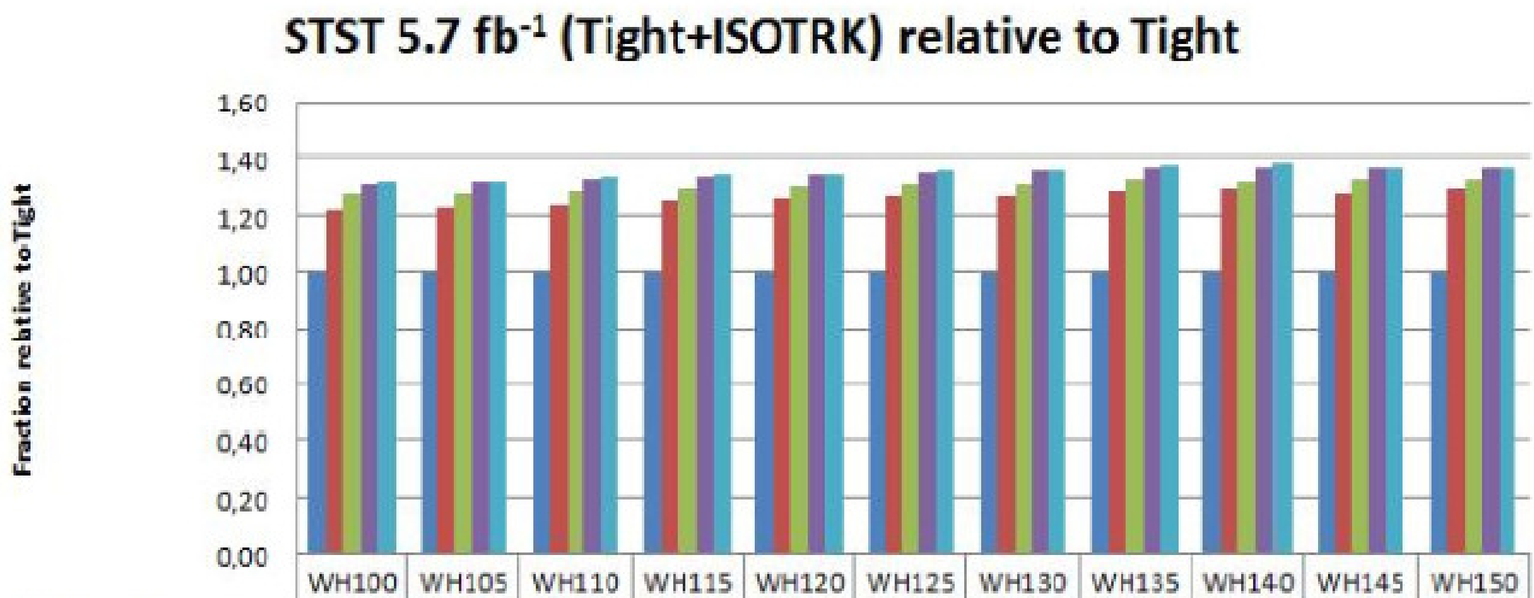
WH115 Signal Yield



	WH100	WH105	WH110	WH115	WH120	WH125	WH130	WH135	WH140	WH145	WH150
Tight	4,41	4,18	3,58	3,04	2,41	1,78	1,51	1,01	0,71	0,46	0,3
Tight+A	5,4	5,15	4,44	3,8	3,05	2,27	1,93	1,3	0,92	0,59	0,39
Tight+AB2	5,66	5,37	4,62	3,94	3,15	2,34	1,99	1,34	0,94	0,61	0,4
Tight+ADC	3,8	3,31	4,73	4,08	3,24	2,41	2,03	1,38	0,97	0,63	0,41
Tight+ABC10	5,83	5,54	4,78	4,08	3,25	2,42	2,06	1,39	0,98	0,63	0,41

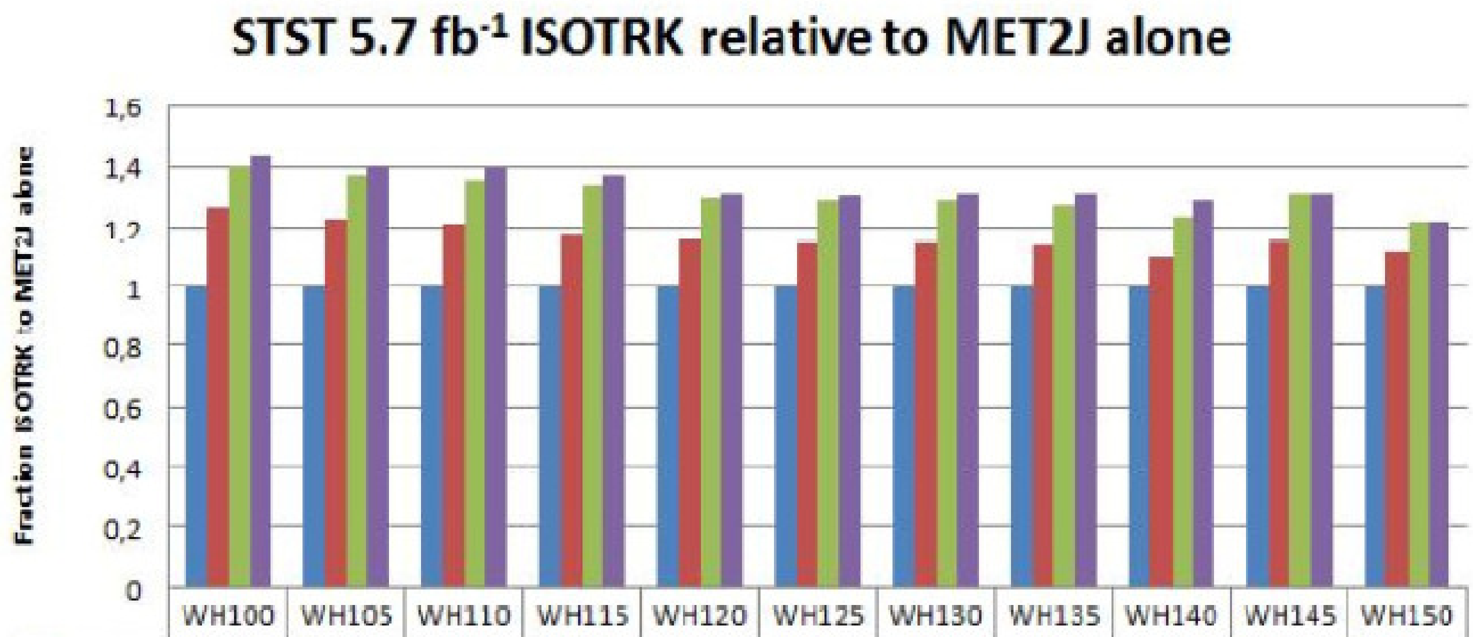
A = MET2J only (like WH ME) – *validated for WH115 with Yoshikazu*
AB2 = MET2J + MET45/MET40 as Yoshikazu – *also validated for WH115*
ABC = MET2J + MET45/MET40 + MET_DIJET as Adrian – my blessing procedure

Signal Percentage Increase



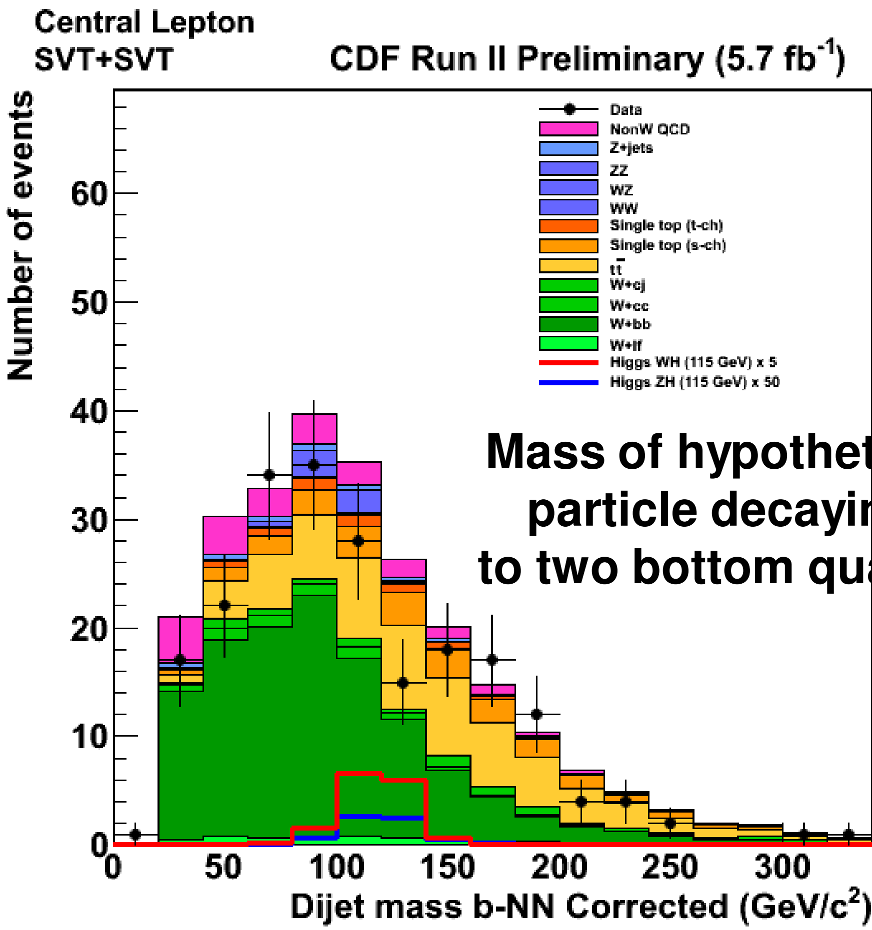
	WH100	WH105	WH110	WH115	WH120	WH125	WH130	WH135	WH140	WH145	WH150
Tight/Tight	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
(Tight+A)/Tight	1,22	1,23	1,24	1,25	1,27	1,28	1,28	1,29	1,30	1,28	1,30
(Tight+AB2)/Tight	1,28	1,28	1,29	1,30	1,31	1,31	1,32	1,33	1,32	1,33	1,33
(Tight+ABC)/Tight	1,32	1,32	1,33	1,34	1,34	1,35	1,36	1,37	1,37	1,37	1,37
(Tight+ABC10)/Tight	1,32	1,33	1,34	1,34	1,35	1,36	1,36	1,38	1,38	1,37	1,37

Different Trigger Combination

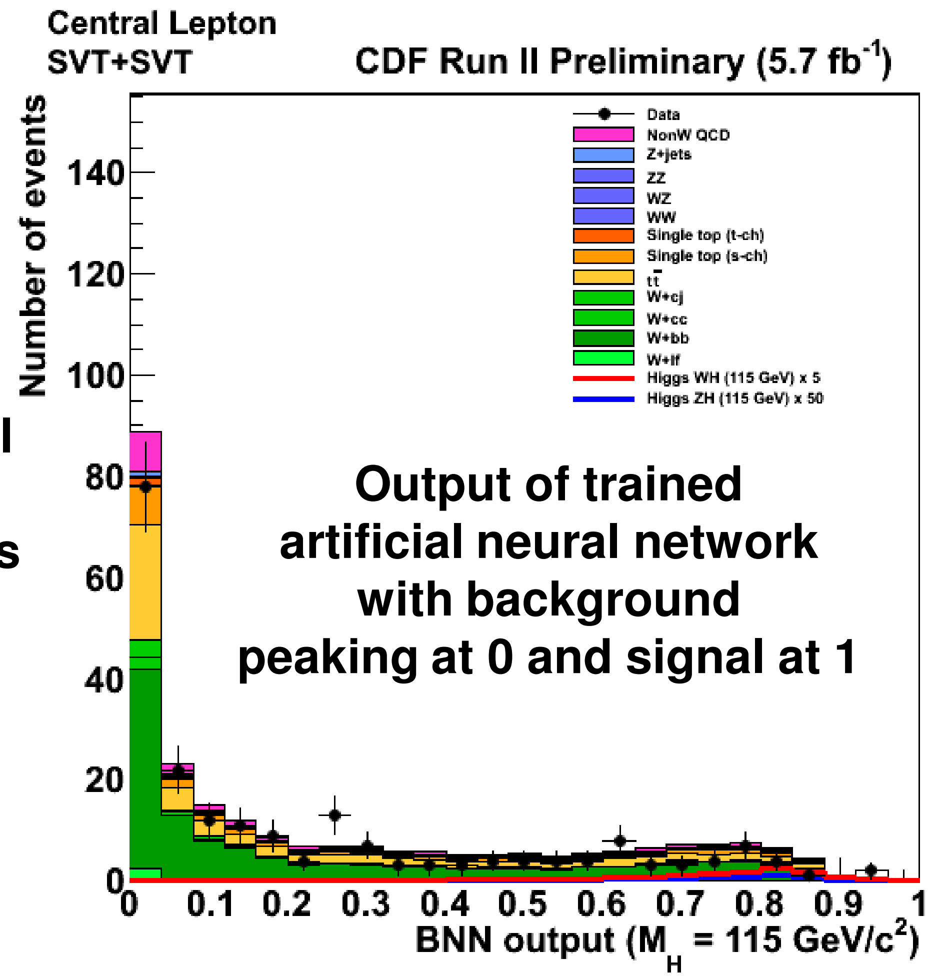


	WH100	WH105	WH110	WH115	WH120	WH125	WH130	WH135	WH140	WH145	WH150
A/A	1	1	1	1	1	1	1	1	1	1	1
AB2/A	1,26	1,23	1,21	1,18	1,16	1,14	1,14	1,14	1,10	1,15	1,11
ABC/A	1,40	1,37	1,36	1,34	1,30	1,29	1,29	1,28	1,24	1,31	1,22
ABC10/A	1,43	1,40	1,40	1,37	1,31	1,31	1,31	1,31	1,29	1,31	1,22

Key Analyses Variables



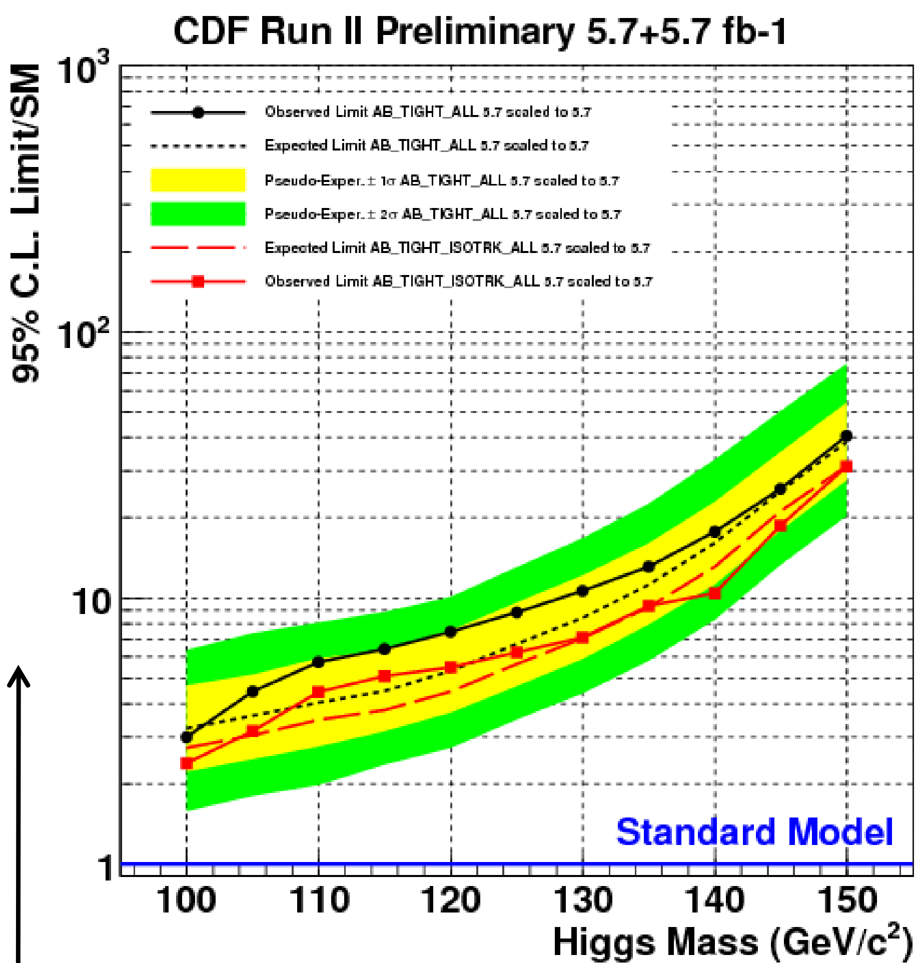
Mass of hypothetical particle decaying to two bottom quarks



Output of trained artificial neural network with background peaking at 0 and signal at 1

Red: WH Signal multiplied by 5 times!

Our Result



Y axis: Measurement divided by theory prediction

Dotted line: how precise our "microscope" is

Solid line: what we actually measure with our "microscope"

Name of the game: drive the solid line below 1 to exclude the Higgs boson!

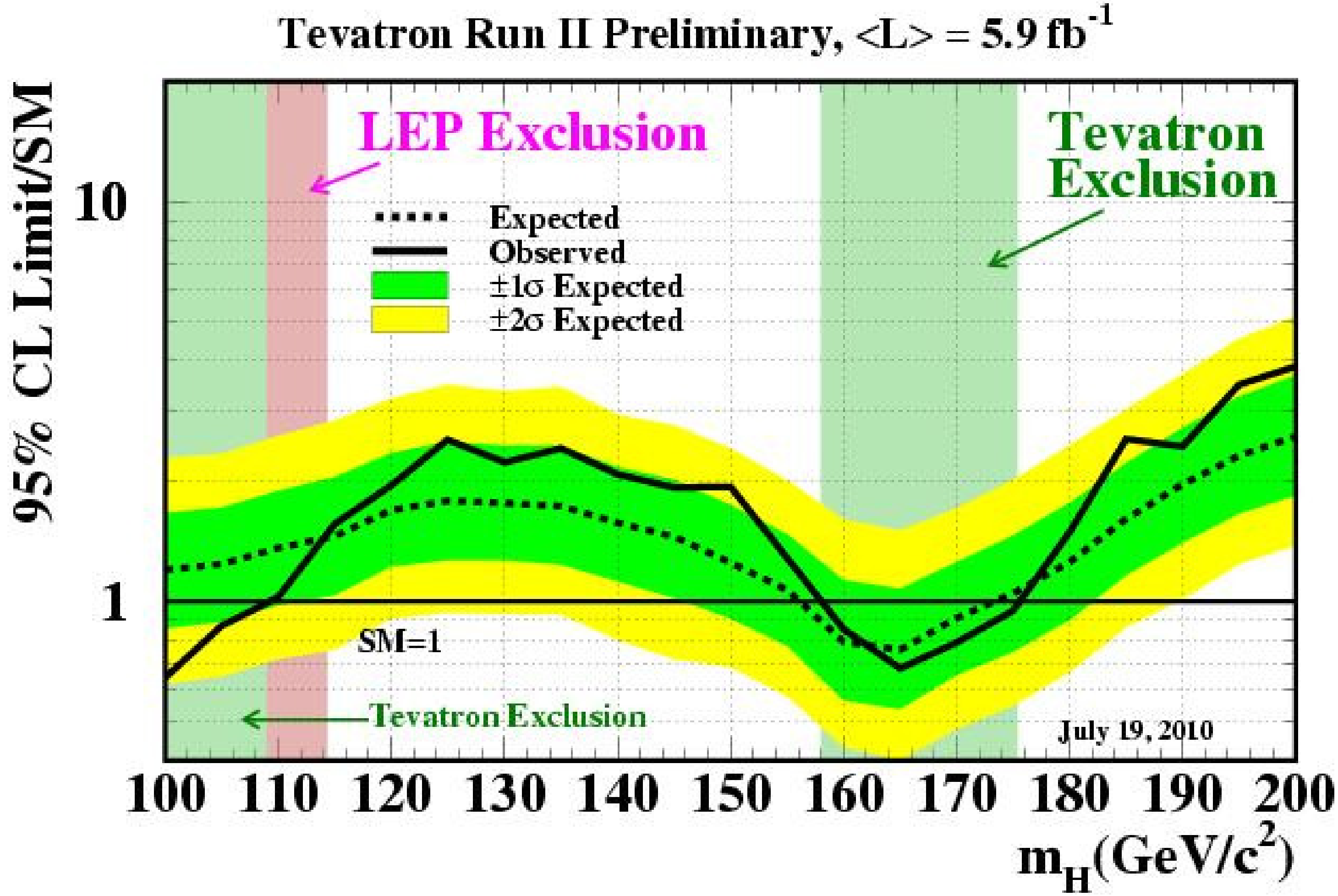
Black: the WH analysis before my contribution

Red: with the addition of my original PhD contribution, the WH analysis improves both the precision of the "microscope" and the actual measurement

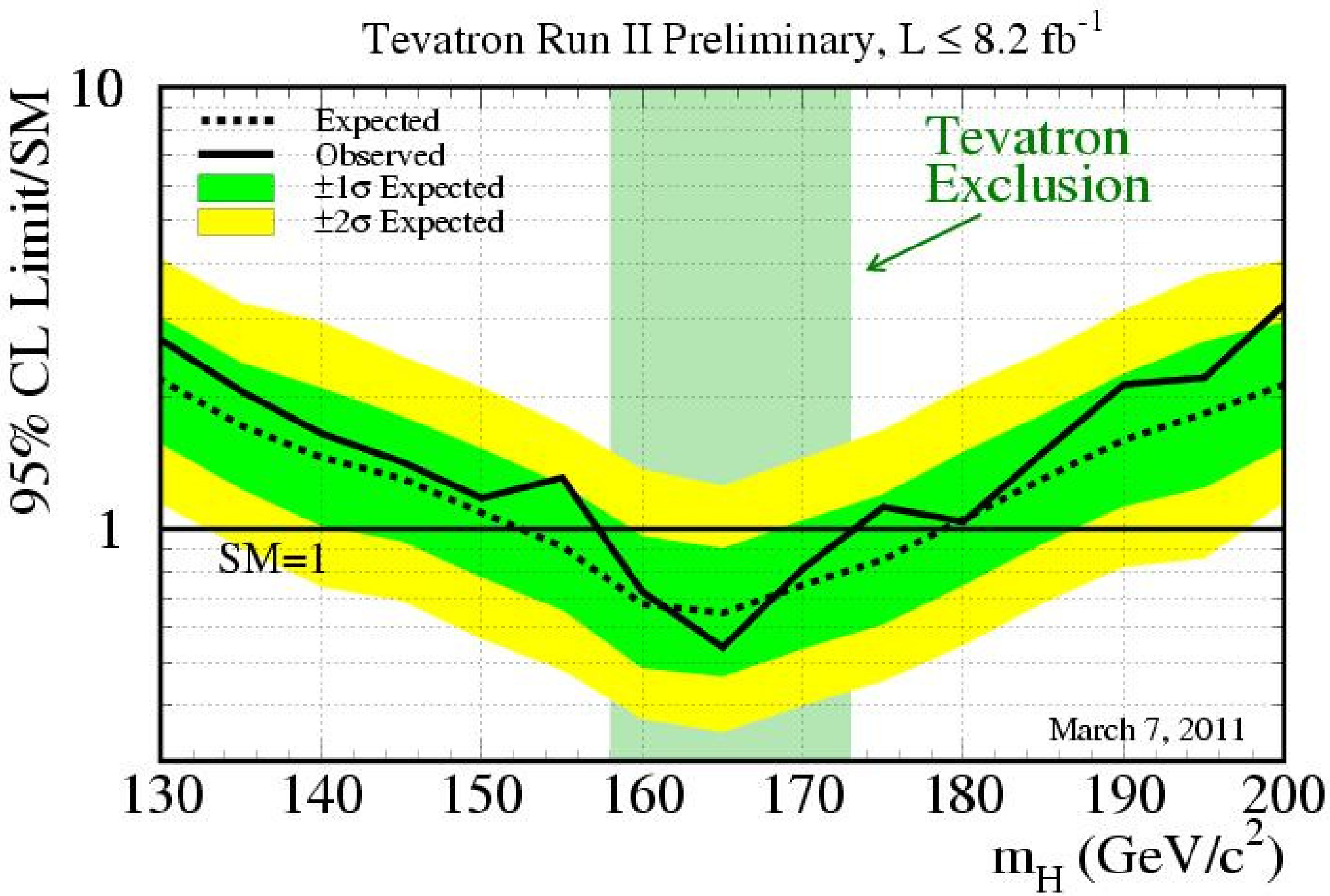
Our numeric result

CDF II Preliminary 5.7 fb^{-1}											
% Improvement due to ISOTRK over TIGHT											
Expected limits											
M(H) in GeV/c^2	100	105	110	115	120	125	130	135	140	145	150
TIGHT	3.23	3.60	4.03	4.46	5.29	6.69	8.41	11.2	16.1	25.1	38.5
TIGHT+ISOTRK	2.73	3.04	3.47	3.79	4.44	5.62	7.04	9.20	13.1	21.1	31.2
% Improvement	15.5	18.4	16.1	17.7	16.1	16.0	16.3	17.9	18.6	15.9	19.0
Observed limits											
TIGHT	3.00	4.43	5.73	6.40	7.43	8.80	10.6	13.1	17.7	25.6	40.5
TIGHT+ISOTRK	2.39	3.15	4.42	5.08	5.48	6.24	7.09	9.32	10.4	18.6	31.1

Tevatron Combination July 10



Tevatron High Mass March 11



Latest Allowed Values

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Allowed mass interval
In atomic mass units: 123 – 170 and 186 -199, in GeV/c^2: 115 – 158 and 173 - 185!

Conclusions

- Experimental search for the existence of the Higgs boson
- Tevatron accelerator
- CDF detector
- W boson + Higgs boson search
- Our contribution: reconstruct more electrons and muons; thus more W bosons; thus more WH signal; thus a better “microscope”

- Many analyses from CDF and Dzero at Tevatron combined

- A large interval in the Higgs boson mass has been excluded in July 10

- In July 2011 the improved Tevatron combination will be released. Stay tuned!

Thank you!

Questions? Comments?

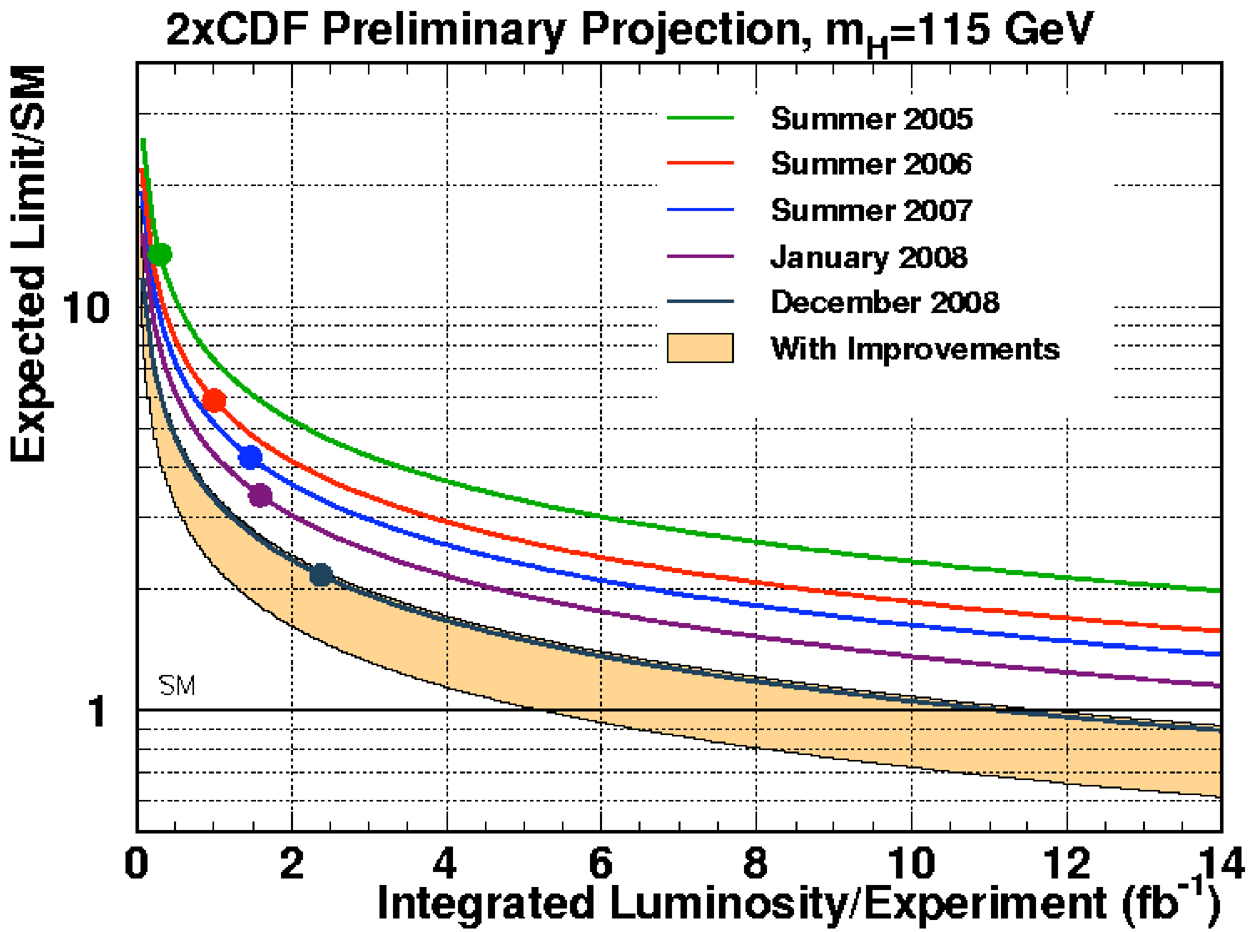
abuzatu@fnal.gov

"Quarks. Neutrinos. Mesons. All those damn particles you can't see. That's what drove me to drink. But now I can see them!"

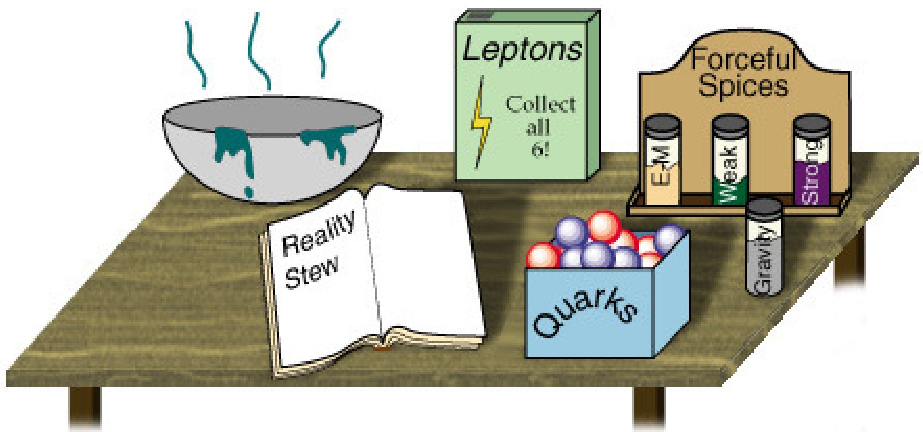
Backup slides

Sensitivity improvement

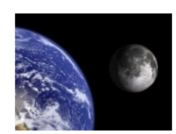
With more data, the Tevatron collaborations will improve the sensitivity for Higgs particle search even at low mass



The Recipe for the Universe



The Standard Model

- The Universe
  - Ingredients (Elementary Particles)
    - Quarks
    - Electrons
    - Other elementary particles
  - Recipe (Interactions)
    - Electromagnetic — Light, radio, radar
    - Strong — Nuclear stability
    - Weak — Radioactivity
    - Gravitational — 

Adrian Buzatu 31 May 11

How Do Particles Get Mass?

Celebrity crossing the room → Then s/he attracts people → S/he slows down, has inertia → As if s/he acquires mass

Normal Particle

A rumour comes into the room → It still attracts people → A group is formed and has inertia → As if group acquires mass

Higgs Particle