



## RESEARCH ACTIVITIES - Konstantin Goulios

**1958-64, Columbia University** Participated in the “two-neutrino experiment” performed at the Brookhaven AGS accelerator. Co-discovered the muon-neutrino (Ph.D. thesis; **1988 Nobel Prize in physics** awarded to Professors Leon Lederman, Melvin Schwartz, and Jack Steinberger). Hardware: spark chamber development; construction and testing of 130 large scintillation counters used for triggering the spark chambers.

**1964-71, Princeton University** Performed experiments on CP violation and time reversal invariance using the Princeton-Penn 3 GeV accelerator. Measured the  $K_2^0 \rightarrow 2\pi^0$  decay rate, reciprocity in  $np \rightarrow d\gamma$ , and  $K\mu 3$  transverse polarization. Worked on hardware: development of wire chambers with magnetostrictive readout.

**1971-present, The Rockefeller University** Worked at Brookhaven National Laboratory (BNL), Fermilab, and the Large Hadron Collider (LHC) at CERN.

### BNL:

Neutrino-proton elastic scattering. High voltage spark chamber electronics.

### Fermilab:

**Internal target experiments, E-36 and follow-ups** including the use of a hydrogen/deuterium gas-jet target (Soviet-American Collaboration). Measured the  $\rho$ -value of  $pp$  elastic scattering, indirectly confirming the rise of the  $pp$  total cross section with energy. Measured  $pp$  and  $pd$  diffraction dissociation and established the  $\sim 1/M^2$  law and factorization. Worked on total absorption and position sensitive silicon detectors.

**E-396** (spokesperson). Measured diffraction dissociation of  $p^\pm$ ,  $\pi^\pm$  and  $K^\pm$  on protons. Established Regge factorization (diffractive cross sections are proportional to the corresponding total inelastic cross sections), and universality between diffractive and non-diffractive charged multiplicity distributions. Developed low mass drift chambers using He as a drift gas.

**E-612** (spokesperson). Measured diffractive photon dissociation: established  $1/M^2$  behavior and factorization. Developed a 15 atm hydrogen gas time projection chamber (TPC), which acted both as a target for a high energy tagged photon beam and as a detector for the recoil protons. Requiring high purity hydrogen, a 150 KV electric field over a drift distance of 75 cm, and a “barrel” of plastic scintillator counters inside the high pressure vessel for measuring the energy of the recoil proton, the TPC was a challenging engineering and detector development project.

**CDF Collaboration** (Rockefeller group leader since 1985). *Physics*: Elastic, diffractive, and total cross sections, prompt photon cross sections, top quark discovery and mass measurement, inclusive jet differential cross section,  $x_T$ -scaling, measurement of “running” of  $\alpha_s$ , discovery of  $\Lambda_b$ , soft/hard diffraction studies. *Hardware*: Drift chambers for the total cross section measurement, design of beryllium beam pipe, MicroPlug calorimeters for diffraction studies in Run I, shower-maximum detector and fiber-splicing machines for the plug calorimeter upgrade, beam-loss/shower counters, MiniPlug calorimeters, scintillator-tile preshower detector.

### CERN:

**SppS, UA6 Collaboration.** Precise comparison of  $\bar{p}p$  and  $pp$  elastic scattering at  $\sqrt{s} = 24.3$  GeV, using silicon detectors to observe protons recoiling from a hydrogen cluster-jet target intercepting the stored proton beams,

<http://www.sciencedirect.com/science/article/pii/0370269389911507>

**LHC, CMS experiment**, <http://physics.rockefeller.edu/>. Higgs-boson discovery, diffraction dissociation measurements and phenomenology.

## RESEARCH HIGHLIGHTS - Konstantin Goulios

1. Discovery of the muon-type neutrino
  - *Observation of High-Energy Neutrino Reactions and the Existence of Two Kinds of Neutrinos*  
G. Danby, J.-M. Gaillard, K. Goulios, L.M. Lederman\*, N. Mistry, M. Schwartz\* and J. Steinberger\*, *Phys. Rev. Lett* **9**, 36-44 (1962).  
\* **1988 Nobel Prize in Physics** for the  $\nu_\mu$  discovery.
  - *Experimental Proof of the Existence of Two Neutrinos*  
Konstantin Goulios, **Ph. D. Thesis**, Columbia University, June 1963.
2. *Experimental Test of Time-Reversal Invariance in the Decay  $K_L^0 \rightarrow \pi^- \mu^+ \nu$*   
D. Bartlett, C.E. Friedberg, K. Goulios and D. Hutchinson,  
*Phys. Rev. Lett* **16**, 282-285 (1966).
3. *Observation of the Reaction  $\nu_\mu + p \rightarrow \nu_\mu + p$*   
W. Lee *et al.*, *Phys. Rev. Lett.* **37** (1976) 186.
4. *Diffraction Interactions of Hadrons at High Energies*  
K. Goulios, *Phys. Repots.* **1** (1983) 169-219.
5. *Diffraction Dissociation of Photons on Hydrogen*  
T. Chapin *et al.*, *Phys. Rev. D* **31**, 17-30 (1985).
6. *Diffraction dijet production in  $\bar{p}p$  collisions at  $\sqrt{s} = 1.96$  TeV*  
A. Aaltonen *et al.*, *Phys. Rev. D* **86**, 03209 (2012).
7. Discovery of the Top Quark
  - A. Abe *et al.*, *Observation of Top Quark Production in  $\bar{p}p$  Collisions with the Collider Detector at Fermilab*, *Phys. Rev. Lett.* **74**, 2626 (2012).
8. Discovery of the Higgs Boson
  - S. S. Chatrchyan *et al.*, *Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC*, *Phys. Lett. B* **716** (2012) 30.
9. *Measurement of diffraction dissociation cross sections in  $pp$  collisions at  $\sqrt{s} = 7$  TeV*, V. Khachatryan *et al.* (CMS Collaboration) *Phys. Rev. D* **92** (2015) 1, 012003.
10. Reference review of *Diffraction results from CDF*,  
K. Goulios, *Int. J. Mod. Phys.* **A30** (2015) 08, 1542003.