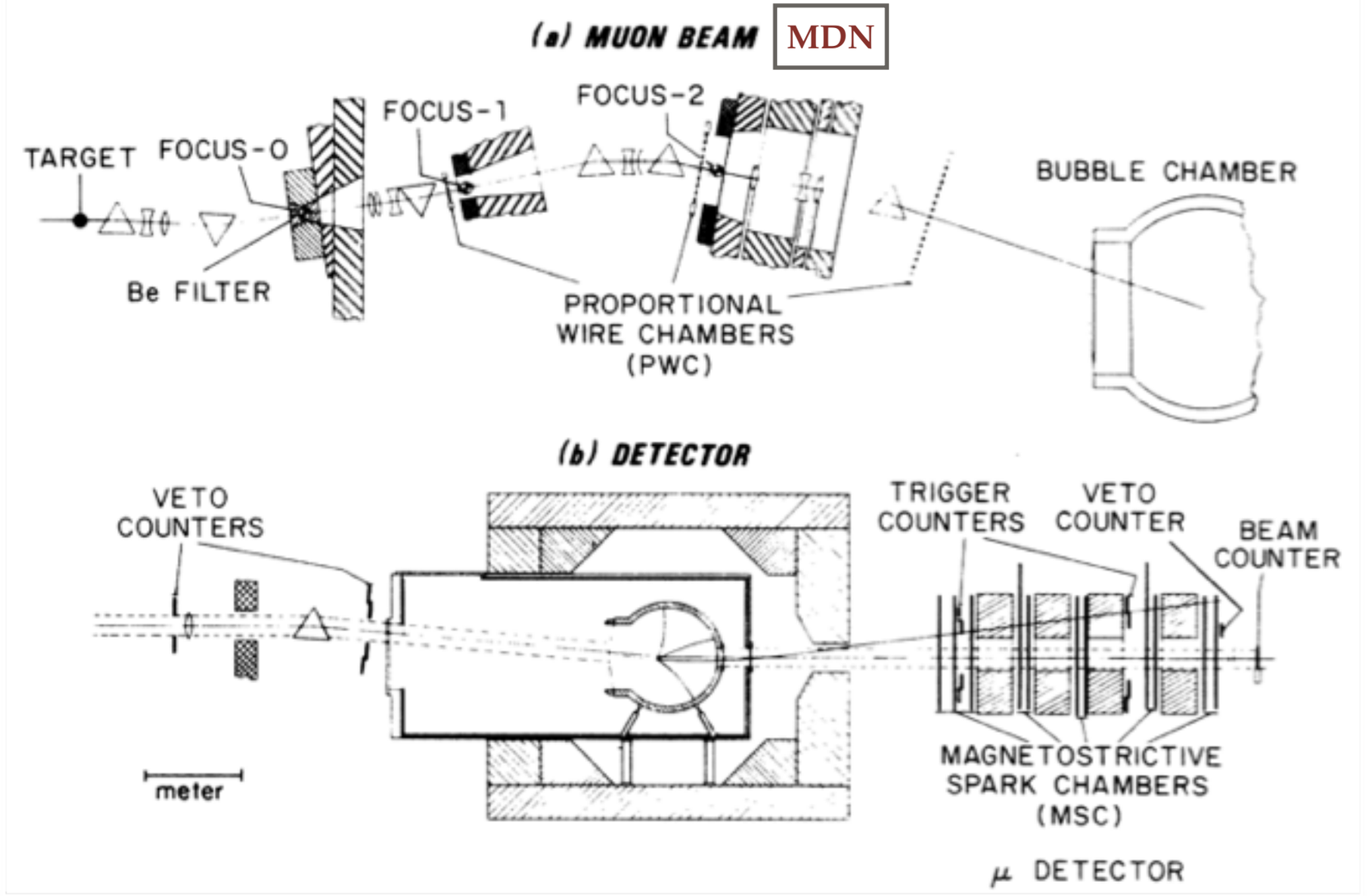
Elliott Bloom, KIPAC-SLAC, Stanford University

The Deep Inelastic Scattering Experiment BC42 at SLAC

Cérémonie en l'honneur de Michel Della Negra, lauréat du Prix Lagarrigue 2014

lundi 14 décembre 2015 de **14:00** à **19:00** (Europe/Paris)

à **Laboratoire de l'Accélérateur Linéaire (Auditorium Pierre Lehmann)** Orsay

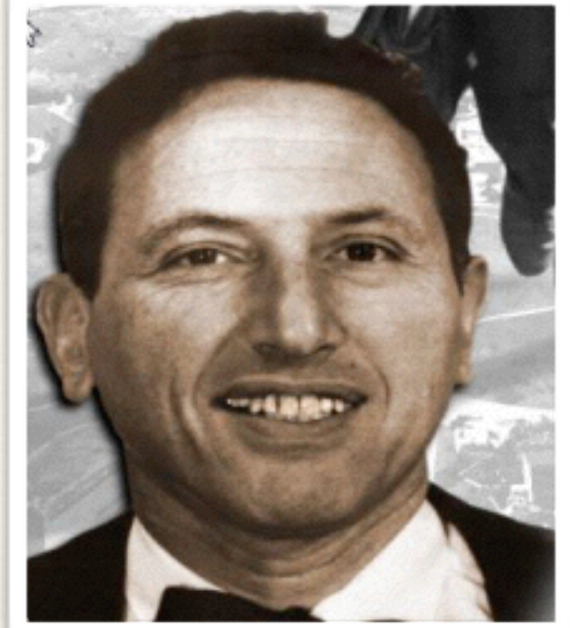


Schematic representation of the experiment from the origin of the muon beam to the muon telescope behind the 40-in. hydrogen bubble chamber. The upper part of the figure, depicting the muon beam, is not to scale.

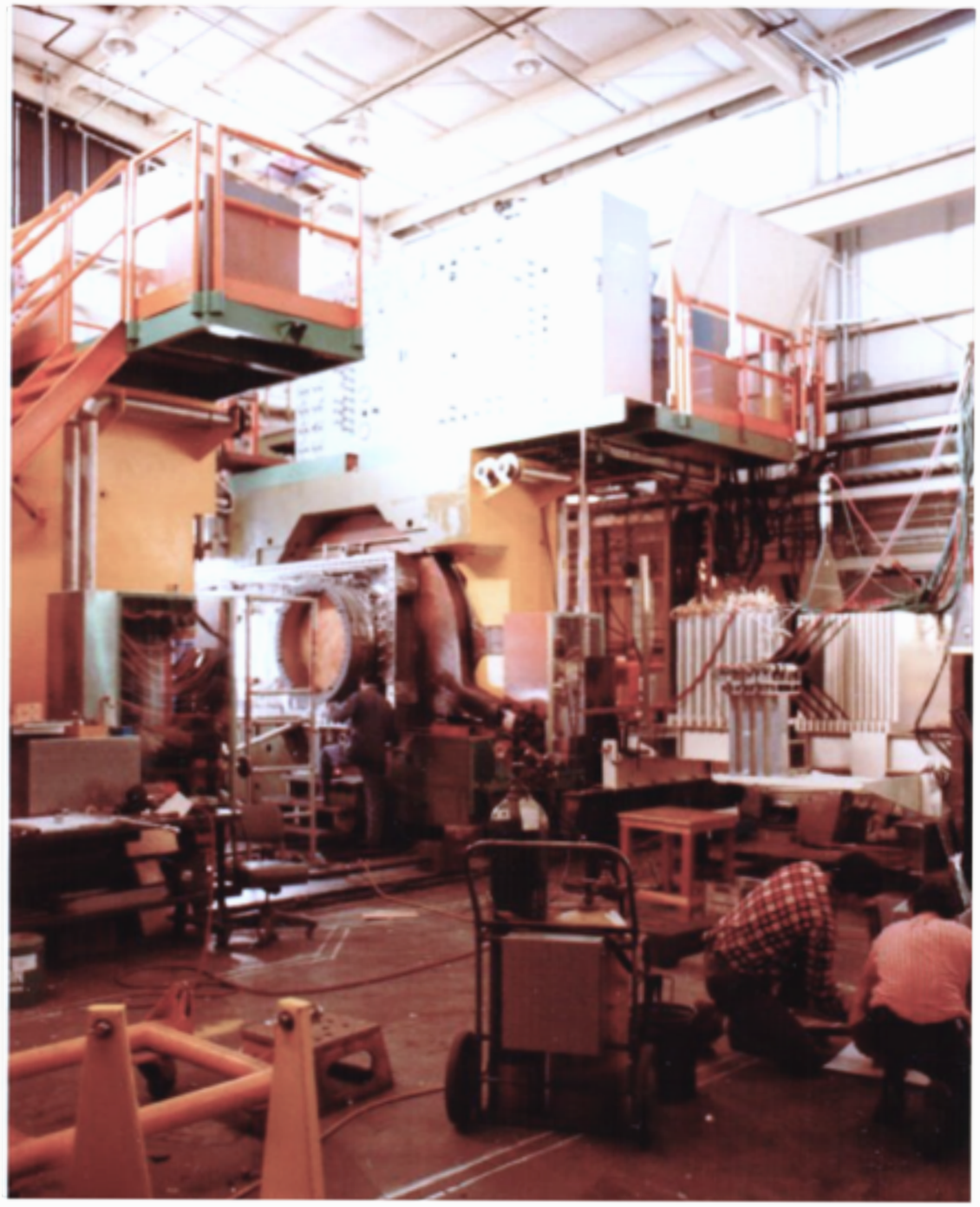
Some BC42 Details

J. Ballam, E. D. Bloom, J. T. Carroll, G. B. Chadwick, R. L. A. Cottrell, **M, Della Negra**, H. DeStaebler, L. K. Gershwin, L. P. Keller, M. D. Mestayer, K. C. Moffeit, C. Y. Prescott, and S. Stein
Stanford Linear Accelerator Center. Stanford University, Stanford, California 94305

SLAC 42″ Rapid Cycling Bubble Chamber Facility -1971



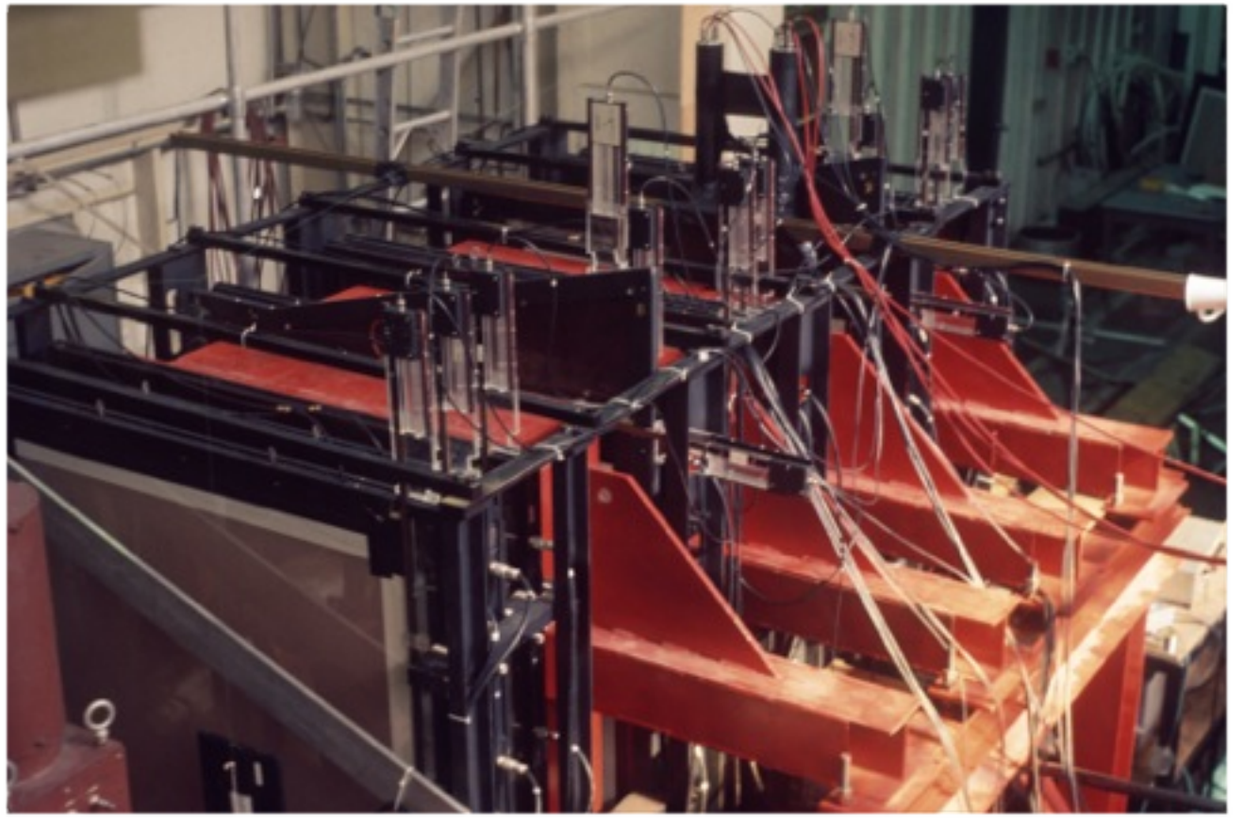
Joe Ballam

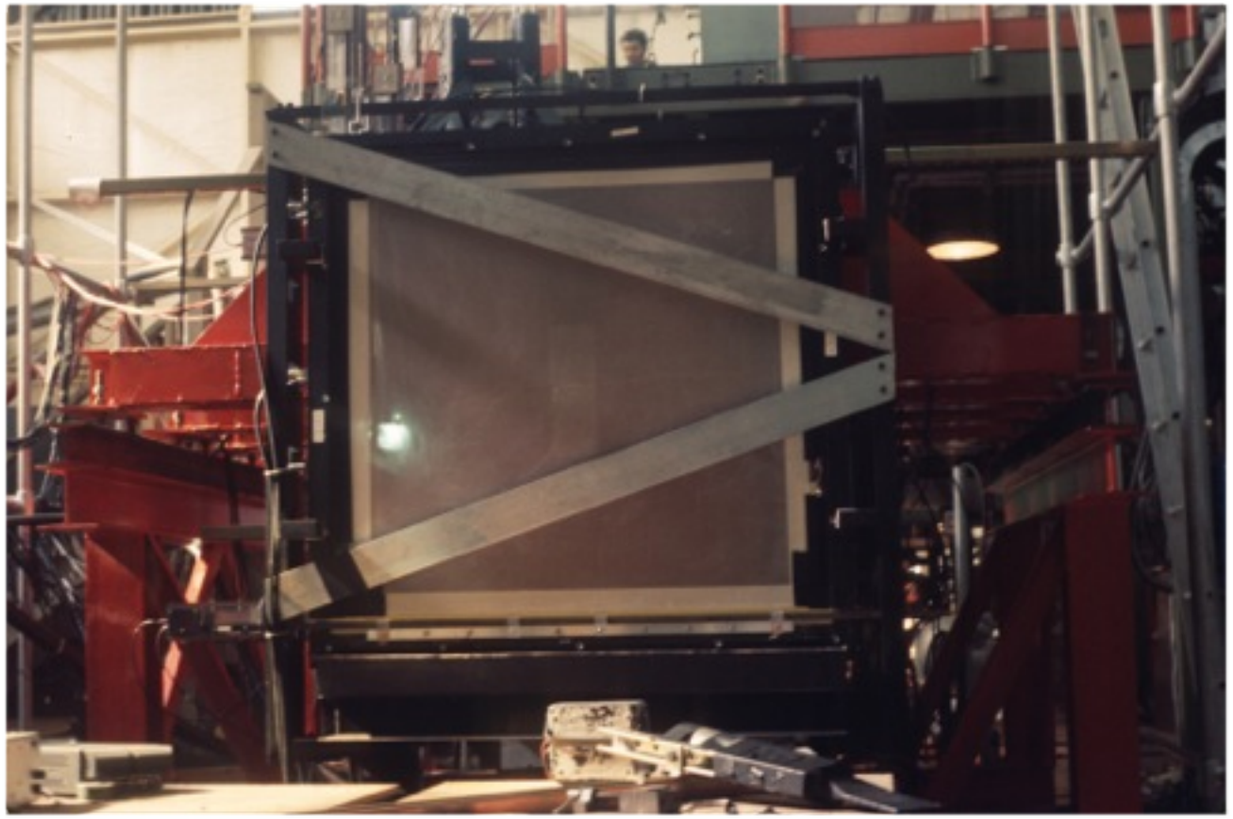


BC appart

BC Control Room

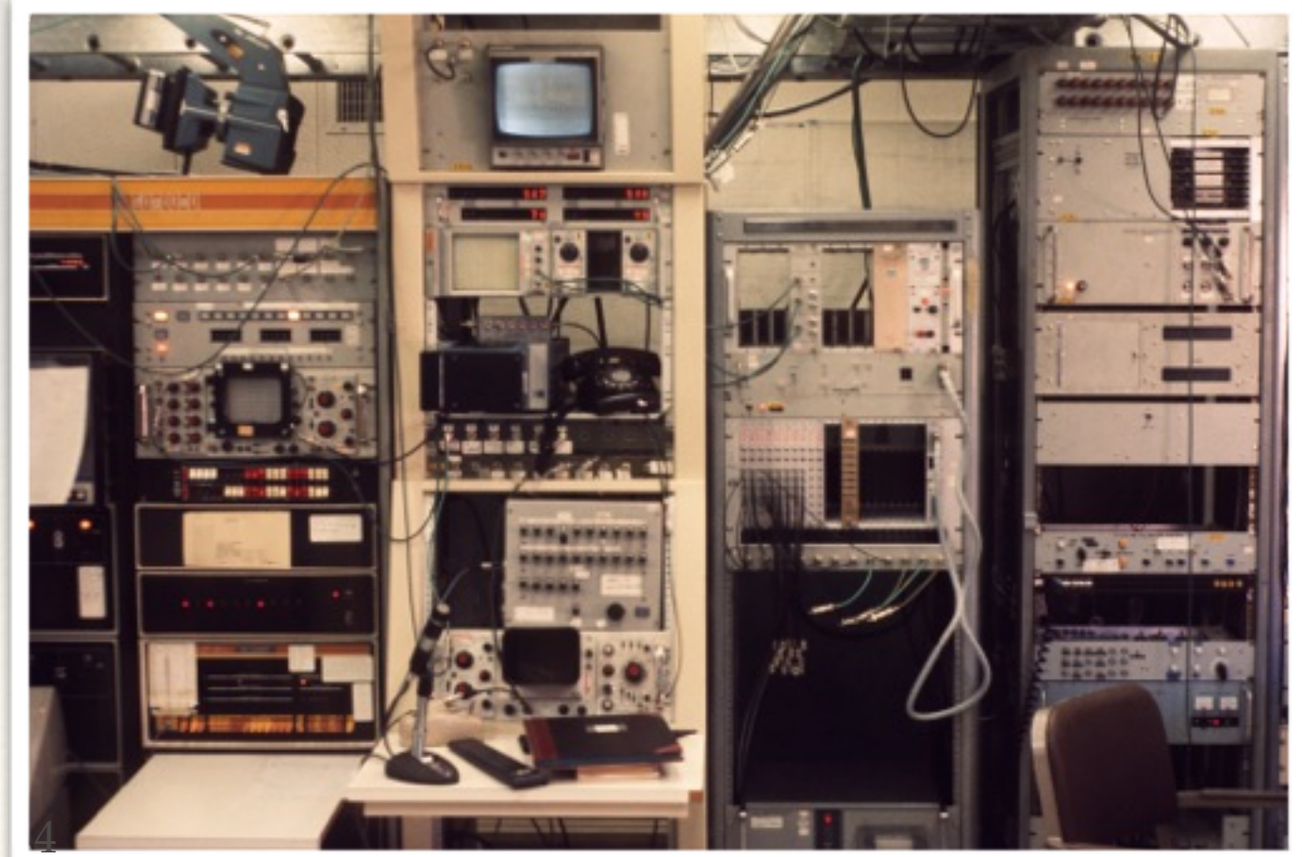
BC 42 Muon Detector Just Downstream of the Bubble Chamber





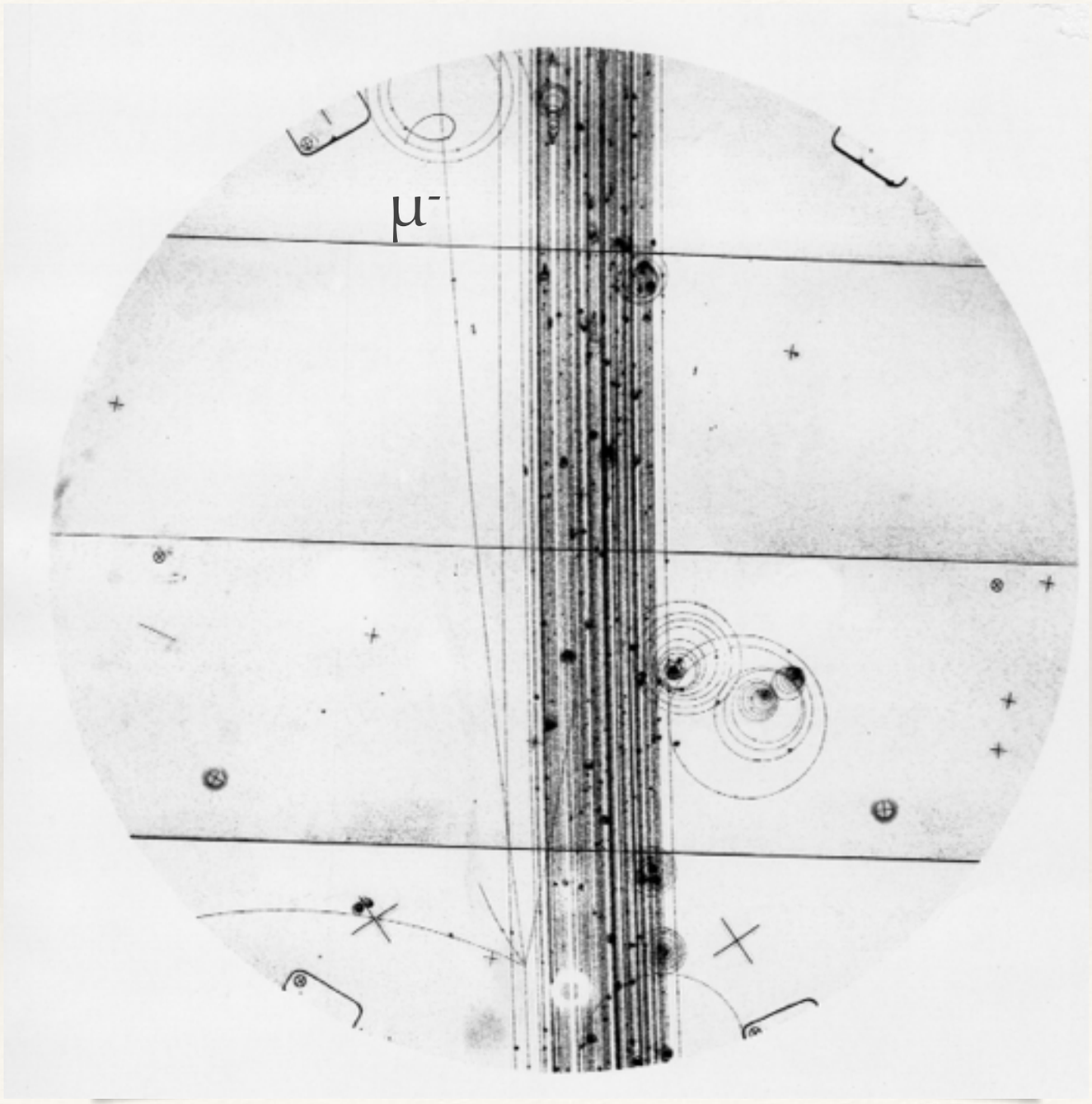
Magneto Strictive Chambers with wand readout. Trigger is hodoscope scintillator coincidence. The final decision to trigger the bubble-chamber camera lights was made using a PDP-8 computer, which calculated that the hodoscope hit pattern could have been caused by a track from the HBC fiducial volume.

Experimental Control Room



Muon Beam in the Chamber

- BC was pulsing at 10 pps for most of the data taking and 20 pps for a shorter time at the end of the run.
- There were about 100 μ^- per pulse in the chamber.
- The event on the right shows the scattered μ^- and a 3-prong event at the vertex. $Q^2 \sim 1.6$ GeV^2, and $W > 2$ GeV.



Setting the Stage - status as of 1971

- **By 1971 the SLAC deep inelastic electron experiments had established:**
  - Scaling of νW_2 (ν/q^2) - predicted bj scaling before the SLAC experiments.
  - $R = \sigma_S/\sigma_T \lesssim 0.2$, and this value favored the quark/parton model. That R was <<1 was predicted by the quark/parton model before the experiment (spin 1/2 partons).
  - n/p ratio scaled within errors and was < 1. If diffraction was operative a value ~1 would be expected.
  - The current algebra derived sum rules were in rough agreement with the quark/parton model.
  - At this time most physicists did not believe that the discovery of quarks was settled science, and there were competing models (e.g., extended vector dominance-EDM, the Michigan cut model (Kane)…) that could a posteriori explain most of the results.
  - More experiments were needed to establish that quarks were discovered. Enter BC 42- looking for evidence of partons in the final hadronic states.

The Roles of Michel Della Negra in BC 42

- Michel contributed to many aspects of the experiment; however, this was a long time ago and my memory may fail me — Michel may remember differently.
- He was a major architect of the μ^- beam line and took an active role in helping to build it
- He was a valiant shift taker
- He scanned most of the bubble chamber pictures (as did I) to find the potentially interesting events and check some of the computer calculations.
- He contributed to the physics analysis and helped write the papers.
- It was a pleasure to have him as a colleague and the experiment would have been much less fun without him.

BC 42 vs the "Doubters"

Parton Model vs Vector Dominance

★ Science News stressed the controversy at that time where most particle physicists did not believe that SLAC DIS had shown compelling evidence for quarks/partons.

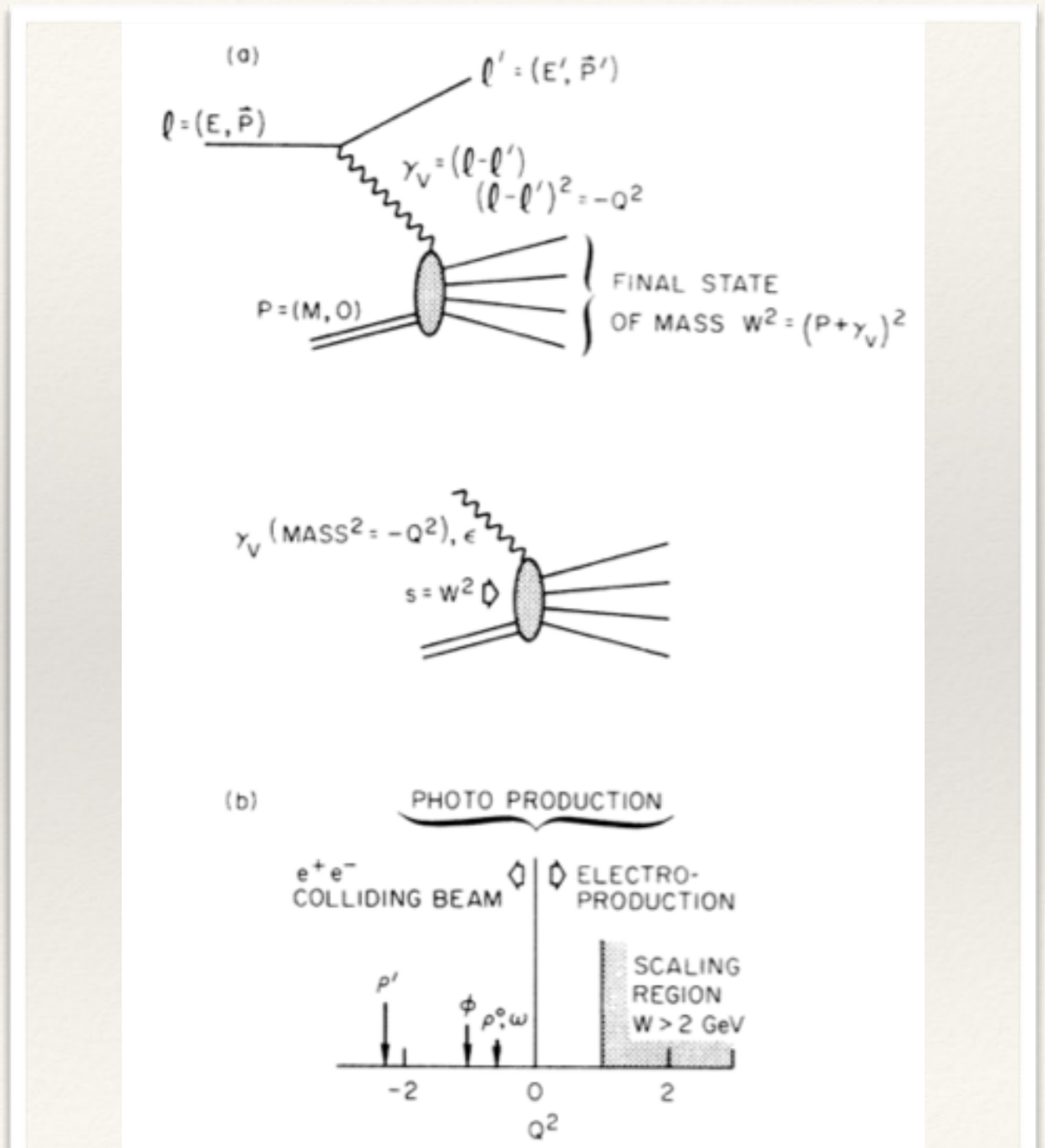
★The article in this issue of Science News featured comments by Dr. William Toner (M. Perl, G. Feldman et al, SLAC-E65) that indicated his optimism that the SLAC DIS experiments could be explained more conventionally, and his competing ep scattering experiment examining the final states would demonstrate that. J. T. Dakin, G. J. Feldman, W. L. Lakin, F. Martin, M. L. Perl, E. W. Petraske, and W. T. Toner, Phys. Rev. D 8, 687 – Published 1 August 1973, SLAC E-65. Also DESY streamer chamber experiment at lower energy was ongoing.

★Science News expressed interest that the question might be settled by the BC 42 $\mu^- p$ and E-65 ep final state studies.

BC 42 Headline Results - Preliminaries

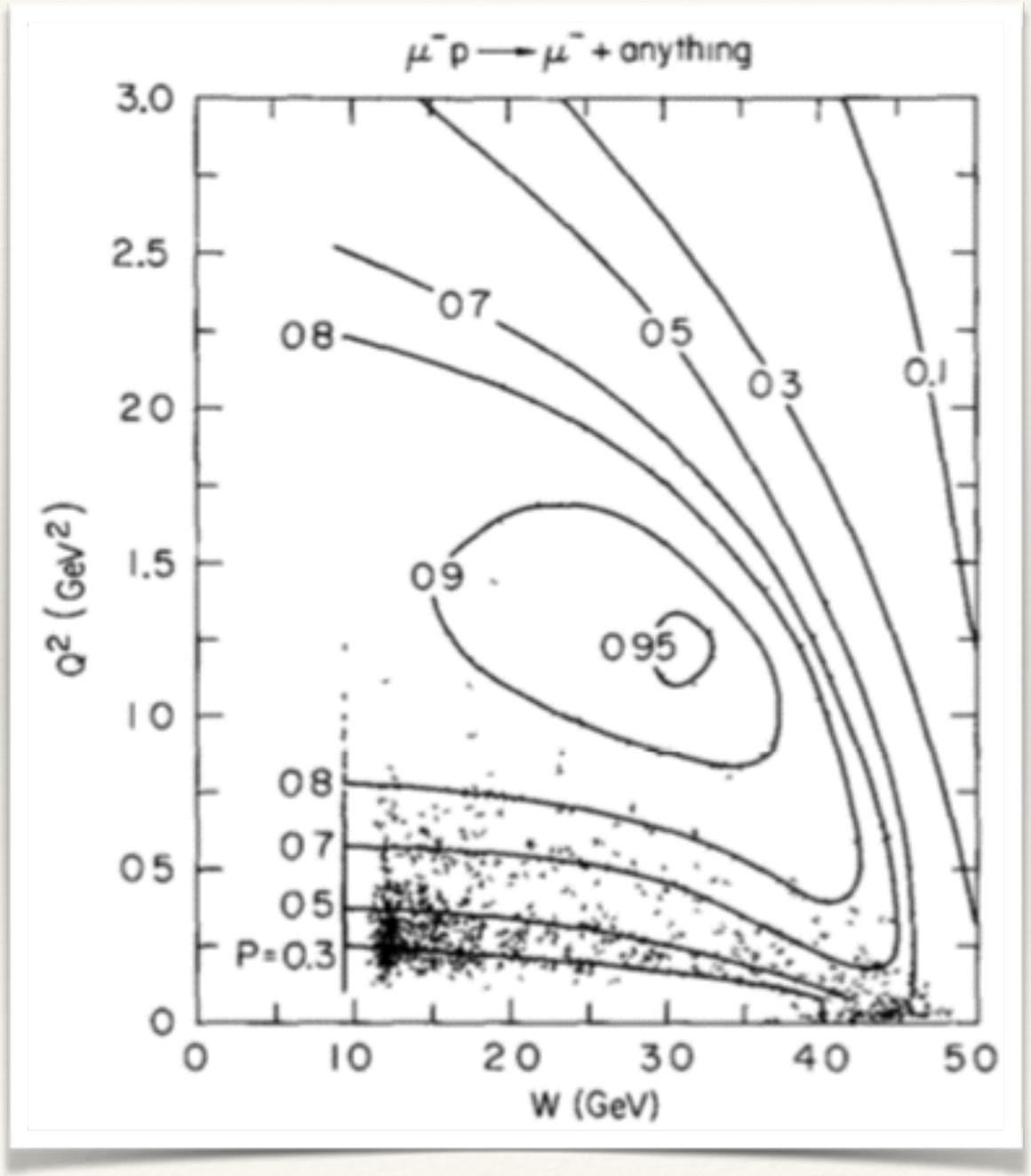
(a) Diagram of the scattering process with the variables and Q^2 and W defined.

(b) Domain in the variable Q^2 of electro-production, photo-production, and colliding- beams experiments.



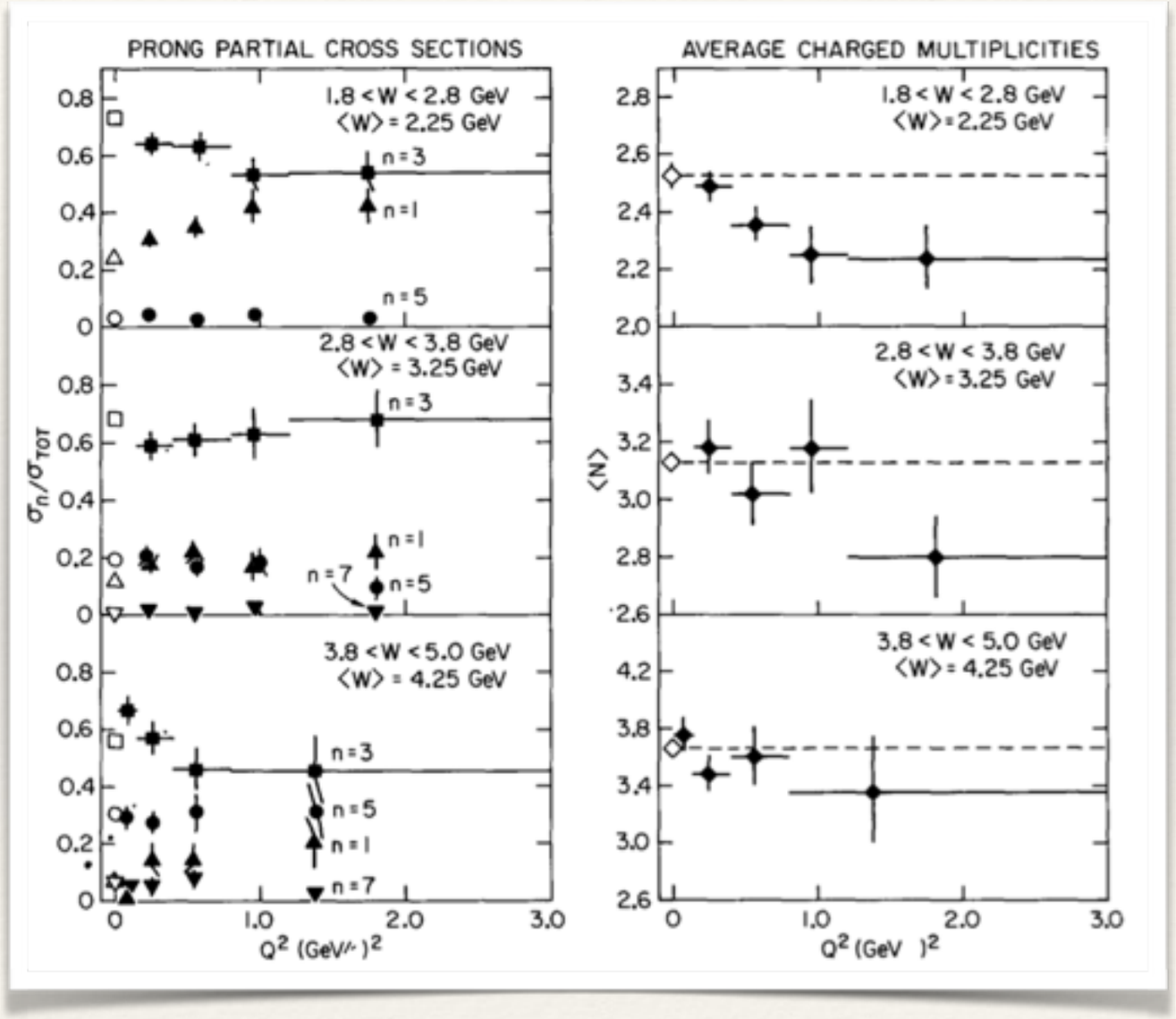
BC-42 Event Distribution in Q^2, W

- Scatterplot of Q^2 (GeV^2) versus W(GeV) for 4,766 events. Superimposed on the data are contours of P, the outgoing μ^- detection efficiency.
- 4π detector.
- About 400 events with $Q^2 > 1$ GeV^2 and $W > 2$ GeV.
- I used foam spheres and thin wooden sticks to model a sample of a couple of dozen of these events with the largest Q^2 and W. Showed final state particles with stick angles from **Q** and length proportional to $\mathbf{p}_{particle}$. Taylor and I stared at these event models, and jets along **Q** were not obvious.



Q^2 Dependence of Partial Cross Sections

- (a) The fractional part of σ_{tot} contributed by n = 1, 3, 5 and 7 prong events, versus Q^2, for three ranges of W. The open symbols show photo-production data. (b) The mean charged hadron multiplicity versus Q^2 for three ranges of W.
- No strong Q^2 dependence is seen, within errors, for n = 5 or 7 prongs or strange topologies. However, as seen in fig. on the left, $\sigma_{1\text{-prong}}/\sigma_{tot}$ tends to increase as Q^2 increases, while for the lowest W bin $\sigma_{3\text{-prong}}/\sigma_{tot}$ tends to decrease.
- Overall average charged multiplicities tend to decrease with Q^2.



Production of Vector Mesons

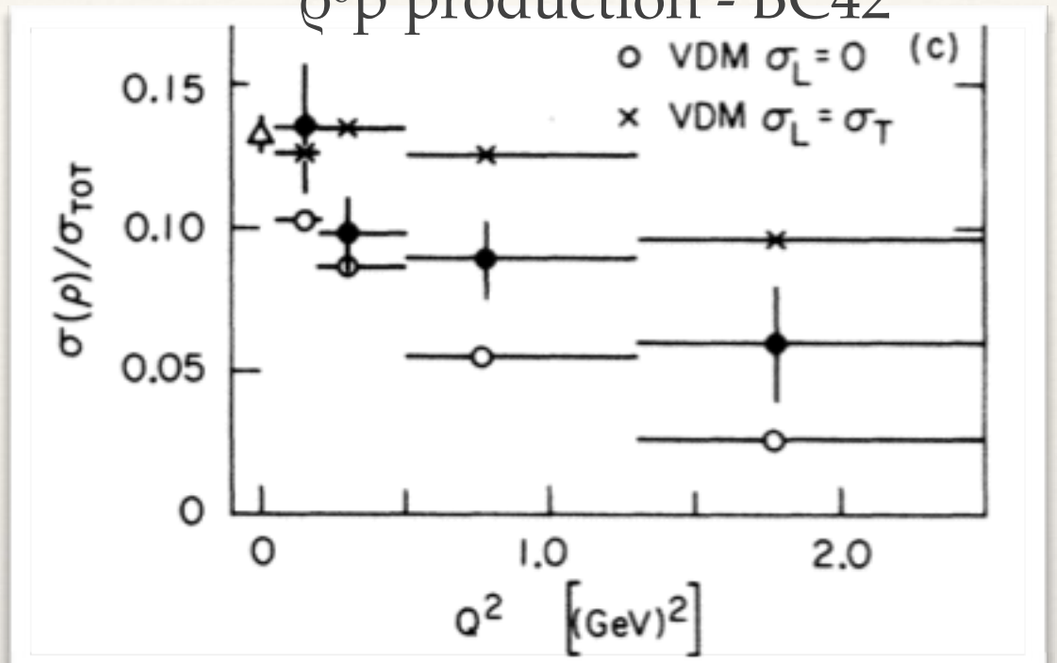
- BC-42 reports on the Q^2 dependence of the $\varrho^0 p$ and $\omega^0 p$ production cross sections and the ϱ^0 decay characteristics from lower Q^2 into the DIS scaling region.
- E-65 also reported on $\varrho^0 p$ and within error obtained similar results.
- The extended vector dominance model of Sakurai and Schildknecht[1], which expresses the longitudinal over the transverse $\varrho^0 p$ cross sections, or $R\varrho$ as:

$$R\varrho = - \xi^2 Q^2 / m_\varrho^2$$

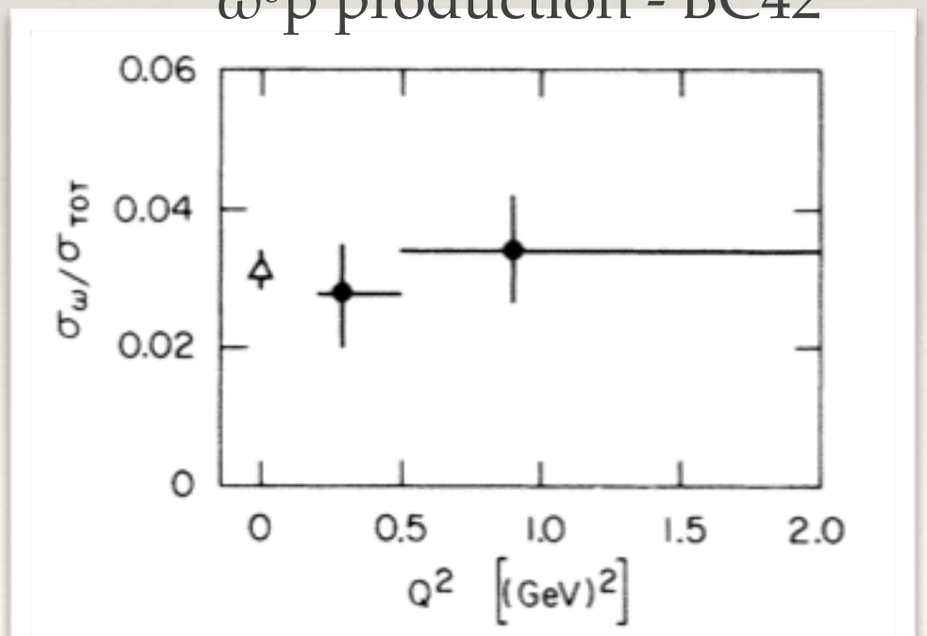
with $\xi^2 \sim 0.06$ to fit the SLAC DIS results, did not fit the BC-42 and E-65 results.

- Both BC-42 and E-65 obtained $\xi^2 \sim 0.5$ as indicated in the top figure for BC-42. E-65 measured $\xi^2 = 0.45^{+0.15}_{-0.1}$.

$\varrho^0 p$ production - BC42



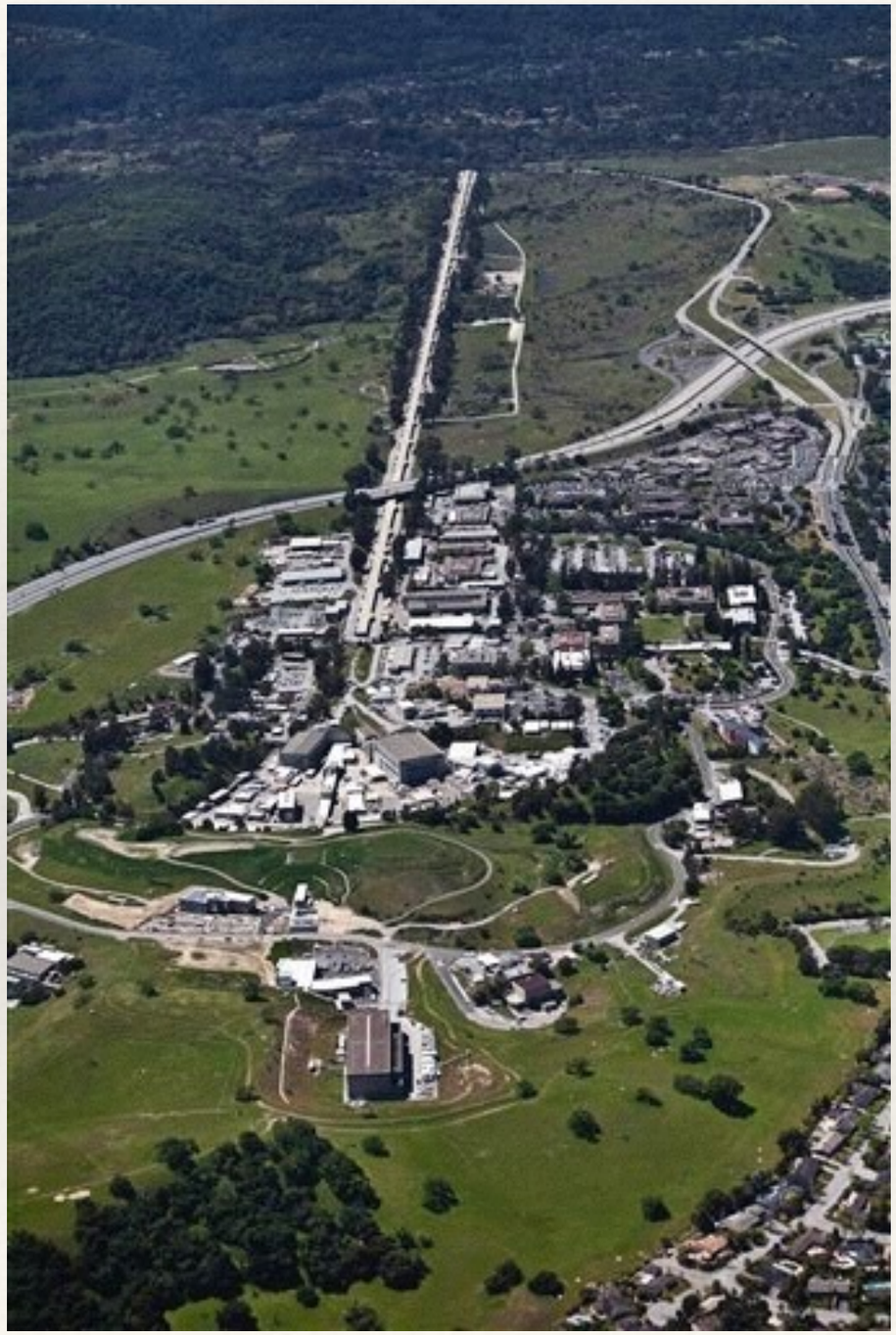
$\omega^0 p$ production - BC42



[1] J. J. Sakurai and D. Schildknecht, Phys. Lett. 40B, 121

The Quark/Parton Controversy After BC-42 and E-65

- The quark/parton model had succeeded in a number of important respects to anticipate the results of BC-42 and E-65, while EVD did not.
  - No sign of jets in the final state. (minus q/p)
  - The vector meson partial cross sections, $\varrho^0 p + \omega^0 p + \phi^0 p$ became a smaller fraction of the total electro production cross-section as Q^2 increased. (minus EVD)
- R_ϱ was much to large for the EVD prediction of 0.06. (minus EVD)
- This was significant evidence against the EVD model, but much more evidence was required before most everybody was convinced that we had found quarks.



Thank You for You Attention