A Perspective from the trenches at Dzero (1992-1995)

Meenakshi Narain

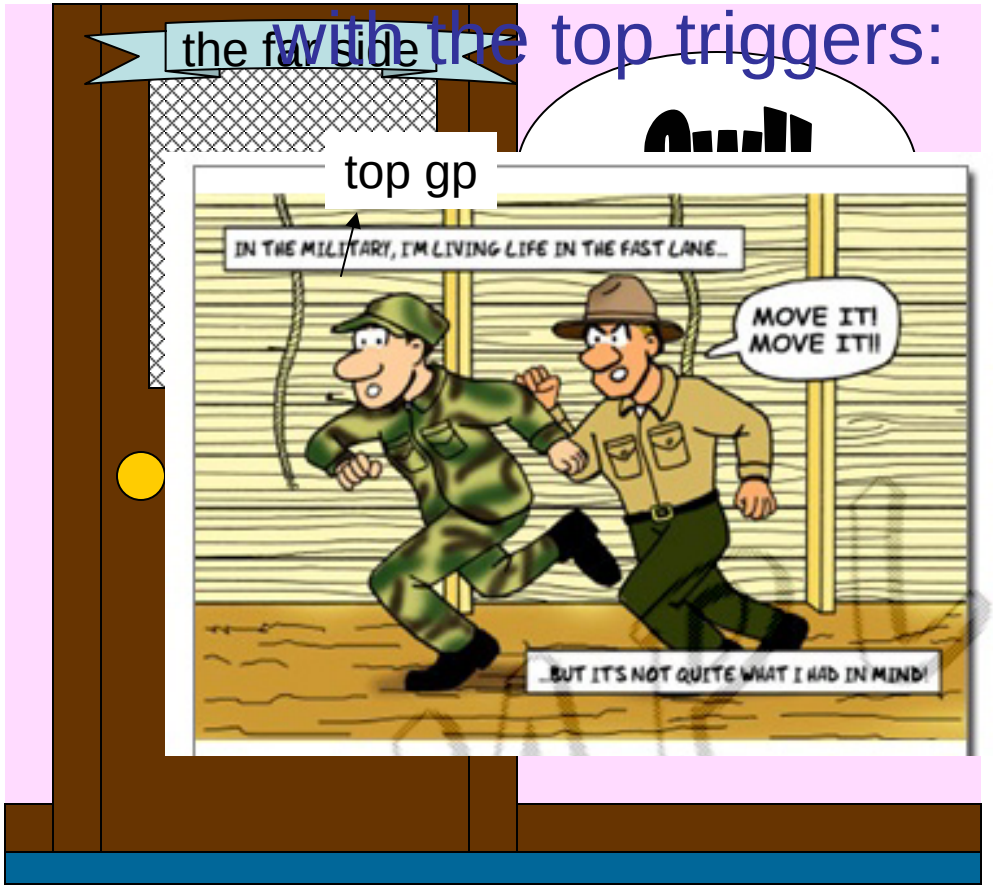
Then RA at FNAL

Now at Boston University

The “Recruitment”

- The year is 1992

- Trigger board deliberations:
  - The reality of dealing with the top triggers:



The early searches

- At Dzero, analyses were “student centric”
  - Decided to join the dilepton gang
  - Concentrated on Calorimeter performance and electrons
- Null Searches, led to limits, limits and more limits and by Jan 1994, we submitted a PRL with a fairly high lower limit on the top quark mass (> 131 GeV @ 95% C.L. U.L.)
- However in the meantime, behind the scenes, a very interesting and educational dialogue was/had taken place.
- So let’s rewind and go back in time…

The “gold plated” eμ event

(See posters – event 417)

- The year is 1993, the month is Jan…
  - An event with exceptional qualities has been found
  - The “excitement” generated by this event was so high, that until Oct – Nov 1993, it subsumed almost every meeting and every person “associated” with the top group.

- Byproducts of this exceptional event are:
  - Both the muon and the central tracking reconstruction are revisited and made more robust.
  - Development of many techniques, including multivariate analyses to compute the probability that this event is inconsistent with background and is due to top quark production.
  - A couple of competing Dilepton mass analyses seem to develop almost overnight, and all indicate that the event is consistent with a top quark of mass between 145-200 GeV !

The Great Debate
Top Discovery or Not ?

- This debate, mostly in the manner it was carried out, is the one which made an everlasting impact on me and my belief that open deliberations on hot topics are essential within large collaborations.

- The environment of inclusiveness and openness is what distinguishes a scientific venture from a top down industrial culture.

- It was amazing that graduate students, postdocs and mighty professors from prestigious universities all had equal weight in determining if this “single impressive event” in 1993 constituted the “discovery of the top quark” or not.

Some quotes from the debate

- **A varied range of opinions:**

Assuming … there are no further surprises, because the event has been around for over a week now, I think we should publish this. By publish I mean not in the New York Times, but a seminar and a paper.

"I, for one, was immediately convinced that it was top. I did not need studies of backgrounds, or of detector response, or of other factual matters. … the event looked more convincing than, for example, Gerson Goldhaber's discovery of the Ω- in K+d interactions, and far more likely than the first Ω- found by Nick Samios et al."

No amount of hard work by the top group will change the fact that 417 is just one event, and one event will not find the top or limit the range of M_top.

[event 417] …is an unusual event and we might as well say so rather than play coy.

  - more impressively, they were divided by age:
    - **Older crowd:** aggressive and restless to publish
    - **Younger crowd:** patient and cautious
  - Cautiousness (maybe too conservative??) prevailed and we published a limit paper, included this event (Jan 1994)

An interesting and unexpected outcome

The Increasing Significance

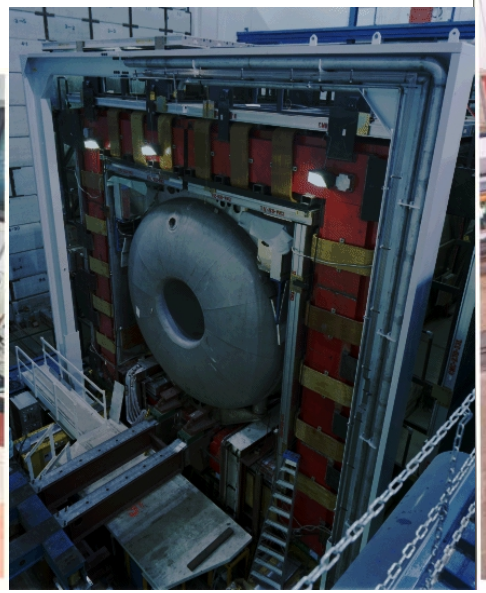
- By mid 1994, given the 131 GeV lower limit, we had optimized our search for a higher mass top quark.

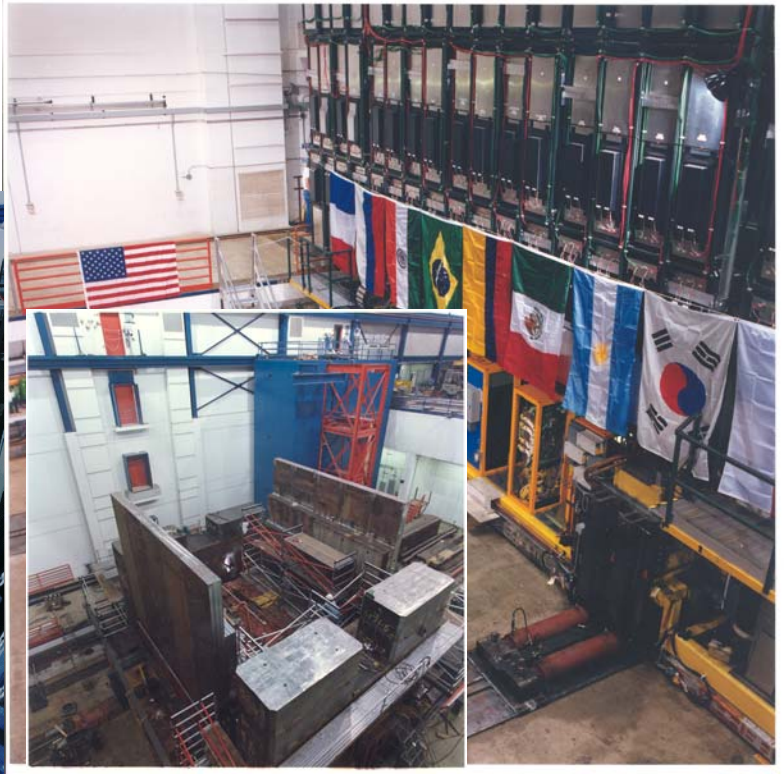
- With 13.5pb^{-1}, we had 1.9σ significance.
  - Published this by Nov 1994.

- This “higher mass” optimization was a significant step in the discovery of the top quark.

The triggers, detectors, and software

- While optimizing the higher mass analysis
  - we pushed and squeezed in all directions
- A and H_T: exploited the strength of the calorimeter (hermiticity)
- The muon tagging of bjets, using the low pT muons exploited the strength of the muon system
  - The calorimeter in this case acted as a background shield!! No punchthroughs
- Use of TRD for electron confirmation
- Triggers were continuously designed to keep the efficiency close to 100%





The timeline to discovery…

- Nov – Dec 1994: (results for Aspen 1995 conference)
  - analysis from doubling of data set ($22pb^{-1}$), with the previously optimized cuts, significance increased to 2.5σ ! (Increased by $\sqrt{N}$)

- And… this realization just moved the race for the top quark to its highest gear!!!!

From: SBHEP::GRANNIS "St Brk 516-632-8088" 5-JAN-1995
14:44:56.63 Subj: A new top push ?

<..>
We suspect that we need to move aggressively to push our combined counting, mass fitting and two-dimensional distribution fitting analyses to a conclusion acceptable to us. I think that we should announce to ourselves a new Top priority campaign, which we hope could converge in two months or so. In the case that these analyses lead to our believing in a statistically significant evidence for top (or other non-SM signal), we would proceed to publish.
<..>

  - Emergence of “blind” analysis (stop adding/looking at data)
  - Optimize for much higher masses based on MC/background models

The Sighting!!!!

From: <KLIMA>
Sent: Thursday, January 12, 1995 12:00 AM
Subject: Wow!

Fermilab, 12-JAN-1995

<..edited..>

After we looked at efficiency loss for top and agreed on a reasonable set of cuts tuned for very heavy tops, I asked the experts to check the effect on the data. The result is quite surprising.

<..edited..>

Boaz

Jan. 12, 1995

Optimizing Top Analysis for Heavy Top - 1st Attempt

In the spirit of making a few well-justified changes wrt the current (=Aspen) top search analysis, we have made the first attempt. As indicated earlier, the idea was to reduce the background as much as we could while maintaining good efficiency for signal. The first attempt contained the following modifications:

<…edited…>

The significance of these new results in terms of probability for not having top in our data ("consistency with no top" hypothesis) is 0.001% (assuming gaussian likelihood - 4.2 sigma)!

<…edited…>

The Musings….

[redacted], 13-JAN-1995

[redacted]

<..edited..>

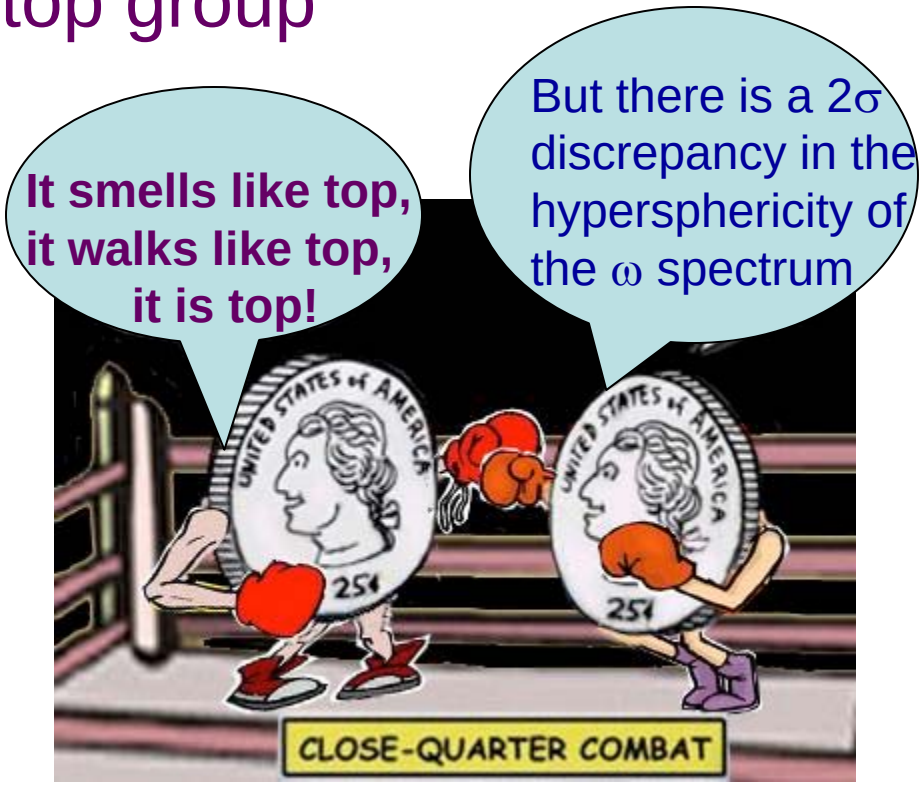
Presumably we will drop these little bombs on 17 Feb during the PAC meeting.
Paul and Mont should be prepared to notify Mel & Bill on about the 10th.

[redacted]

The Friendly Competition

within the top group

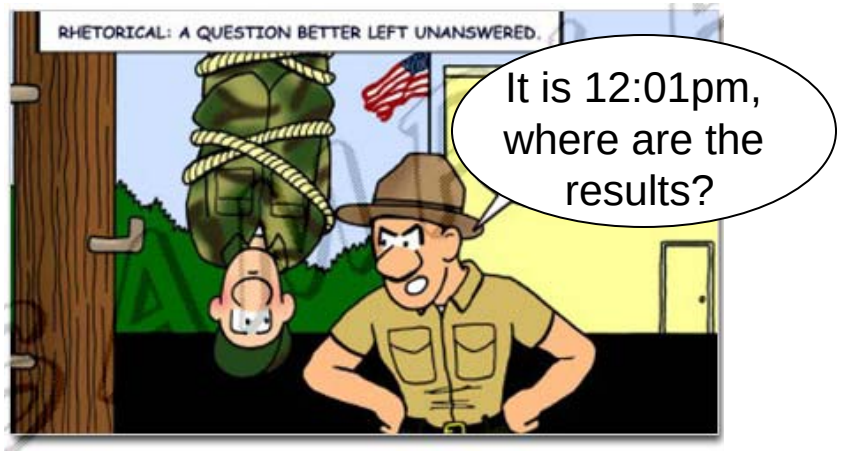
- Cut based cross section analyses in different channels
- mu-tagged analyses
- 2D analyses as cross checks:
  - $M_{top(hadronic)}$ vs.$M_{W(hadronic),}$ and
  - A vs. H_T
- Mass determination of the candidate events
- Multivariate analyses
  - Alternate methods to cut based



- The most debated issues were:
  - Our confidence in modeling the background
    - (W+jets + mis-id backgrounds)
  - The understanding of candidate event characteristics.

The constant requests for updates

- While Nick and Boaz played
  the good cop – bad cop role.
  - It felt like a boot camp!



- Ferbel (2/6/2005):
  - I wonder whether our enthusiasm is blinding our pursuit of truth (top)?"

- Rich Partridge (2/9/2005):

  The cutoff date for defining our data set is tomorrow. Lepton + Jet analyzers are urged to update their sample over the weekend. The mass fitting group urgently needs your list of candidate events. Here is a tentative schedule for the next week:
  - Weekend: Updating of data samples
  - Monday: Final list of events passing each sets of cuts (PRL, Loose, Tight1, Tight2)
  - Tuesday: Preliminary numbers for efficiencies and backgrounds for each set of cuts
  - Wednesday: Check numbers for errors, consistency
  - Thursday: Presentation of results at top meeting"

Getting to all the luminosity

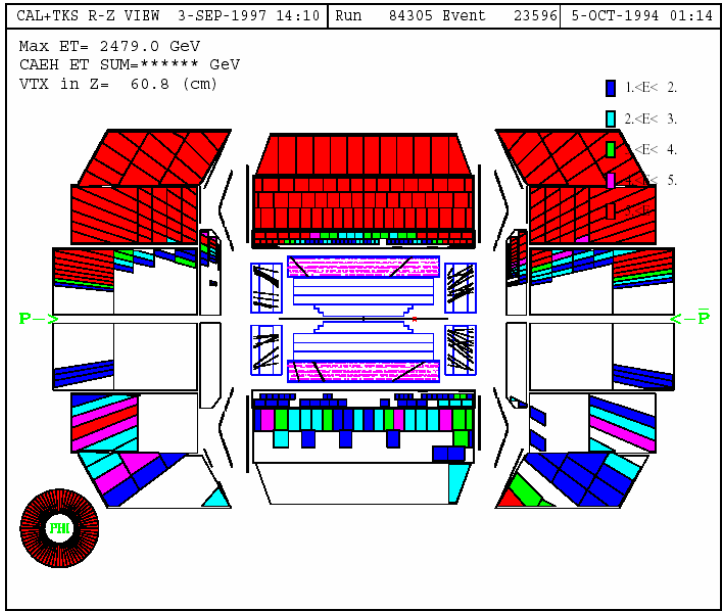
- Every event was important for the discovery analysis.
- We took over the event reconstruction farm (1/28/1995)
  - much to the annoyance (mild?) of other groups, as they thought we are going crazy over results to be shown at winter conferences….
  - Probably they did not realize we were ε away from discovery
- And data taken in Jan were available in Feb for analysis
  - A heroic effort by the reconstruction and farm team.
- We devised ways to recover Main Ring events!! (see poster)

From: FNALV::MONT 10-FEB-1995 16:59:20.9
Subj: dielectron luminosity

Ia 13.5 * 1.08(microblank) = 14.58
Ib 33 *1.14(MRBS)* 1.07(microblank)= 40.03
Total 54.9

Subj: 38 + 13 > 50 !!! We passed this one...

From: D0UCR7::CHOPRA 12-FEB-1995 01:59
Subj: Luminosity for all the files processed



The effort to be unbiased

- High Standards were being adhered to while optimization to get the best S/B or mass measurements.

From: BNLD0::SERBAN "Serban Protopopescu (516) 282-3721" 30-JAN-1995 09:20:14.02
Subj: RE: Significance of Tagging.

bnld0, 30-JAN-1995

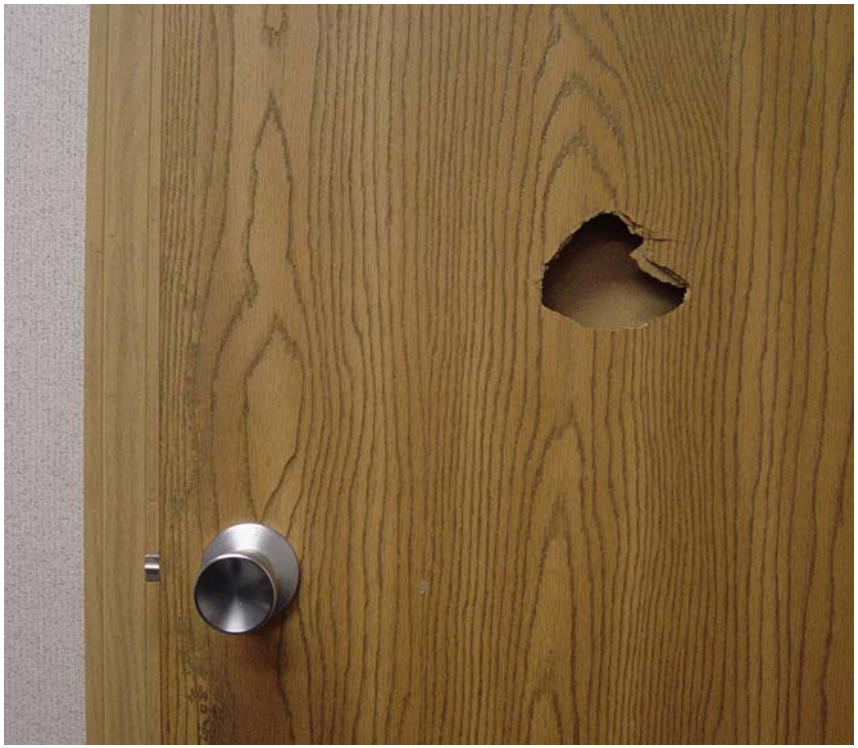
<..deleted text...>
I don't know the answer to that question because in my NTtuple I didn't keep track of the jets assignments. It is easy enough to do so I'll do it soon. However, given the somewhat arbitrary nature of my assignments the answer may not be that favorable. Before doing this so I cannot be accused of cheating I want to change some of my procedures for selecting combinations. The path I intend to take is the following:
<..more deleted text ..>
My philosophy in the above is to search for a method that gives me maximum discrimination between signal and background, not for a method that gives me the best way to measure either the W->2 jets mass or the top mass (it may end up being the case that the same method does both).

Serban

The Fallout from “blind” optimization

- The lost di-electron event due to standardization of the object-IDs across analyses…

  $\Rightarrow$ a hole in the office door…



The Convergence

- The contact with John Peoples:

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From: SBHEP::GRANNIS      "St Brk 516-632-8088" 27-JAN-1995 10:04:31.61
To:   FNALV::PEOP
CC:   MONT,GRANNIS
Subj: Discovery discussion

Dear John,

<..deleted text..>
We would like to be sure that the old 'agreement' concerning discovery from CDF
or D0 are still in place -- namely that if either collaboration converges upon a
discovery paper, we have a discussion with you and both co-spokesmen followed by
a week for the other collaboration to present its evidence.
<..deleted text..>
            regards,

            Mont and Paul
```

- The marathon:

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From: D0SFT::KLIMA        "Boaz Klima (708)840-2323"  8-FEB-1995 11:52:00.21
Subj: Converging next week!
                                                      Fermilab,  8-FEB-1995

<..deleted text..>
         I'd like to propose  that we'll have a two  days marathon next week in
which  we'll discuss  and agree  on our  FINAL results  for the  Top Discovery
Paper.
<..deleted text..>
                                      Boaz
```

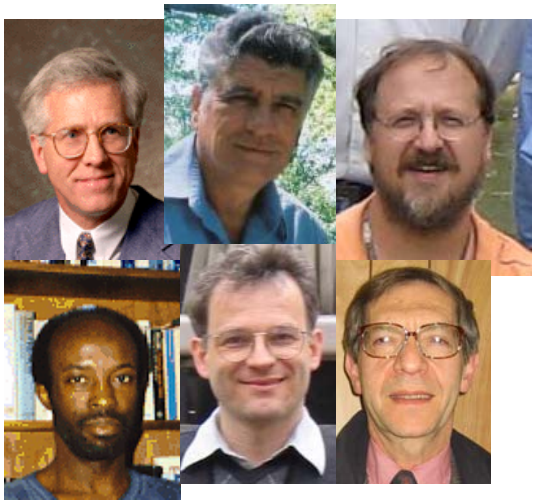
My apologies to a few, whose pictures I could not find…

The Two Day Top Marathon…

The Conveners

The spokes

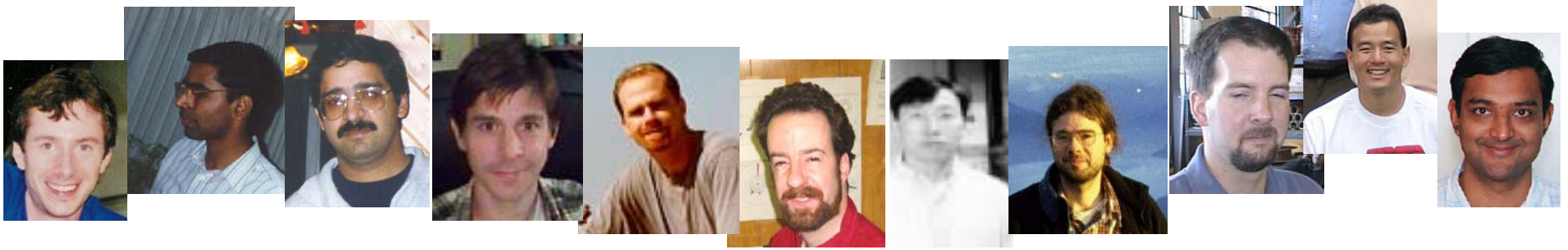
The subgroup conveners



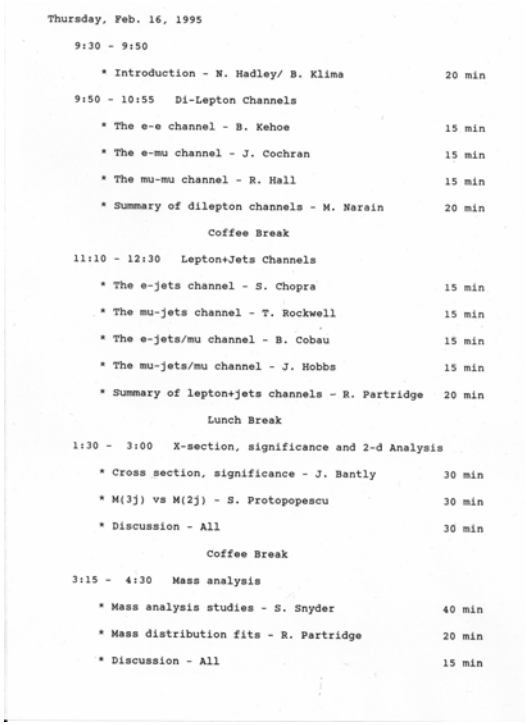
Top Marathon

Feb. 16-17, 1995

Welcome!



Dotting the i's and Crossing the t's
The discovery numbers!!!



Thursday, Feb. 16, 1995

9:30 - 9:50

* Introduction - N. Hadley/ B. Klima 20 min

9:50 - 10:55 Di-Lepton Channels

* The e-e channel - B. Kehoe 15 min
* The e-mu channel - J. Cochran 15 min
* The mu-mu channel - R. Hall 15 min
* Summary of dilepton channels - M. Narain 20 min

Coffee Break

11:10 - 12:30 Lepton+Jets Channels

* The e-jets channel - S. Chopra 15 min
* The mu-jets channel - T. Rockwell 15 min
* The e-jets/mu channel - B. Cobau 15 min
* The mu-jets/mu channel - J. Hobbs 15 min
* Summary of lepton+jets channels - R. Partridge 20 min

Lunch Break

1:30 - 3:00 X-section, significance and 2-d Analysis

* Cross section, significance - J. Bantly 30 min
* M(3j) vs M(2j) - S. Protopopescu 30 min
* Discussion - All 30 min

Coffee Break

3:15 - 4:30 Mass analysis

* Mass analysis studies - S. Snyder 40 min
* Mass distribution fits - R. Partridge 20 min
* Discussion - All 15 min

Observed: 17 events
Expected background: 3.8 ± 0.6 events.

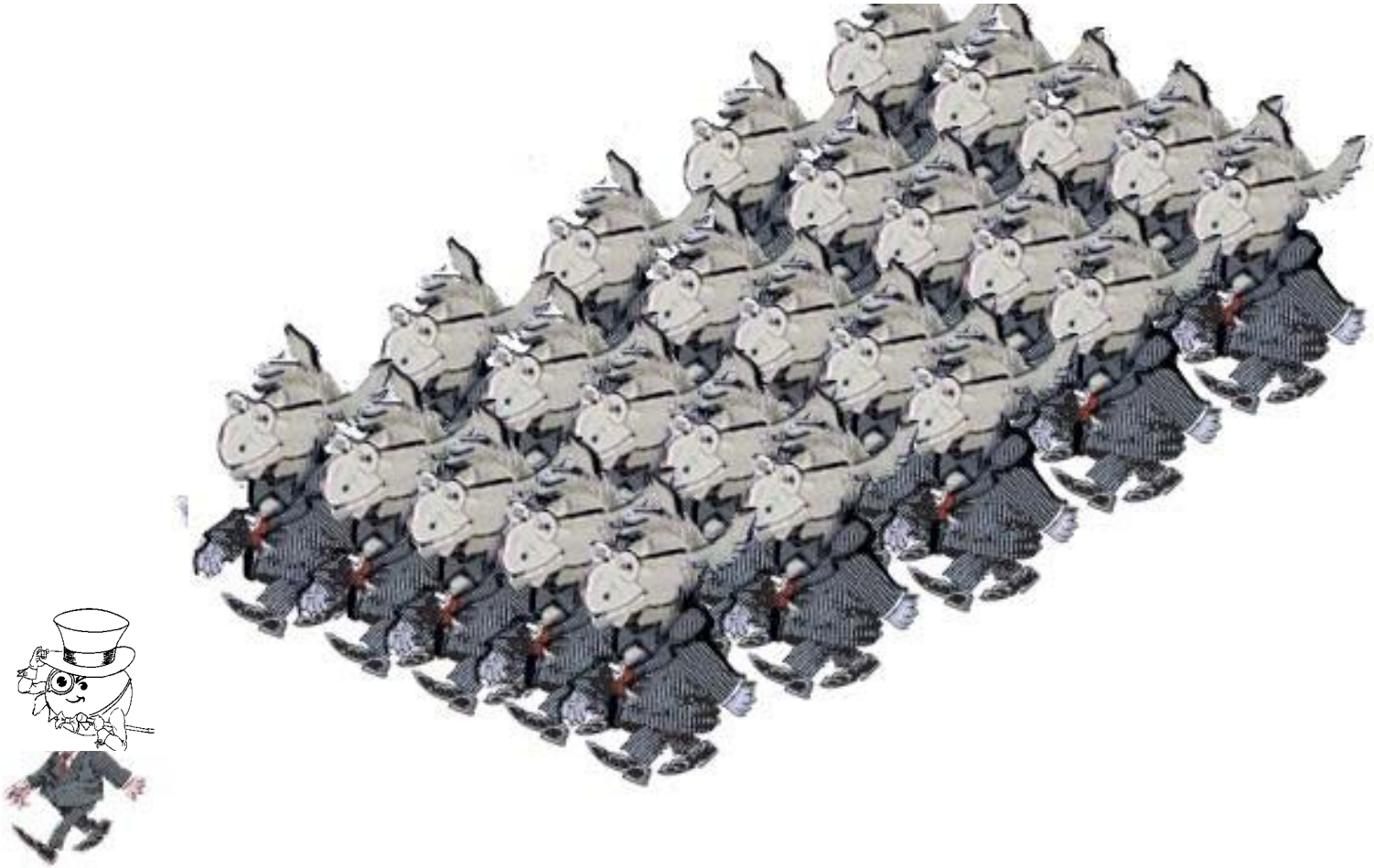
Significance: 4.6 σ

Probability for an upward fluctuation of the background to produce the observed signal is 2×10^{-6}

Boaz & Nick

You don't get to be part of a team which discovers a new elementary particle more than once!

By the end of the marathon, the collaboration had been assimilated into the top group



The drafting of the "Discovery Paper"

- Jan. 17, 1995:
  - Drafting committee and Editorial Board formed for top quark discovery paper
- Jan. 29, 1995:
  - First draft of top discovery paper (long paper).

  .
- Feb. 16-17, 1995:
  - Top quark discovery analysis review is final.
- Feb. 17, 1995 (Friday):
  - Director notifies Dzero at 4:20pm of CDF's intention to submit top quark discovery paper to PRL within one week.
- DØ decides for a simultaneous PRL submission.

- Feb. 18-19, 1995 (Saturday, Sunday):
  - PRL length paper drafted from the long paper.
- Feb. 20, 1995 (Monday):
  - Top discovery PRL is posted for a 24 hour collaboration review.

The fear of leaks

- Hide the paper in the QCD group project area.

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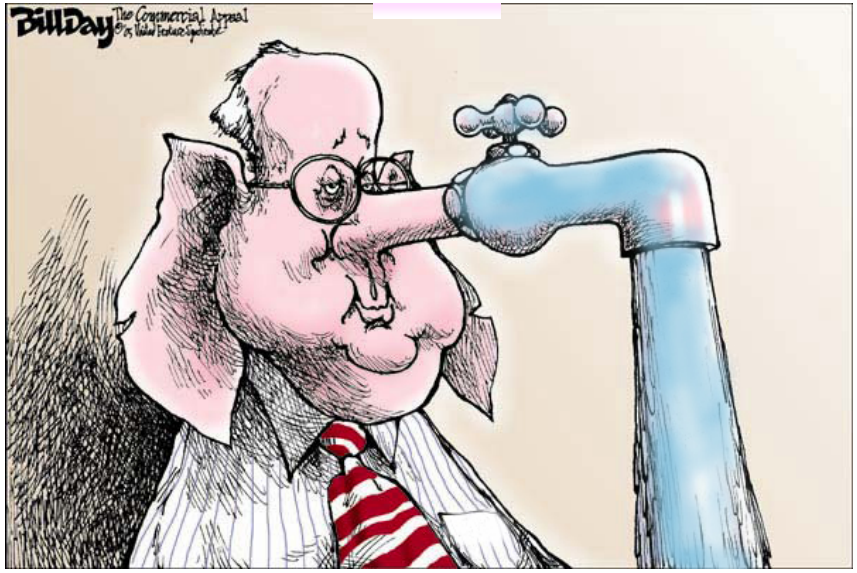
From: D0SFT::JMBUTLER     "John M. Butler (708) 840-8705" 17-FEB-1995
Subj: paper location

                                                Fermilab, MS 357, 17-FEB-1995


    Paul,
In a crude attempt at sublety, I've put the paper and "final" tables in
    PRJ$ROOT227:[QCD_3.CUCKOO]PAPER_V0-5.PS
    PRJ$ROOT227:[QCD_3.CUCKOO]TABLE_II.EPS
    PRJ$ROOT227:[QCD_3.CUCKOO]TABLE_IV.EPS
<..deleted text..>
                                    jb
```

- It still happened…
  - We also had their paper!
    - We have not yet figured out who our Karl Rove and Judith Miller are…



The Editorial Board Process

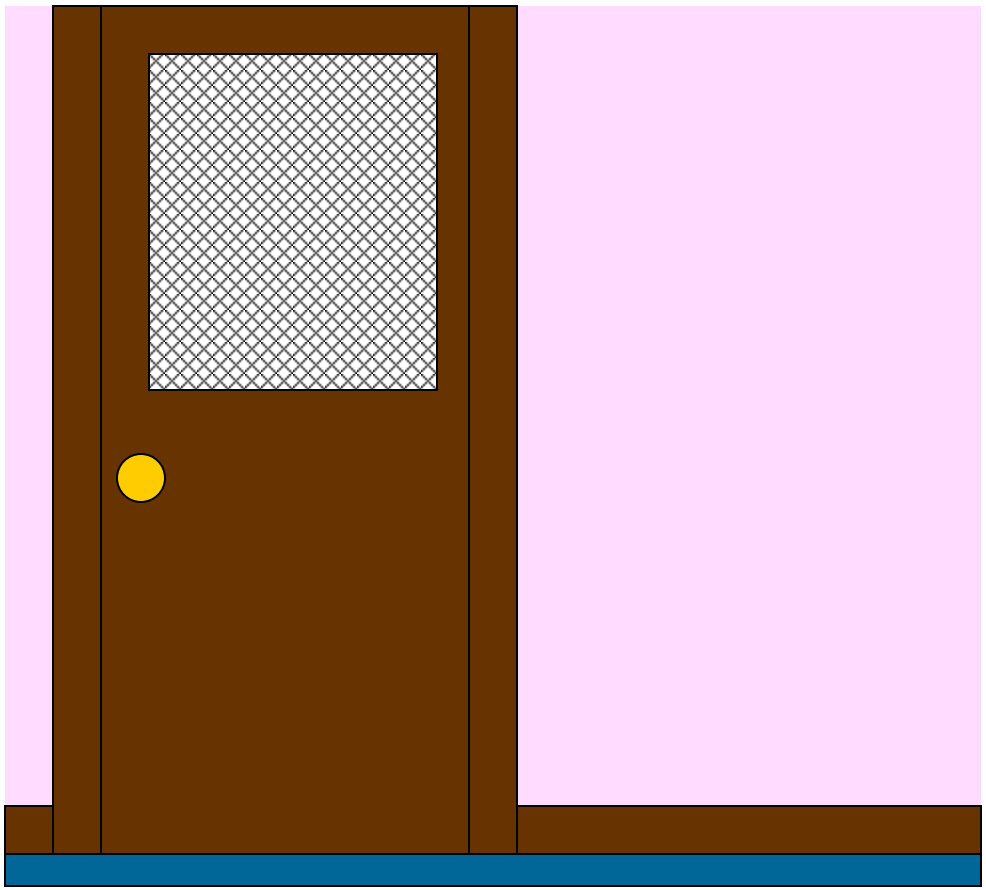
- Feb. 21, 1995 (Tuesday) : Over 200 collaborators submit comments.

> And you really used the D-word finally! Did you happen to visit Mars or were you in a trance last night or had an attack or somnambulance?

- Feb. 22, 1995 (Wednesday):
  - Editorial board meets from morning until night to review collaboration comments and revise PRL draft.

- Feb. 23, 1995 (Thursday): PRL draft is finished for submission.

> Date: Thu, 23 Feb 1995 18:36:10 -0600 (CST)
> From: Man van Staal
> Subject: Top PRL draft ready for submission.
>
> Fermilab, Feb-23-1995
>
> Dear Mont and Paul:
>
> the editorial board for the Top Physical Review Letter: "Observation of the Top Quark" has finished its deliberations an hour ago. The final version of the paper can be found in the principal author's area on FNALD0:USR$ROOT4:[GREENLEE.PRL2]PRL95A.PS
>
> The editorial board,drafting committee and top conveners have all agreed on this version and we sealed it appropriately with liquor. The letter is finished and there are no contentious issues left concerning the contents of the letter.
> <...deleted text...>
> It is now time to celebrate !!
>
> Harry



It's official!

Feb. 24, 1995, Friday, 11:00 a.m.:

- Top discovery paper submitted by H. Greenlee et. al. electronically to PRL.

Mar. 2, 1995 (Thursday) - Public announcement of top quark discovery; press conference.

And finally….

- We were all fatigued and exhilarated at the same time.

- It is a lifetime experience and once again it would be fun to be in the middle of something similar!