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The interplay of theory and experiment in high energy physics - a historical-epistemological perspective

why the interplay of theory and experiment in high energy physics?

- key subject for historical epistemology (beyond high energy physics!)
- research gap in the history of high energy physics
- productive starting point for exploring new aspects of the history of high energy physics
- (last but not least) the history of CERN offers relevant, untapped sources

This talk is only a very sketchy attempt to support some of these claims:

- a research gap? some historiographical remarks
- a simple example of some possible questions and answers: the interplay of theory and experiment in the „discovery“ of the first particle resonance (work in progress from the DFG-project „Concept formation in early particle physics“)

„experiment“ ---> experimental practices „theory“ ---> theoretical practices

many studies on the dynamics of one or the other field, but what about their interplay? often simplified to a linear back-and-forth:

experiment delivers information ---> theory formalizes it ---> experiment looks closer ---> theory is sharpened...

“A theorist like Gell-Mann could propose a particle along with its quantum numbers, and experimenters could make it one of their targets. Conversely, particles could emerge from the scanning processes, and theorists would work on to integrate it into their schemes” (Galison, 1997)

is it really that easy? theory and experiment are not monolithic!

- what theoretical practices did or did not connect to a given experimental constellation - and viceversa? did processes go on in parallel?

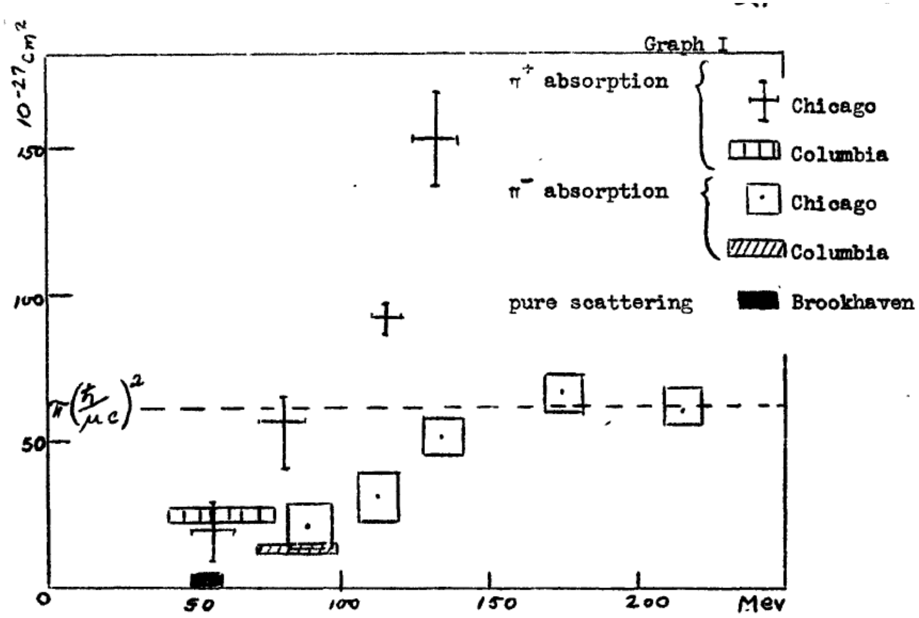
- which actors and representations mediated between the two spheres?

- which practices on both sides contributed to processes of concept formation? (premise: concepts as an epistemic factor which does not only pertain to the theoretical sphere!)

(tentative suggestion): an independent epistemic dynamics of the interplay?

The first pion-nucleon resonance (ca. 1950-54) - a simplified description

1951: pion-proton scattering experiments in Chicago:
$\pi^+ p \rightarrow \pi^+ p$, is more frequnt than $\pi^- p \rightarrow \pi^- p$ and $\pi^- p \rightarrow \pi^0 n$ for energy ~150-200 MeV



1951-52: „Keith Brueckner, who had heard of these results, suggested that a resonance in the pion-proton system was being observed and noted that a spin 3/2, isospin 3/2 resonance would give a ratio 9:2:1 for the frequency of the three processes [$\pi^+ p \rightarrow \pi^+ p$, $\pi^- p \rightarrow \pi^- p$, $\pi^- p \rightarrow \pi^0 n$]“ (Cahn&Goldhaber 2003)

1952-54: the prediction turns out to be correct - the resonance is "discovered"

---> what had experimenters expected to see from pion-proton scattering? who was Keith Brueckner? how did he "hear of these results"? was the notion of „(particle) resonance“ already there? when/from where did it emerge?

from ca. 1950: experiments on π-meson production and scattering, e.g.

N + N ---> π + N ; γ + N ---> π + N (Berkeley); N + π ---> N + π (Chicago)

motivations from experimental, socio-economic, political factors:

- technical development of accelerators and detectors
- funding from U.S. government (Defense)
- competition among U.S. University - attempts to diversify

what about theory? only a rather generic role in motivating experiments

- interest in pion-nucleon interactions (pions seen as „Yukawa meson")
- spin of pion? existence of π^0 ?

BUT: no generally accepted theory of pion-nucleon interactions, no predictions

which theorists (if any) try to make some quantitative or qualitative predictions for these experiments?

at Berkeley, the job is in the hands of PhD-students and young post-docs...

Keith Brueckner, theorist, PhD Berkeley (1950), later Princeton
PhD: higher order computation of meson production in various models - little or no significant predictions (largely due to lack of input parameters)

Kenneth Watson, young Post-Doc in Princeton (IAS), then Berkeley

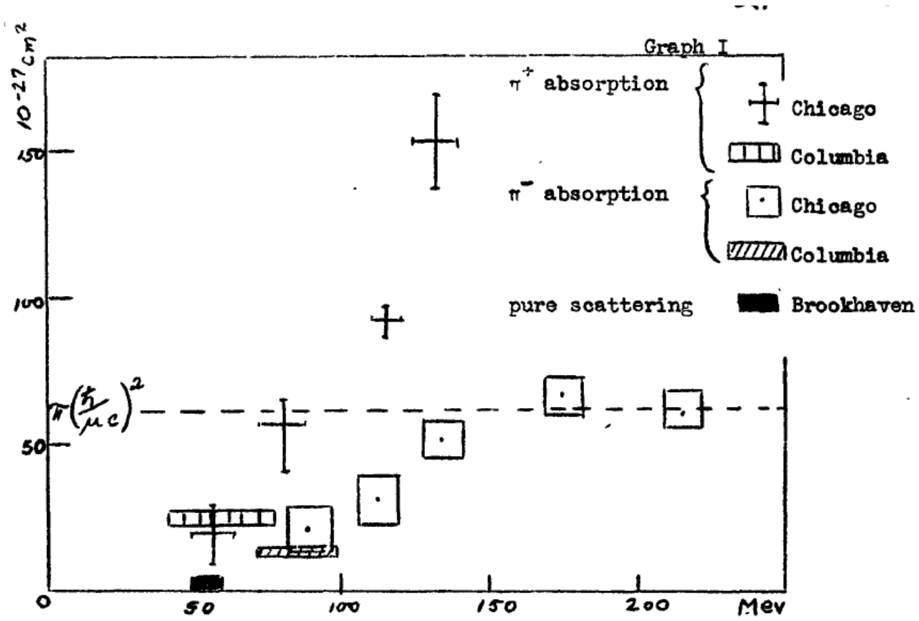
Brueckner and Watson (Jul. '51): analysis of pion production in N-N scattering with partial wave analysis for angular momentum and (a novelty!) isospin
----> partial wave analysis and isospin were both well-known in nuclear theory, yet Brueckner and Watson (and some Japanese theorists) were the first to put them together to analyze experimental results

Kenneth Case - young Post-Doc from Harvard (Schwinger), Princeton, Berkeley

Brueckner and Case (Sep. '51): analysis of π-photoproduction - partial wave analysis with isospin + assumption of a „isobar“ (excited state of proton) enhancing the cross section for (s=3/2,I=3/2)
---> isobars were a well-known element of the strong coupling theories of nuclear interactions (~ 1940), but Brueckner and Case (and some Japanese theorists!) were the first to use them to analyze experimental results

Brueckner (Dec. '51): analysis of Chicago data on πN scattering:

- partial wave analysis, isospin, isobar
- use of the Wigner-Eisenbud parametrisation (Breit-Wigner formula) of the energy dependence of (nuclear) resonance scattering to fit πN scattering



the Breit-Wigner formula was well-known in nuclear theory (chain reactions), but Brueckner was the first to use it to analyze experimental results

Brueckner's proposal is well received by the Chicago group, especially by Enrico Fermi, who introduces it at the 2nd Rochester Conference (Jan. '52), adding to it the 9:2:1 prediction making it instantly famous among both experimentalists and theorists

Some tentative generalizations from this case study:

- around 1950s experimenters were interested in pion production and scattering, but no established theorists were interested in trying to provide numerical predictions for their experiments...
- ...so that PhD-students and young Post-Docs were doing this „service“
- the theories developed so far for pion-nucleon interactions (Yukawa, strong coupling...) were not capable of providing a quantitative or qualitative connection to experiment...
- ...but there was a wealth of theoretical practices from data analysis in nuclear and scattering theory which could be (but apparently had so far not been) tapped for analysing higher-energy phenomena
- young U.S. theorists (and Japanese ones) were the first to look in that direction - from the "periphery" of the community?
- once the step was taken, renowned theorists (e.g. Fermi) immediately followed
- the concept of "(particle) resonance" only slowly emerged in the 1950s from the combination of isobars, Breit-Wigner "peaks" (and more)