LETTER of INTENT to PAC

CDF/PHYS/EXOTIC/CDFR/5585

March 22, 2001

A Search for the Higgs Boson using Very Forward Tracking Detectors with CDF.

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Higgs Search using VFTD with CDF

- A new way to search for the Higgs
  … and other new physics (SUSY, LED?,…)
- Millions of 99.9% pure gluon jets, other QCD studies in unique way.
- Small additions to CDF way downstream (55 m)
- None of existing CDF is affected (moved …)

➢ The Tevatron will need to be (slightly) modified (in 1.5 or 2.5 years time).
No R&D, no change in working point, changes will be well understood.

CDF NOTE: 5509

Very Forward Track Detectors
VFTD

Mike Albrow	(Fermilab, contact person)
Muzaffer Atac	(Fermilab, Fast Timing Cerenkovs FTC)
Paul Booth	(Liverpool, Silicon strip detectors)
Isi Dunietz	(Fermilab, Software)
Dave Finley	(Fermilab, Tech.Div, Tevatron and vacuum vessels etc)
Beate Heinemann	(Liverpool, post-doc)
Rauno Lauhakangas	(Helsinki Inst., DAQ)
Dmitri Litvintsev	(Fermilab, Comp.Div, software and event displays)
Ted Liu	(Fermilab Wilson Fellow, Triggers and DAQ)
Craig Moore	(Fermilab, Beams Division, Tevatron modifications)
Risto Orava	(Univ.Helsinki and Helsinki Inst, vacuum vessels + mechanics)
Andrey Rostovtsev	(ITEP Moscow, Counters, FTC)
Rob Snihur	(Univ. College London, Tracking and Monte Carlos)
Stefan Tapprogge	(Helsinki Inst., Triggers and Detectors)
William Wester	(Fermilab, Detectors, triggers)
Kenneth Österberg	(Univ. Helsinki, Detectors)

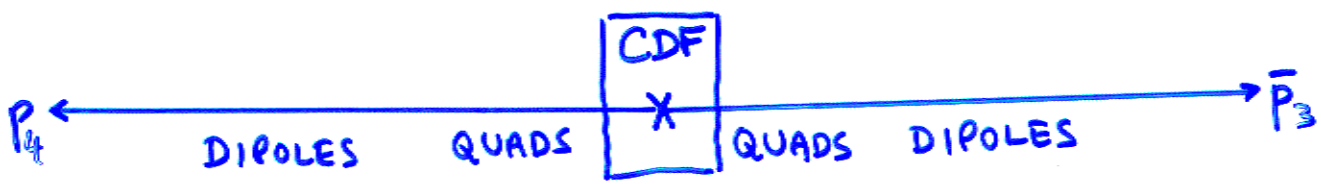
+ Ronan McNulty (L'pool), Tara Shears, Peter Bagley (unofficially) B.D.
+ P. Bussey (Glasgow) + S. Kartan (Istanbul)

Study of X in $\bar{p}\,p \rightarrow \bar{p}\,X\,p$

- The system or state X can have the quantum numbers of the vacuum {IG JPC = 0+ 0++}
- Known or hypothesized states include:
- f_o (980), χ_c (3415), χ_b(9860)
- Glueballs
- Hybrids {$c\bar{c}g$} and {$b\bar{b}g$}
- Higgs H
- Black Holes (if there are Large Extra Dimensions)

Near Future (Tevatron Run II)

- **D0 will have roman pots on both p and $\bar{p}$ arms (scintillating fibers, quadrupole spectrometers + 1 D)**
- **CDF will have pots on one side and good gap detection**
- **CDF proposal : VFTD, pots on both sides (dipole spectrometers) with silicon strip detectors and FTC for 30 ps timing.**
- **Missing Mass resolution ~ 250 MeV**

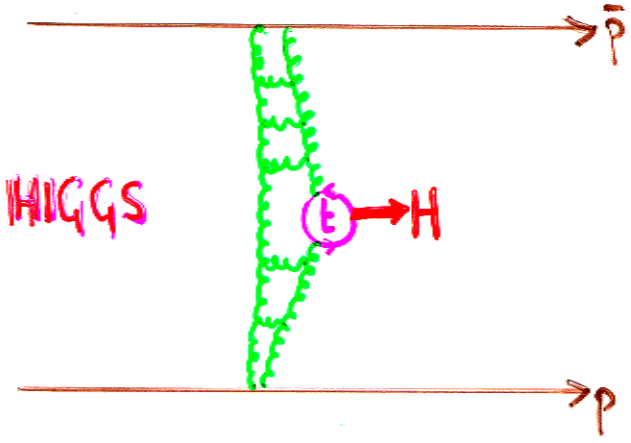


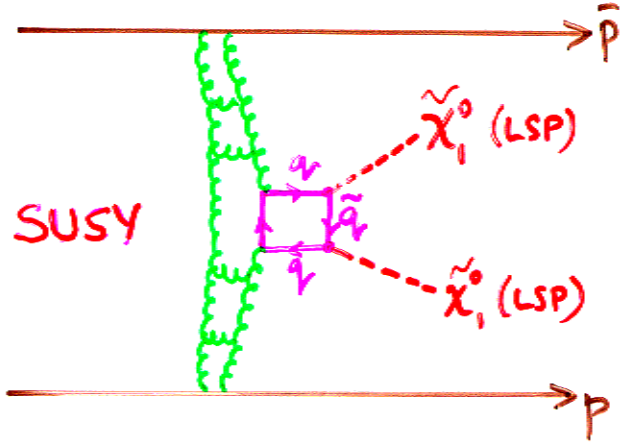
$$MM^2 = (p_1 + p_2 - p_3 - p_4)^2 \quad \text{(4-vectors)}$$

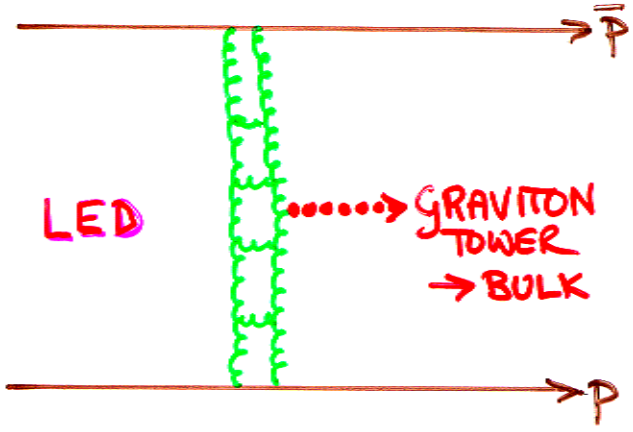
($\leftarrow -\Sigma p_i$ (central) sometimes)

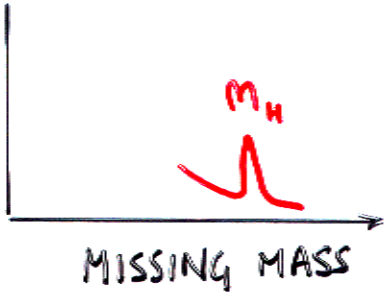
Higgs and Exotic Processes

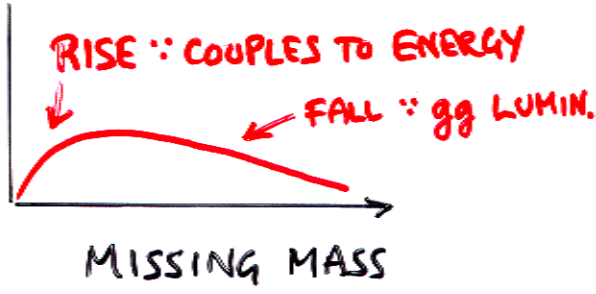
EXCLUSIVE EXOTICS







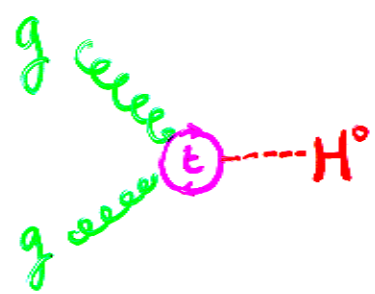




CONDITION : $b\bar{b}$, $\tau^+\tau^-$, W^+W^-
↳↳ LEPTONS
~ NO BACKGROUND

CONDITION :
CDF ~ EMPTY
(NO PILE-UP ALLOWED)

CDF ~ EMPTY
"



IS LARGEST σ

($>100 \times t\bar{t}H$ eg)

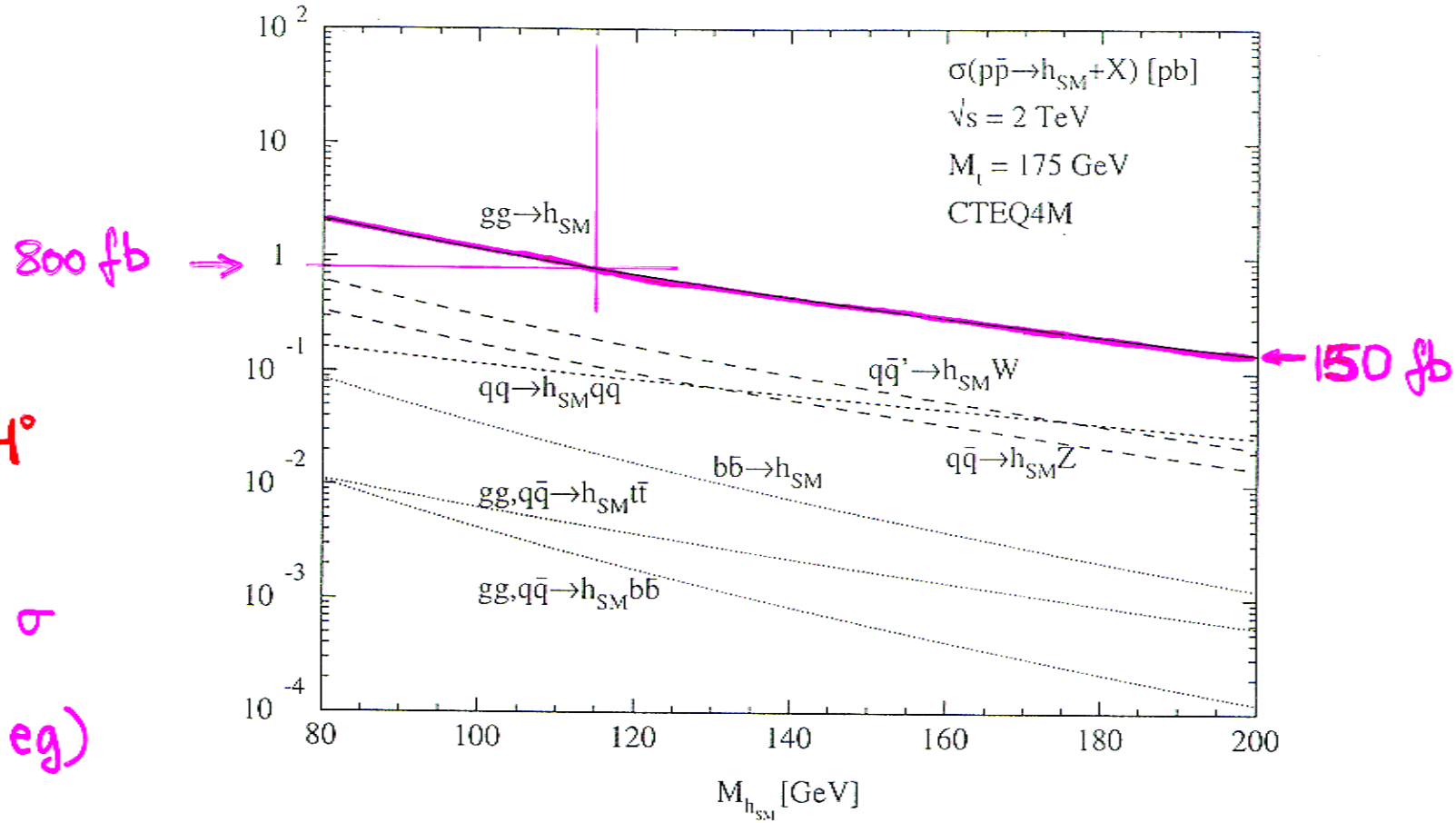


FIG. 2. Inclusive Higgs production cross sections vs M_H

IN 15 fb^{-1} ~ 12,000 H(115) PRODUCED BY gg

H BRANCHING FRACTIONS (S.M.)

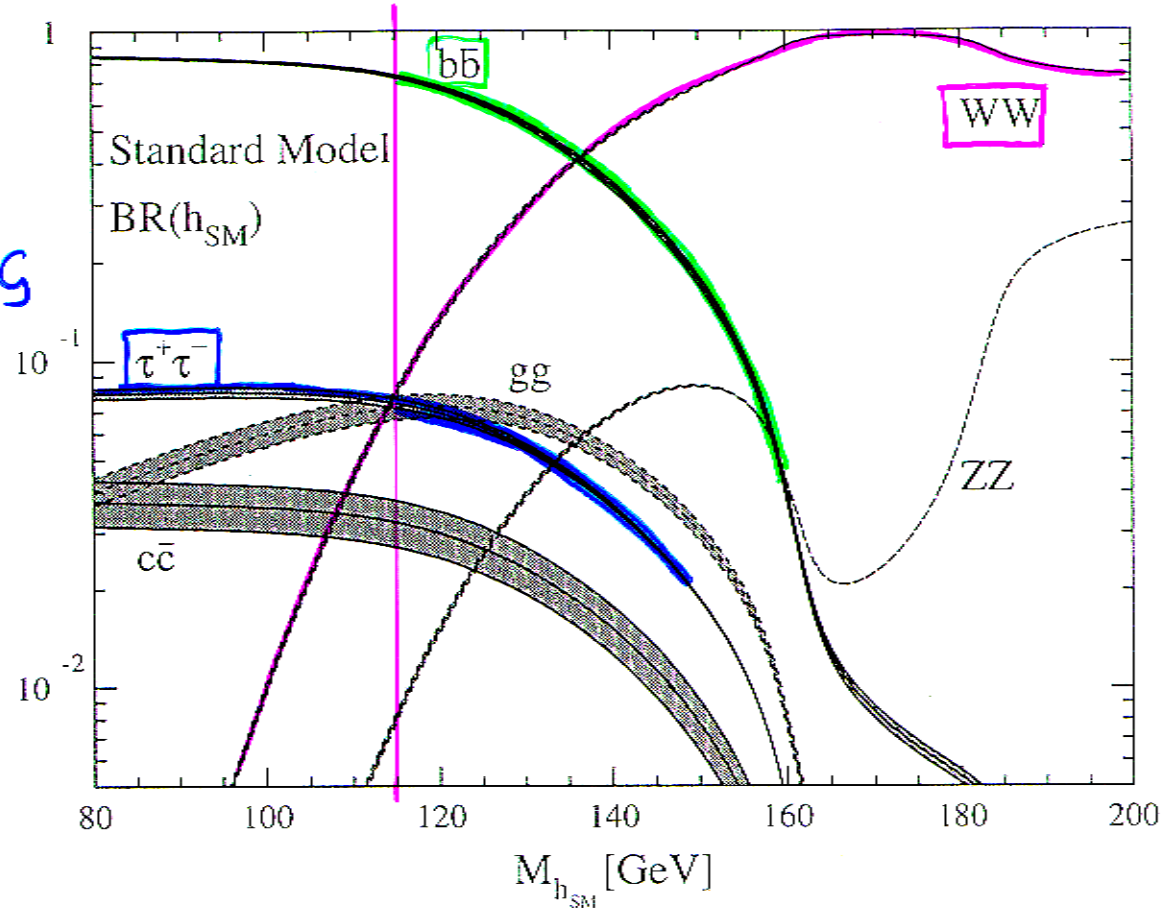


FIG. 3. SM Branching fractions as a function of M_H.

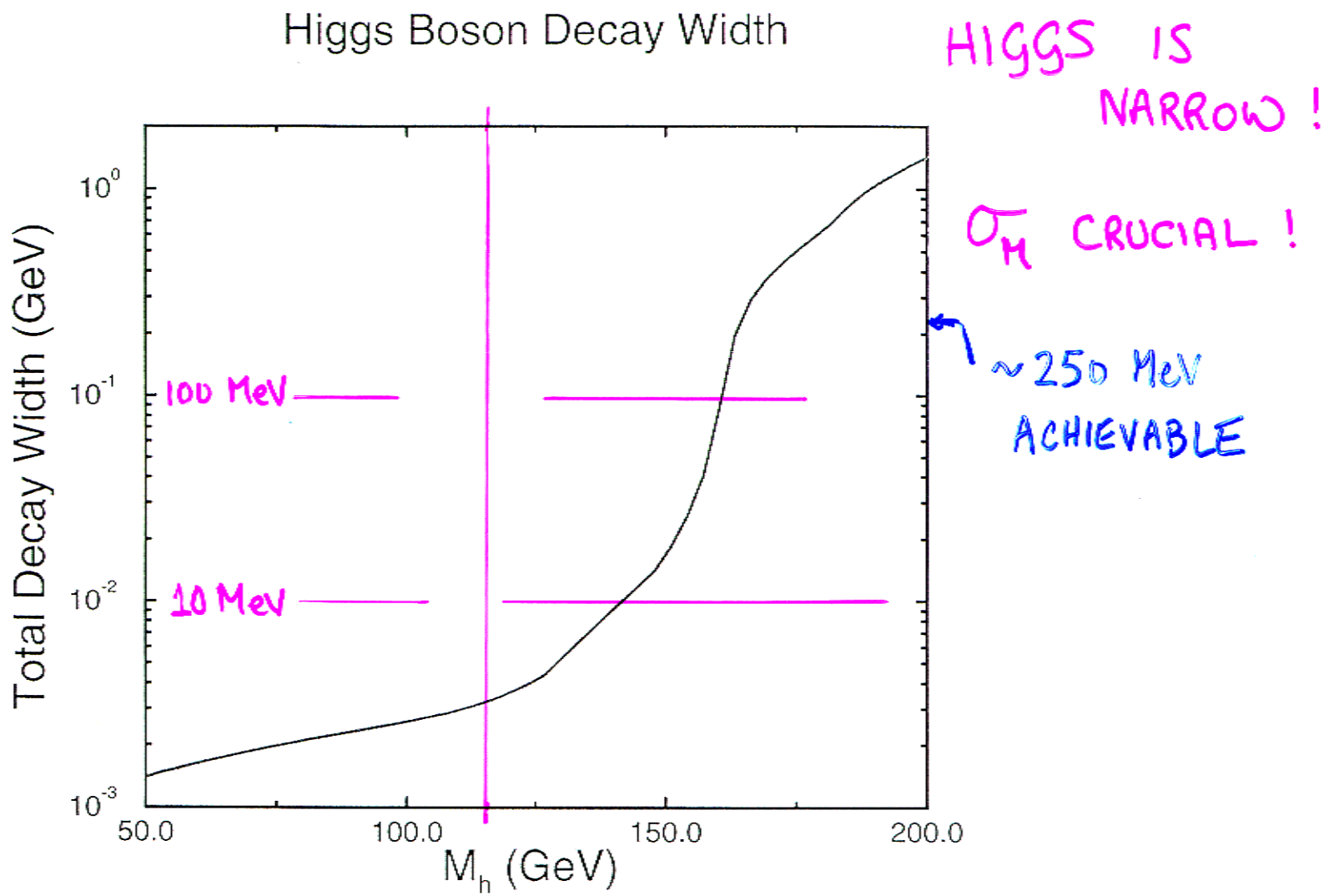


FIG. 4. SM Higgs width as a function of its mass.

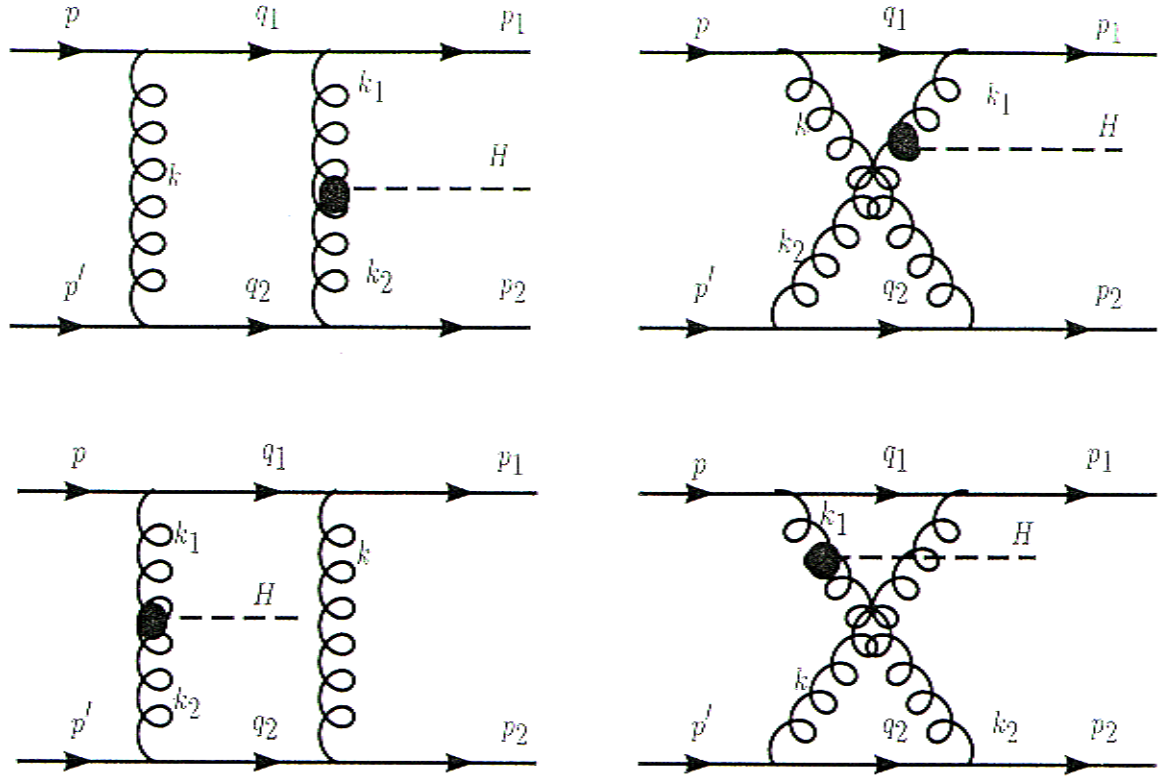


FIG. 1. Exclusive Higgs production diagrams (CH).

● ≡ TOP LOOP (t)

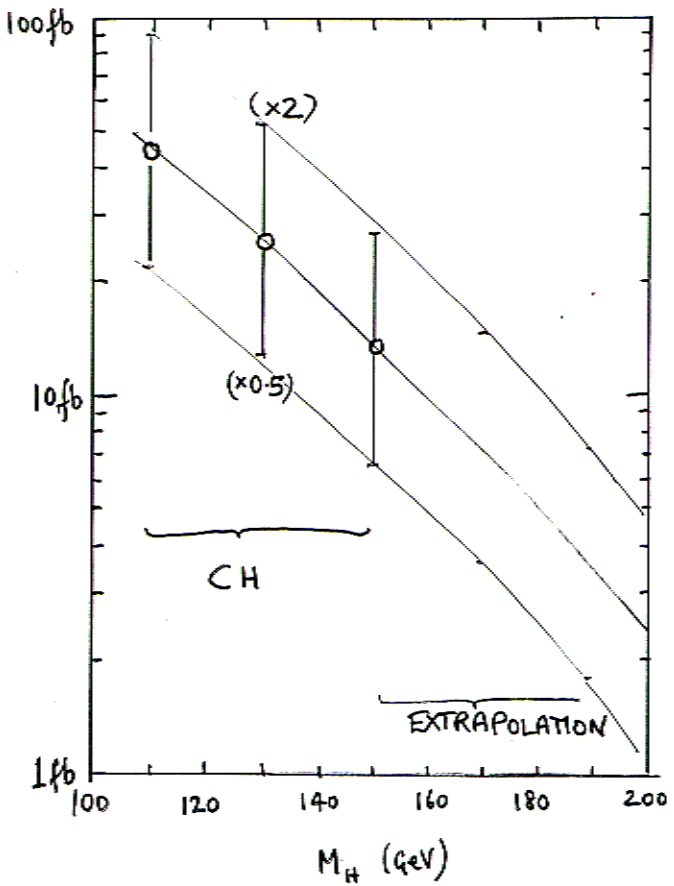
+ 4th GENERATION LOOP IF ∃ 4

+ $\tilde{q}$, $\tilde{g}$ LOOPS IF ∃ ~

$MM^2 = (p + p' - p_1 - p_2)^2$

4-VECTORS

$\sigma_{MM} \sim 250$ MeV $\ll \sigma_{JJ} \sim 10-15$ GeV



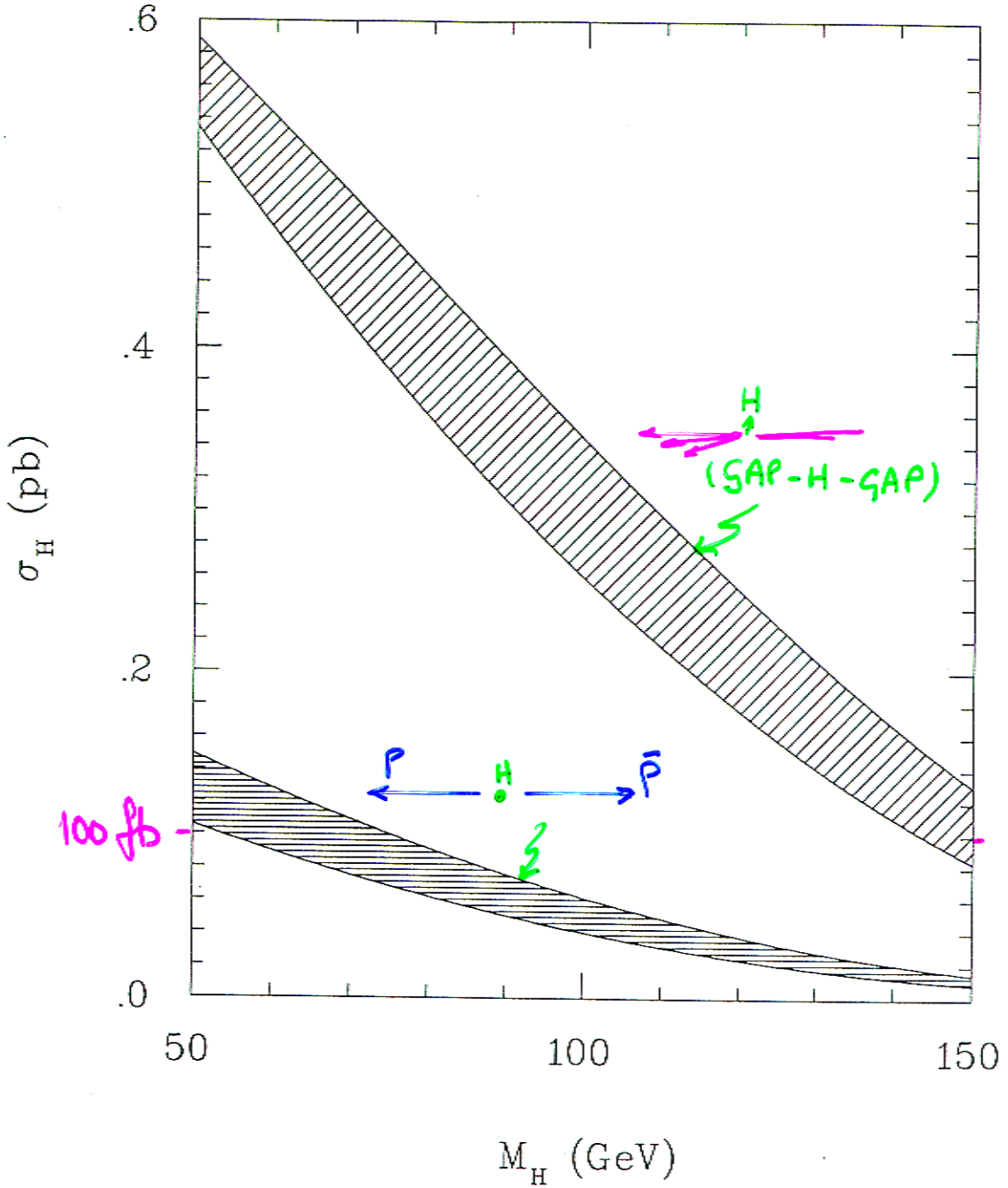


FIG. 5. CH exclusive cross-section $p\bar{p} \to pH\bar{p}$ (lower band). The upper band is when the p and/or $\bar{p}$ are allowed to diffractively dissociate.

TABLES

ASSUME 10^{-4} OF N.D.

M_H (GeV)	$\sigma(CH)$ (fb)	Mode	BR	σ.BR.BR (fb)	Events 15fb^{-1}	Background* /250 MeV
110	45	$b\bar{b}$	0.770	34.6	260	< 37.5
(115)					208	< 23.4
		$\tau^+\tau^-$	0.076	3.4	26 (21)	< 0.1
130	25	$b\bar{b}$	0.525	13.1	96	< 7.5
		$\tau^+\tau^-$	0.054	1.35	10.0	< 0.1
		WW^*	0.289	0.72	5.4	$\ll 1$
150	13.5	WW^*	0.685	0.93	7.0	$\ll 1$
170	6.0	W^+W^-	0.996	0.58	4.3	$\ll 1$
180	3.5	W^+W^-	0.935	0.34	2.5	$\ll 1$
170	6.0	$W(l\nu)W(jj)$	0.996	2.49	18.5	$\ll 1$
180	3.5	$W(l\nu)W(jj)$	0.935	1.47	11.1	$\ll 1$

EVEN 9.6 ON 7.5 IS 3.5σ

$l\nu\, l\bar{\nu}$ MODES ONLY

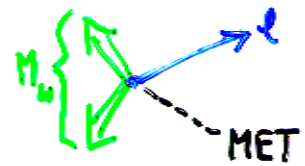
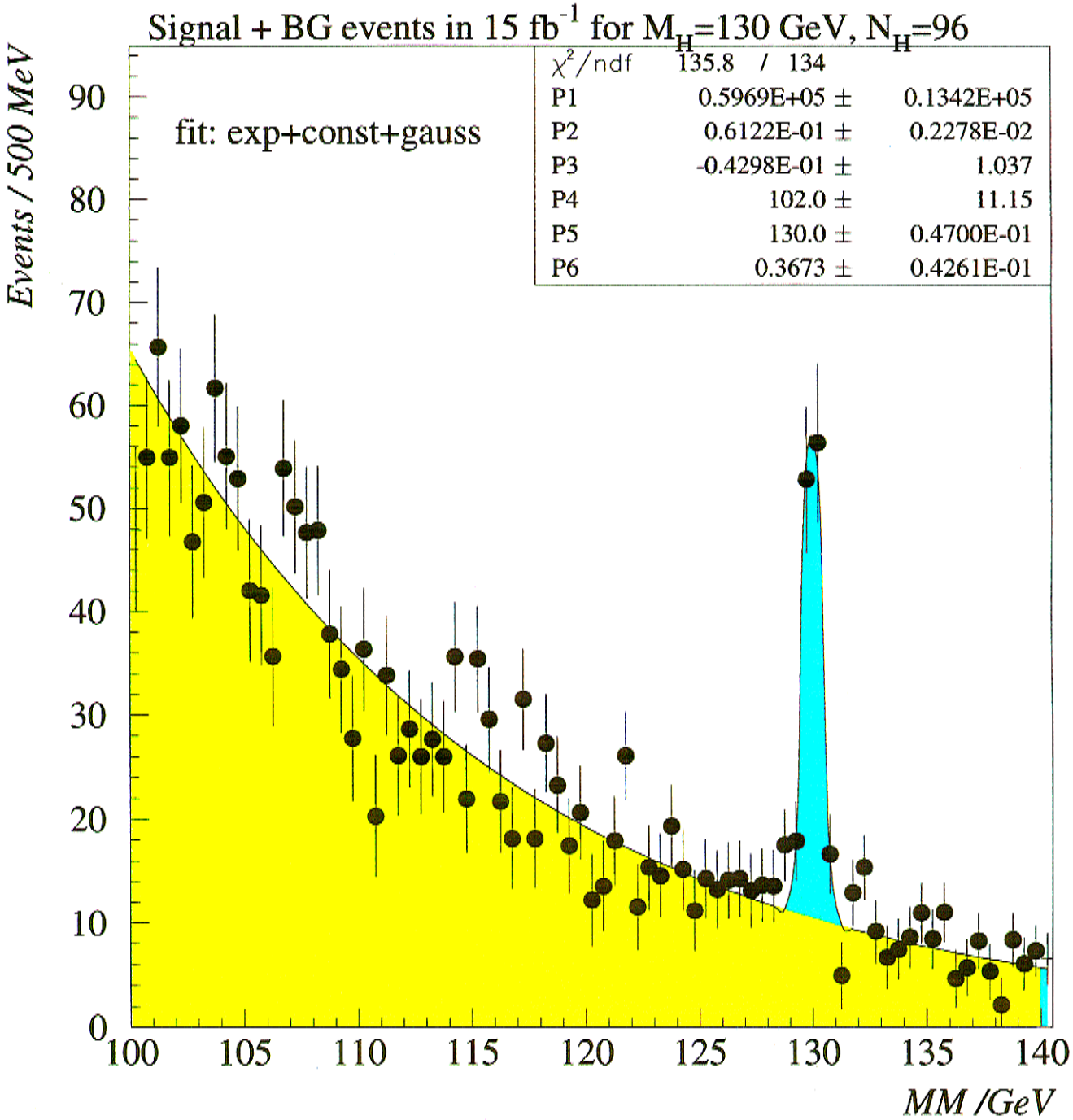
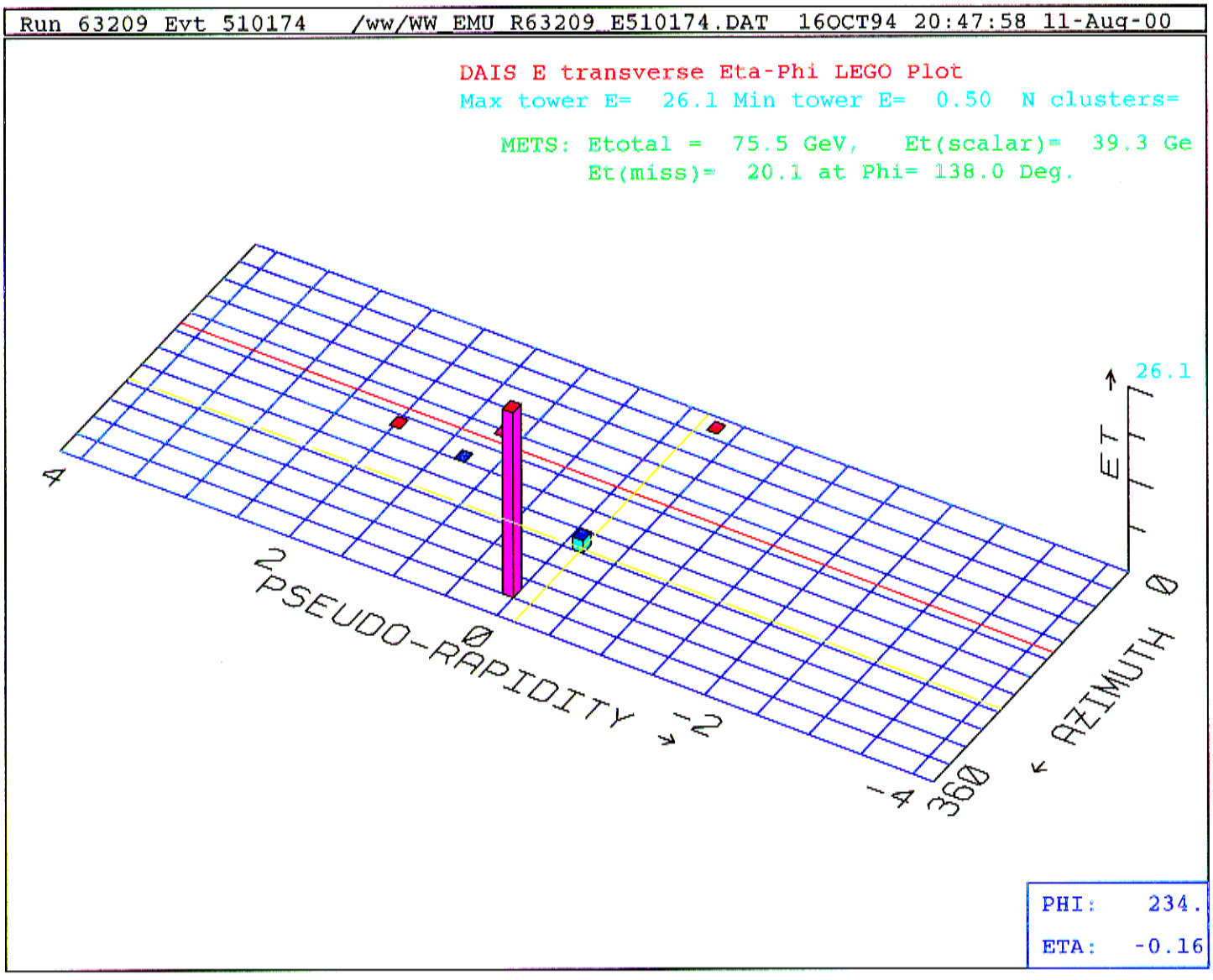


TABLE I. For various Higgs masses, the exclusive production cross section according to Cudell and Hernandez at 1.8 TeV. Column 5 shows the cross section $\times$ branching fractions either to two b-jets or to two charged leptons, or, for the last two rows, one W decaying leptonically and one hadronically. A factor 0.5 has been applied to events and background for acceptance/efficiency.

NOTE: IF HEAVY 4TH GENERATION (allowed)
$\sigma \nearrow \sim \times 8$

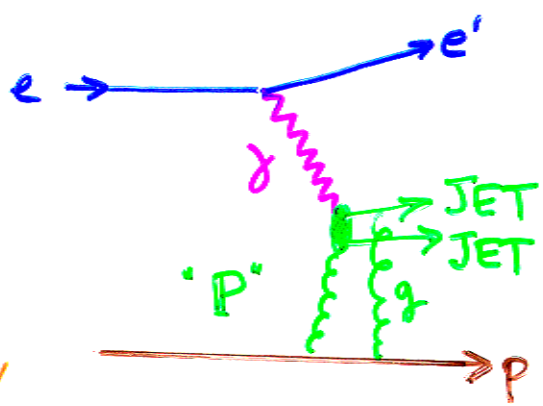

Signal + BG events in 15 fb^{-1} for M_H=130 GeV, N_H=96
fit: exp+const+gauss
χ^2/ndf 135.8 / 134
P1 0.5969E+05 ± 0.1342E+05
P2 0.6122E-01 ± 0.2278E-02
P3 -0.4298E-01 ± 1.037
P4 102.0 ± 11.15
P5 130.0 ± 0.4700E-01
P6 0.3673 ± 0.4261E-01
Events / 500 MeV
0
10
20
30
40
50
60
70
80
90
100
105
110
115
120
125
130
135
140
MM /GeV

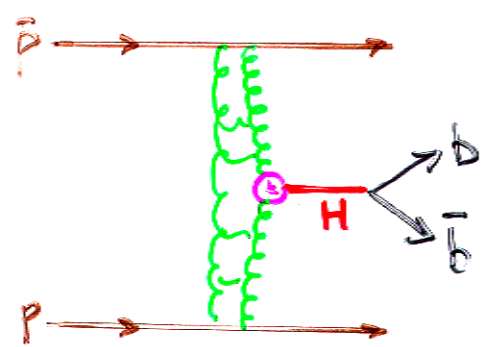
A REMARKABLE RUN I $W^+W^- \to \ell^+\ell^- \not{E}_T$ EVENT
$(e^+\mu^-)$

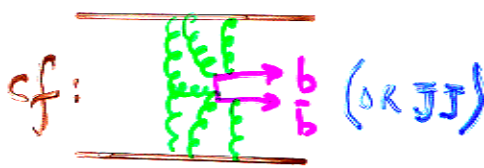


Other (than CH) predictions

- Bialas and Landshoff (Phys.Lett.B 256 (1991) p.540)
- → about 1% of all H will have p and $\bar{p}$ with $x_F \sim 0.95$
- Lu and Milana (1994) : hopeless (few events/year even at LHC)
- Khoze, Martin and Ryskin (2000) : 0.06 fb for 120 GeV Higgs but this depends on re-scattering probability
- Kharzeev and Levin : 19-140 fb (!) for M(H) = 100 GeV
- SO HUGE UNCERTAINTY! Experiments are needed!





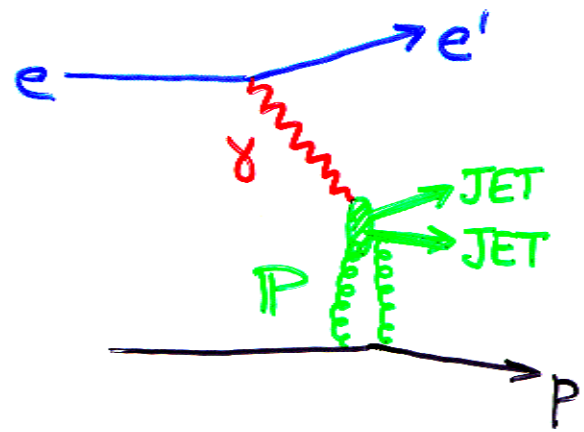


(LATE) OR WW→ℓℓνν̄

COLOR-BLIND PART

IF $\dfrac{p\, b\bar{b}\, \bar{p}}{b\bar{b}\ \text{INCL.}} \sim 10^{-4}$ HOW COULD $\dfrac{p\, H\, \bar{p}}{H_{\text{INCL}}}$ BE $\sim 10^{-2}$?

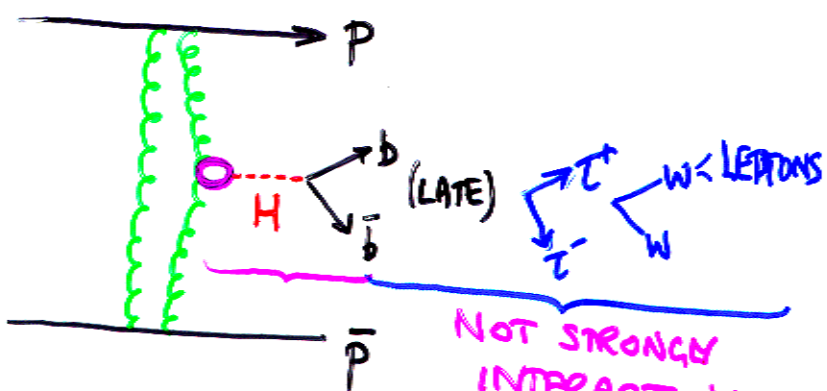
RECALL:



$\sim 10^{-1}$ ALL DIJET

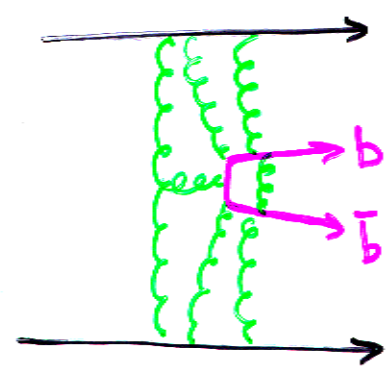
cf $\sim 10^{-2}$ FOR $\left(\dfrac{\text{DIJET + GAP}}{\text{ALL DIJET}}\right)$ AT TEVATRON $p\bar{p}$.

➡ e, e', γ NOT STRONGLY INTERACTING



$(\sim 10^{-1})^2$?

cf



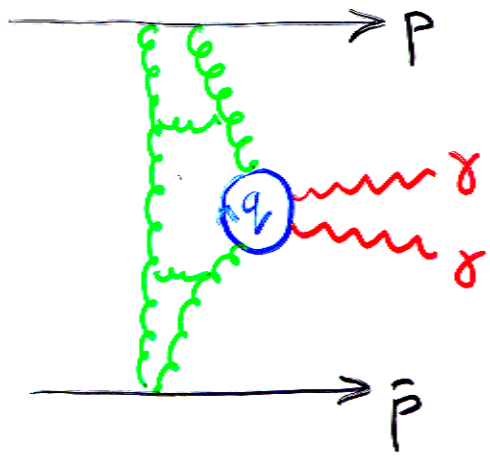
(OR JJ)

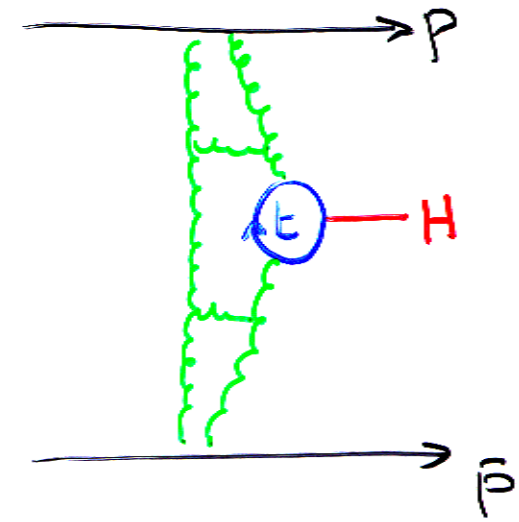
ALL S.I.

$(\sim 10^{-2})^2$

$p\bar{p} \to p\,\gamma\gamma\,\bar{p}$

(Thanks HENRY FRISCH)





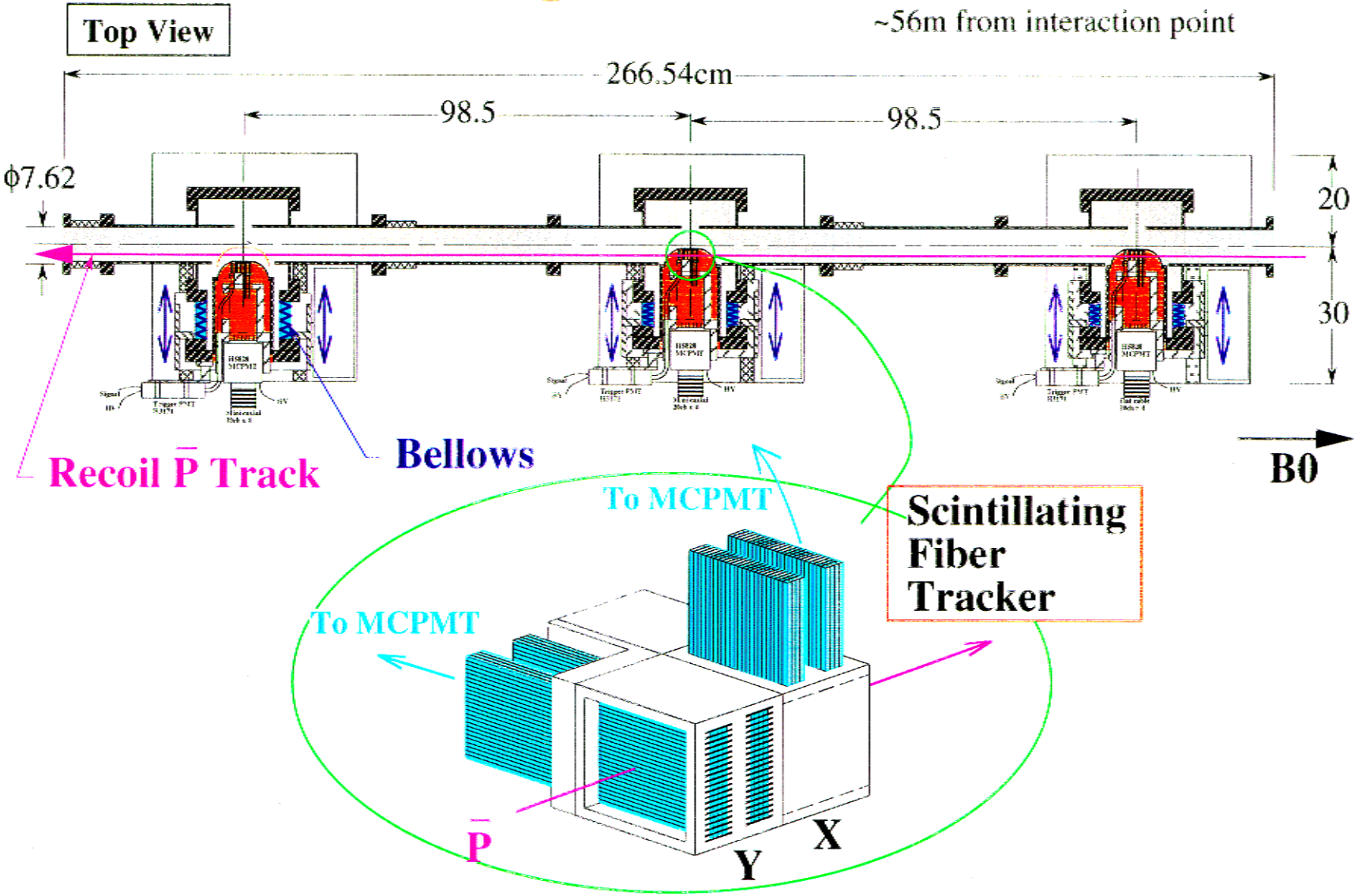
VERY SIMILAR

NON-PERTURBATIVE PART CANCELS IN RATIO

Gamma Gamma

- All quarks in loop instead of top quark in loop
- H and $\gamma\gamma$ are not strongly interacting (to 1st order)
- H decay products either too late (bb) to interact strongly at production, or $\tau^+\tau^-$ or in H → WW → $\ell^+\ell^-\nu\bar{\nu}$
- So $\frac{d\sigma}{dM_{\gamma\gamma}} / \sigma_H(M)$ should be independent of non-perturbative QCD.
- We can already study isolated $\gamma\gamma$ events (Beate Heinemann, Run 1 and Run 2a)
- <u>This should enable us to exclude H in mass range if we do not see it at the expected level.</u>

Roman Pot Arrangement



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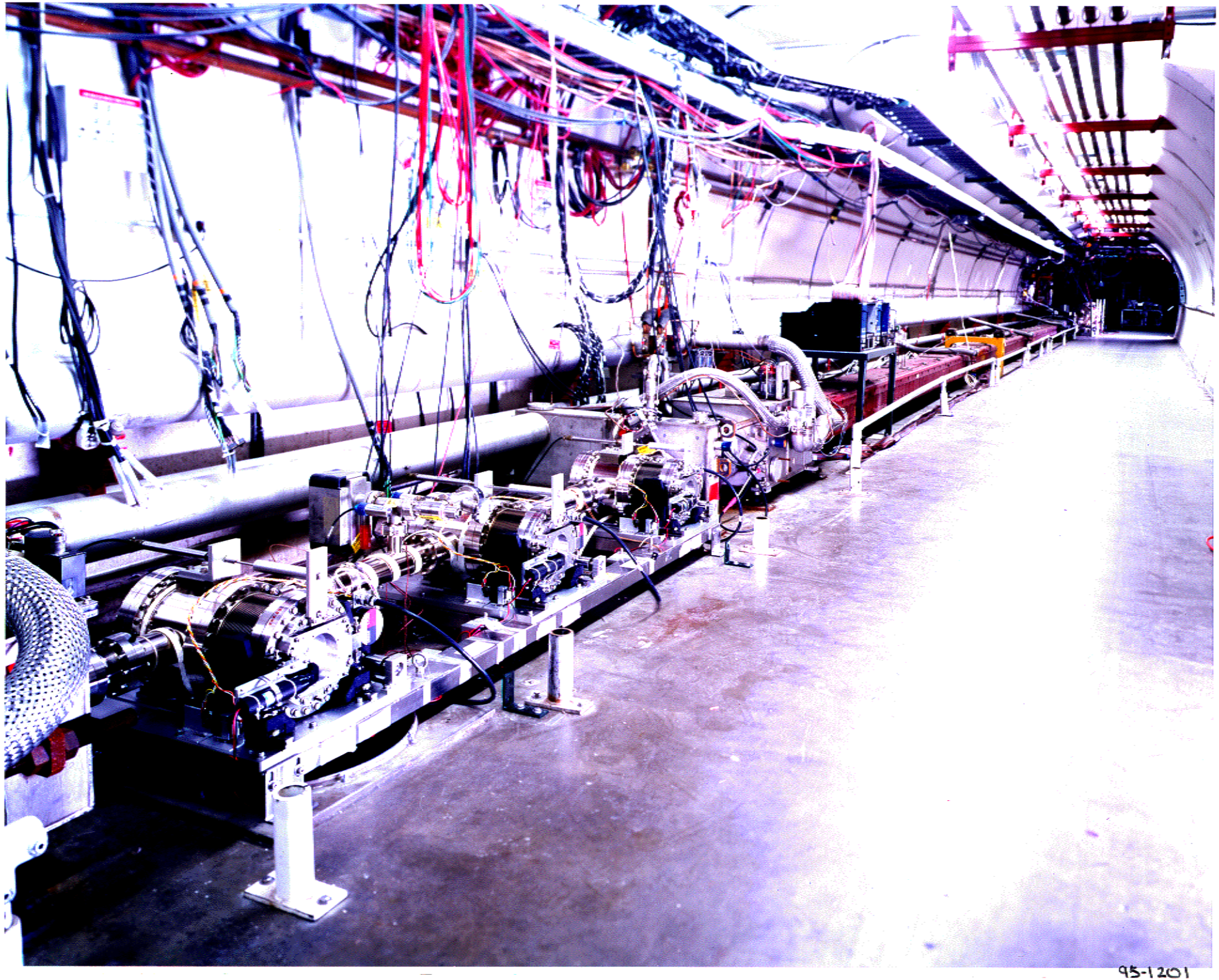
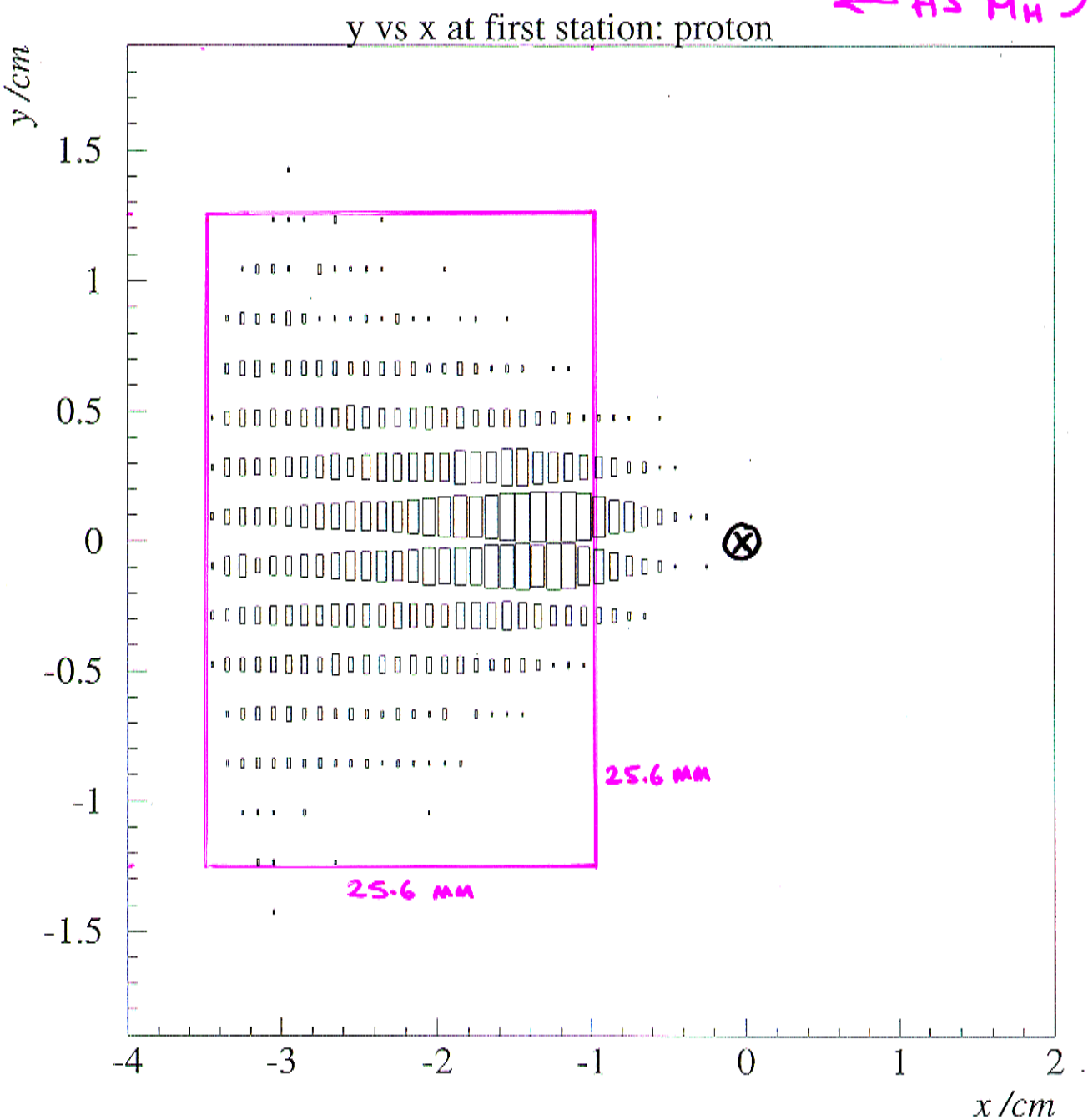


95-1201

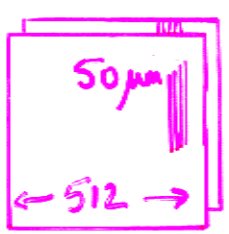
$M_H = 115$ GeV

← AS M_H ↗



Silicon Strip Detectors

- XX …XX ← ≳1m → XXY'Y" Strips
- Square detectors with 512 x 50 μm strips →25.6 mm
- 8 x 512 channels = 4096 channels / arm, x 2 + 2 halves = 12,228
- Expect about 5 μm resolution
- High precision (< 5 μm) positioning scheme (wrt external ref.)
- Positioning calibrations (in x) from low mass exclusives
- E.g. $\pi^+\pi^-\pi^+\pi^-$ Missing Mass = Effective Mass, Check with elastics.



ACTUAL SIZE

Modifications to Tevatron

- Remove Q1 Quadrupoles on E (p) side (gain 2.809 m)
- Slide 3 Dipoles closer to B0.
- Replace spool at B18 with shorter spool, gain 0.737 m
- Slide 6 dipoles away from B0 to compensate.
- New cryo-bypass around new warm section on E side.

- 4 roman pots on each side.
- Tevatron working point the same, effect on machine operation being studied.

Running Conditions & Triggers

- NO SPECIAL RUNNING CONDITIONS --- want maximum luminosity
- Every CDF event should record roman pot information.
- Can use multiple interactions in a crossing because of FTC timing
- Triggers will be X . E . W with MM calculation at L2 and central requirement dependent on MM
- E.g. ELASTIC : MM ~ 0 with colinearity constraint. Record just pot info.
- Grav + BH : Not elastic, but CDF Empty or Central M << MM
- b-bbar sector (hybrids and χ_b^0) MM ~ 10 GeV and 2 – 4 TOF counters
- Higgs : b-bbar dijet with 100 < M < 150 GeV
- $\tau^+\tau^-$ candidate
- 2 leptons + MET
- lepton + MET + dijet

- Do not want to prescale (except perhaps elastic)
- Will ask for ~ 5 Hz (incremental)

VFTD/CDF

- Letter of Intent to APRIL PAC {920}
- http://www-ppd.fnal.gov/albrow.myweb/pacprops.pdf

- Proposal planned for November PAC
- Hope for Spring 2002 Approval
- Installation before end Run 2A if possible
- Run → > ~2007

Far Future

- Around 2007 LHC at CERN will be giving physics with 7 TeV + 7 TeV pp.
- DPE masses up to ~ 700 GeV ($x_F > 0.95$)
- Hopefully later, Very Large Hadron Collider VLHC
- ~ 20 TeV + 20 TeV so M(DPE) → 2 TeV
- Phase II : 100 TeV + 100 TeV & M(DPE) → 10 TeV
- Maybe then we'll be able to study BLACK HOLES!