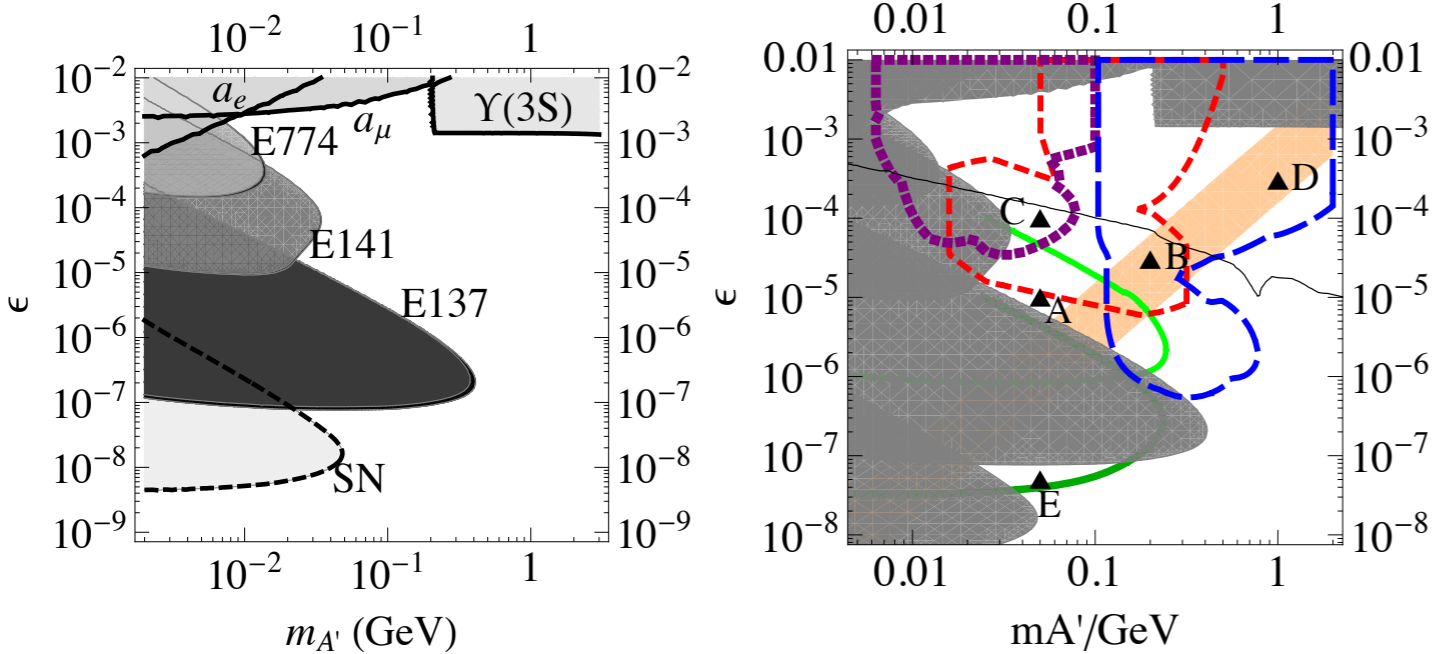


Bj Searching for Hidden Sectors

Natalia Toro



Dark Beginnings



me

Rouven
Essig

now at
Stony Brook

Philip
Schuster

now at
SLAC

In 2009, three Stanford/SLAC postdocs were very excited about a class of models with light, weakly coupled force carriers.

Dark Beginnings

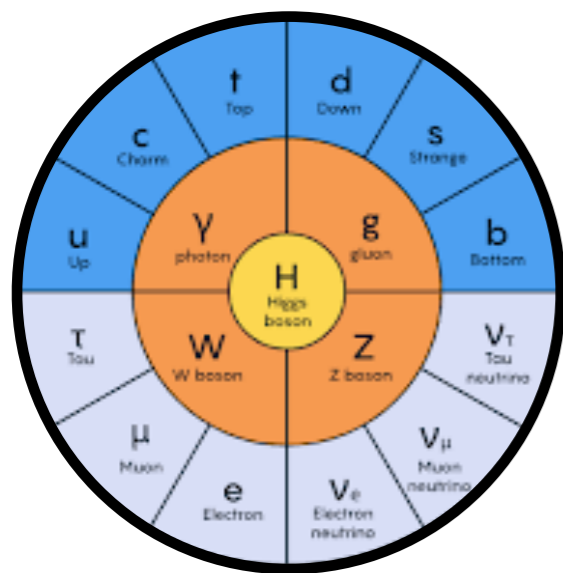


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In 2009, three Stanford/SLAC postdocs were very excited about a class of models with light, weakly coupled force carriers.



Standard Model

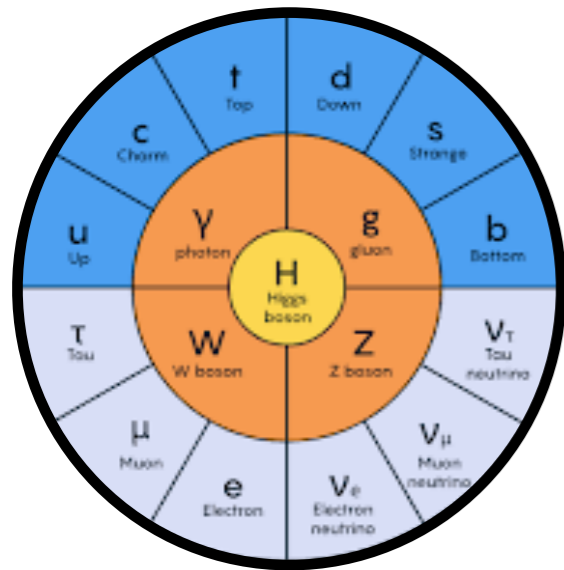
+ 1 massive vector boson A'

generically **mixes** with photon ($\epsilon F^{\mu\nu} \partial_\mu A'_\nu$)

80's: Holdom, Okun,
Galison and Manohar

→ electric charges
couple to it with
strength ϵ

Dark Beginnings

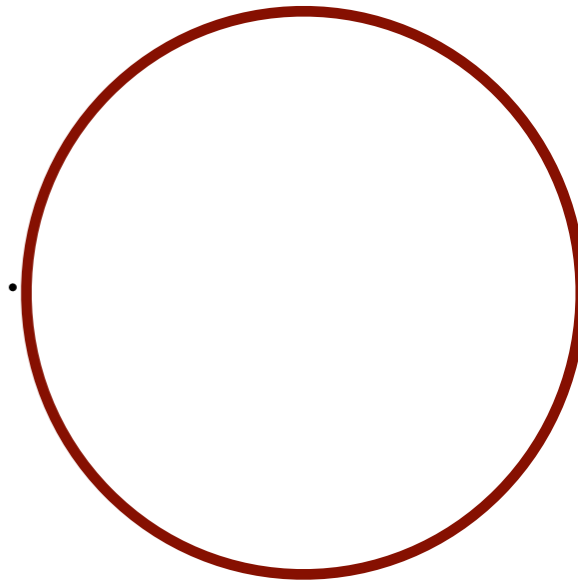


Standard Model

massive vector boson A'

$$\epsilon F^{\mu\nu} \partial_\mu A'_\nu$$

Natural **bridge** through which matter neutral under familiar forces (including dark matter?) could interact with familiar matter



Dark matter sector?

Rocketed to prominence with 2008 papers (Arkani-Hamed-Finkbeiner-Slatyer-Weiner and Pospelov-Ritz) invoking an A' with $\lesssim \text{GeV}$ mass to explain several dark matter anomalies – similar interactions studied by Fayet and Boehm in 2003

Dark Beginnings

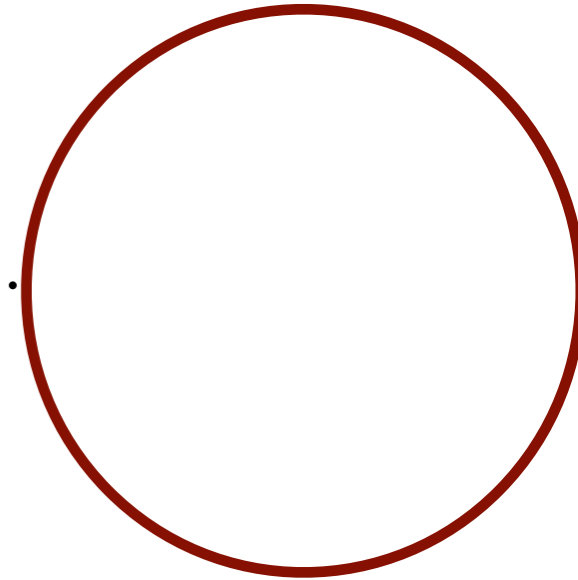


Standard Model

massive vector boson A'

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Dark matter sector?

Shocking claim: new physics in a **very** well-studied mass range — the realm of light-flavored mesons!

Hidden by the relative weakness of its coupling, but still copiously produced at high-intensity accelerators.

First Contact

 From: Michael Peskin 2/14/2009

You will notice that Bjorken was an (experimental) co-author on the first two papers. BJ has a soft spot in his heart for this physics. You should write to him.”

 From: Philip Schuster 4/10/2009

Dear Professor Bjorken...

A great way to search for these are with beam dump experiments... somewhat similar to beam dump searches for axions, although there are some important differences.

It would be really great if we could meet and talk with you, not only about past experiments that have been done, but also about possible future ones.

Unfortunately for us, bj was driving to Driggs the next day...

A Curious Collaboration

The SLAC Sector



The Driggs Sector



We posted our paper to the arXiv in early June, after two months of phone calls and emails.

bj was back in late June, but we were traveling — so we didn't actually meet until September.

By that time, our remote collaboration with bj had already profoundly influenced how all of us approach physics.

✉ Subject: bj in the dumps (4/17/09)



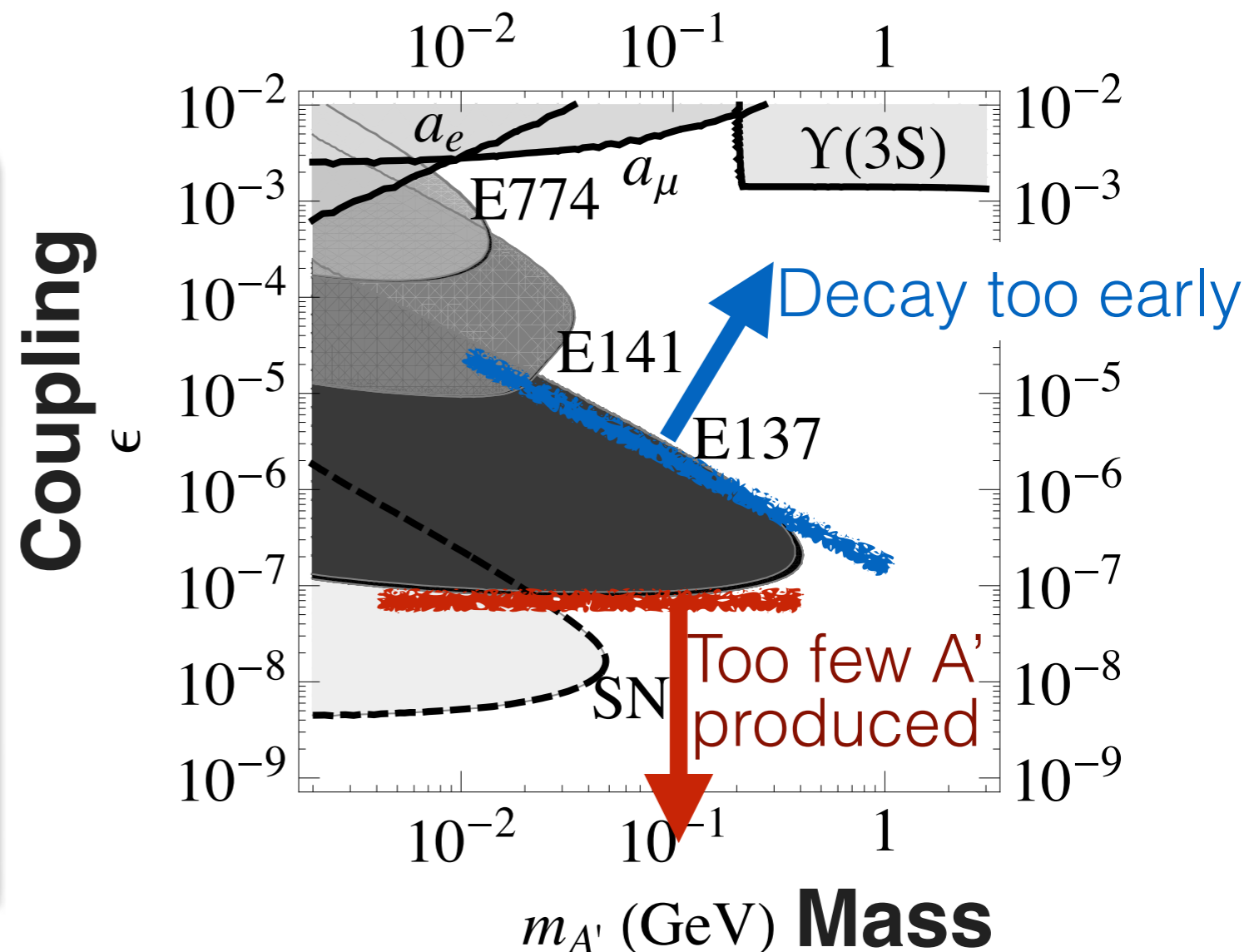
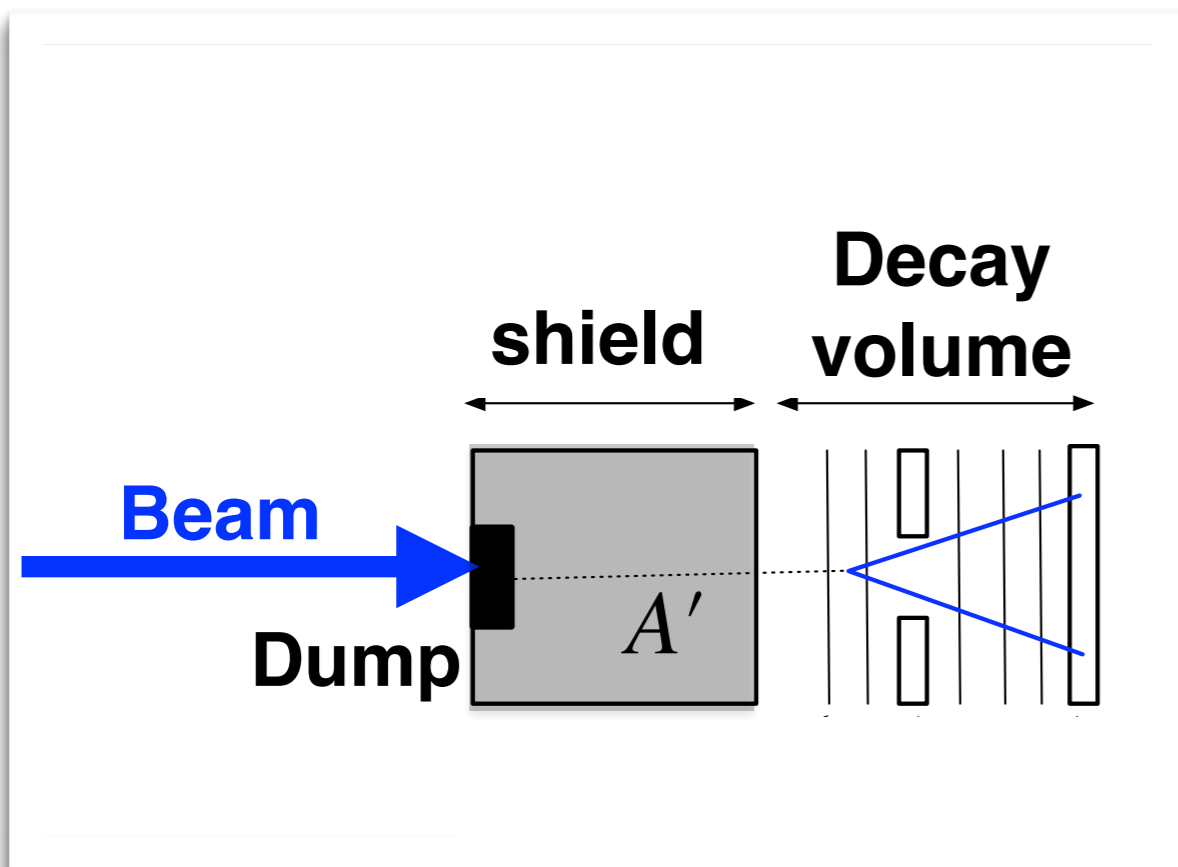
How I remember the early rhythm of our collaboration:

- We sent bj an email with results of several days' calculations and asked to talk on the phone.
- bj's reply (usually with a colorful self-deprecating subject line) compared our results with what he calculated over breakfast, and proposed a time to talk in between his day-long hikes in the Tetons.
- Between phone calls, we scrambled to understand experimental terms (e.g. the virtues of "small angle stereo" configurations in silicon strip detectors) that bj used, to reconstruct experimental scenarios from his verbal descriptions of drawings, and to calculate their signal yields before our next discussion

It was delightful, because we were ***learning all the time*** and ***could just barely keep up.***

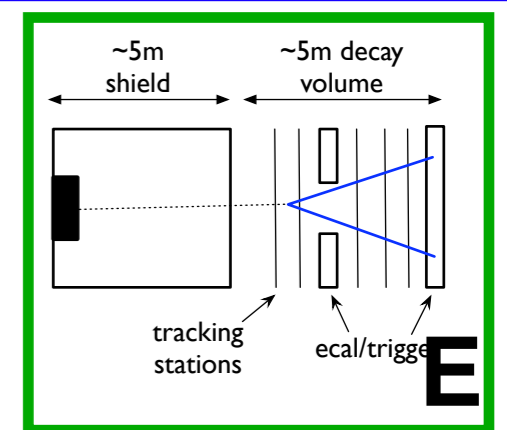
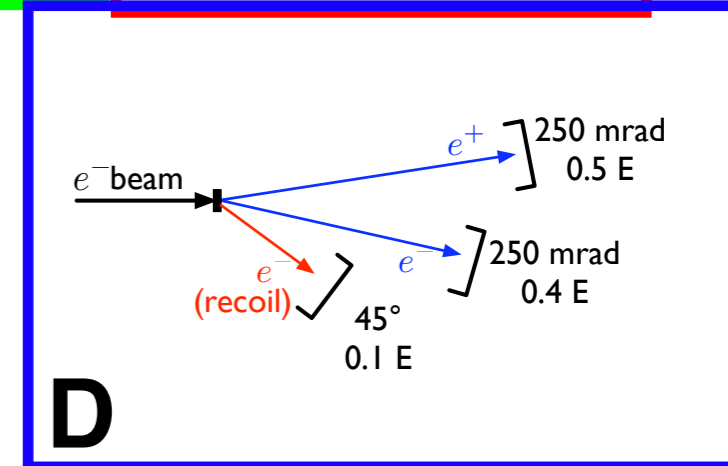
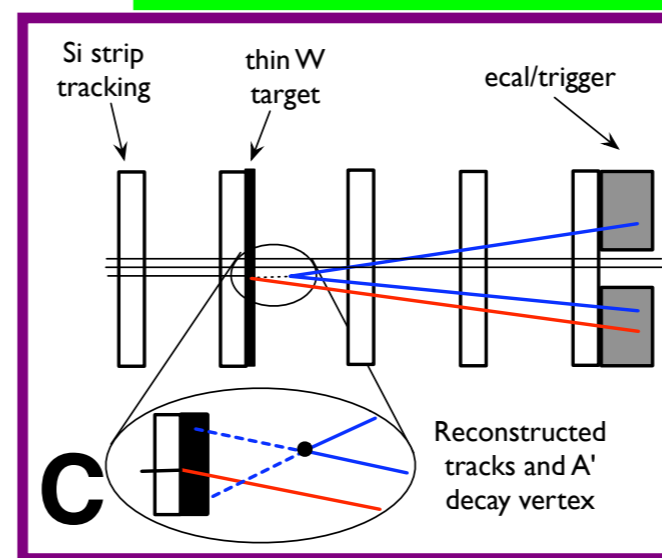
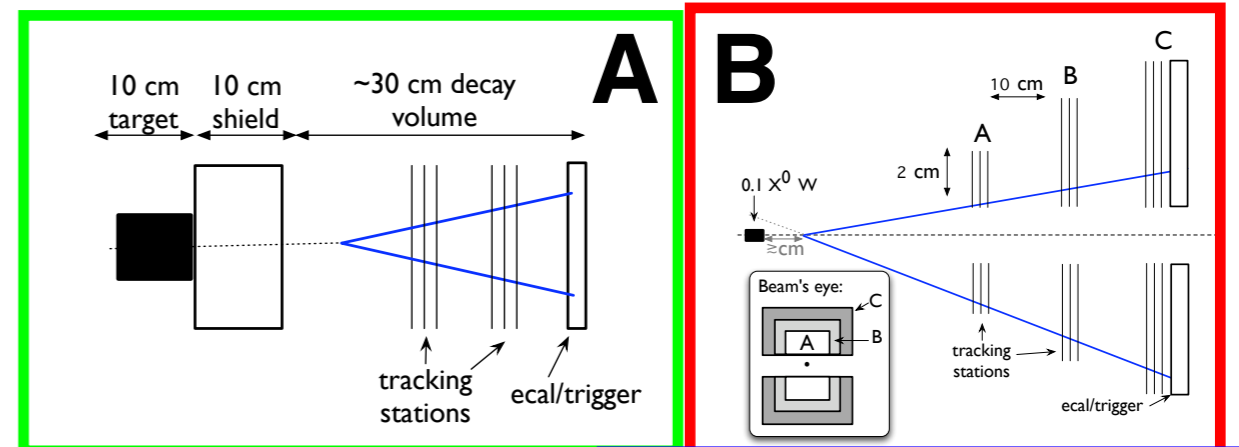
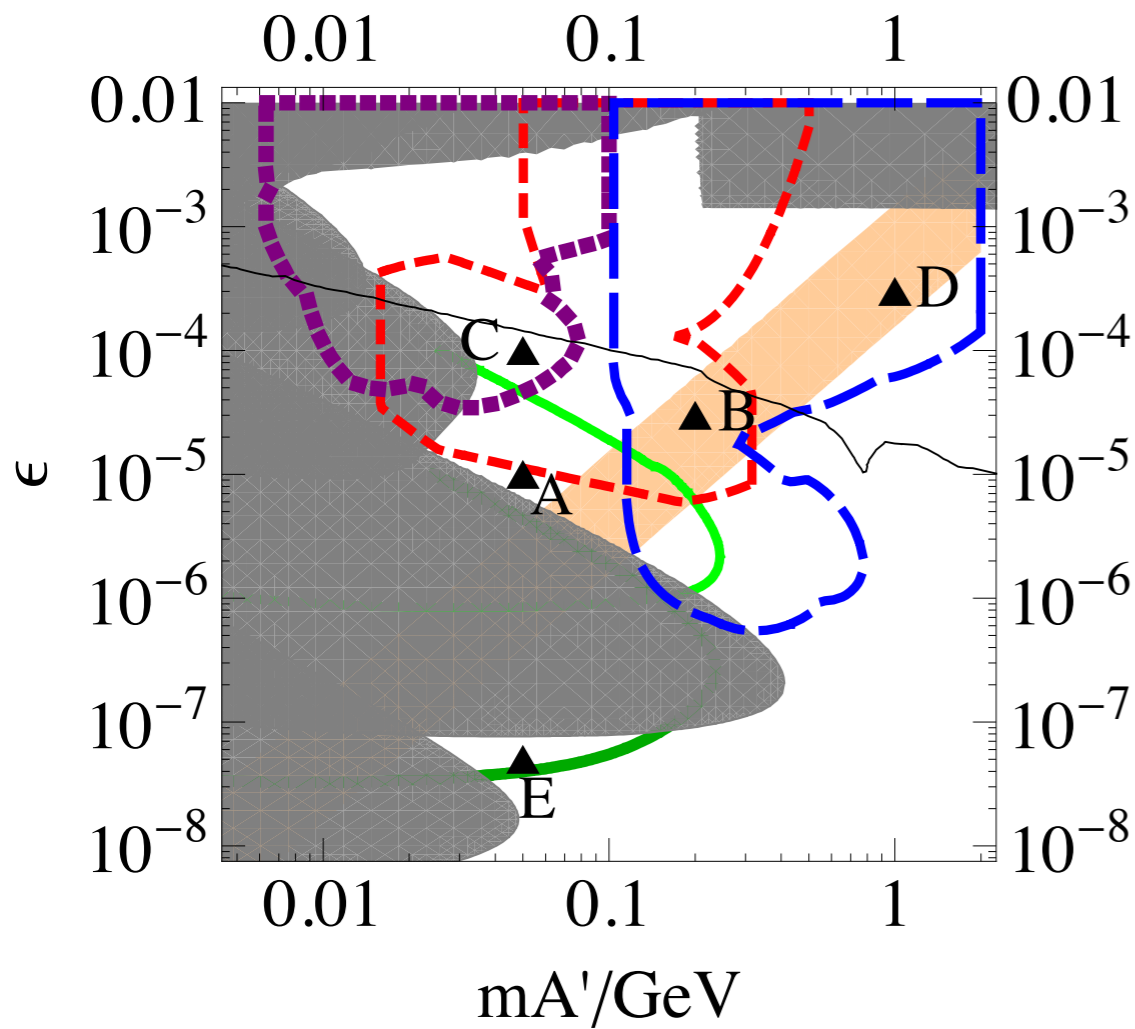
Subject: b_j in the dumps (4/17/09)

The old beam dump experiments, including bj's own E137, explored a lot of the interesting parameter space! But there were also large swaths they couldn't reach.





Subject: jlab – 4/30/09



Our paper focused on ideas to cover the short-lifetime parameter space – broadly, spectrometer experiments at a high-rep-rate beam, and we focused increasingly on on JLab.

✉ Subject: bj in the dumpster – 4/23/09

✉ Subject: bj crawling out of the dumpster



Overnight I recognized a huge background which I should have seen from the getgo. *[Described the background from two Coulomb-scattered electrons hitting the calorimeter at the same time...and an approach to mitigate it]* So far I do not see the problem as a killer, but it certainly is **one of the first things that needs to be thought through well.**

bj ***thought through the physics*** of experimental issues like backgrounds and detector resolutions, in a way unlike any other theorist I've met.

Of course, one needs detailed simulations eventually (and as John Jaros taught me, the factors of 2 always go the wrong way) but once you understand the dominant effects, basic calculations get you in the ballpark.

✉ Subject: RE: Large angle search, magnets, backgrounds...etc 4/29/09

A general comment--we should not try to design a full experiment ourselves. That is for the proponents; they should put their stamp of originality on it and...identify strongly with the design and implementation from start to finish. If that is followed, the product is sure to be better. As I see it, we only have to go far enough to make sure that we don't suggest a program that is patently unrealistic.

bj knew a lot of physics – **and a lot of physicists!**

We benefitted greatly from bj's phone conversations with old friends and discussions on cross-country roadtrips. His example led us into serious discussions with experimentalists at JLab (especially Bogdan Wojtsekhowski, Stepan Stepanyan) as well as SLAC (John Jaros, ...) that grew into collaboration on proposals for APEX and HPS.

Subject: talking later, and name ordering

When it came time to publish, bj had misgivings about ordering the author list alphabetically, which would put him first.

We thought he deserved it — but rather than argue, we accepted his justification that it would make for a good acronym.

New Fixed-Target Experiments to Search for Dark Gauge Forces

James D. Bjorken,¹ Rouven Essig,¹ Philip Schuster,¹ and Natalia Toro²

¹*Theory Group, SLAC National Accelerator Laboratory, Menlo Park, CA 94025*

²*Theory Group, Stanford University, Stanford, CA 94305*

(Dated: June 3, 2009)

Dark Forces Workshop

bj attended the “dark forces” workshop we organized at SLAC on hidden sector searches. He graciously co-chaired the fixed-target working group with John, and summarized their findings.



How? Possible Experiments

Data Mining:

- J Lab Existing Data $eA \rightarrow A' \rightarrow e + e - X$ (6GeV) $.2 < m < 2\text{ GeV}$ $\epsilon > 10^{-3}$
- BLAST?
- Proton experiments? Miniboone, Microboone analyzing...
- Muons (COMPASS, MINOS)

J Lab Future Proposals with Existing Apparatus

- 50 MeV up, $\epsilon > 10^{-4}$? Ticking clock (2 mo. to propose)
- Hall C: muon wall behind Qweak?

New J Lab Experiments

- FEL – MIT/Berkeley (LOI this fall, also Mainz) $10 < m < 80\text{ MeV}$, $\epsilon > 10^{-3.5}$
- Hall B – JLab/SLAC $100 < m < 600\text{ MeV}$, $\epsilon > 2 \cdot 10^{-5}$ (gap $\sim 10^{-4}$)

New beam dump experiments: $m < 100\text{ MeV}$, $\epsilon \sim 10^{-5}$ or $10^{-8} - 10^{-7}$

Positron Experiments

- e^+ on H: $5 < m < 30\text{ MeV}$, $\epsilon > 10^{-4}$ (indep. of decay mode)
- OLYMPUS internal target $e p$ elastic (data taking 2012)

Resonant Extraction from Damping ring experiments:

- Possible opportunities at SLAC, CESR, Bonn, MAMI (cw)

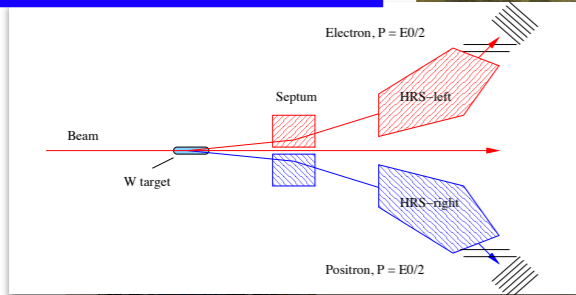
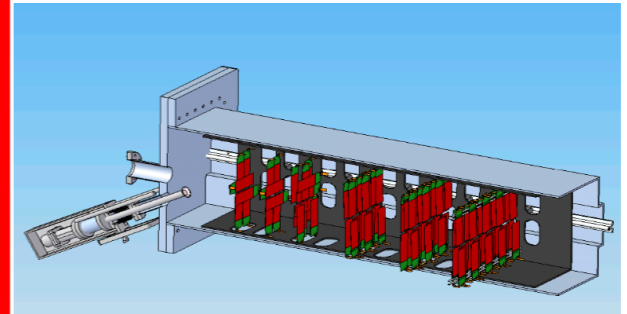
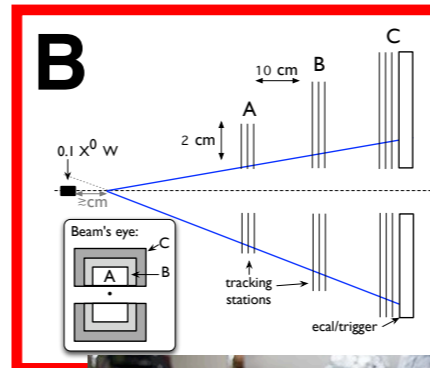
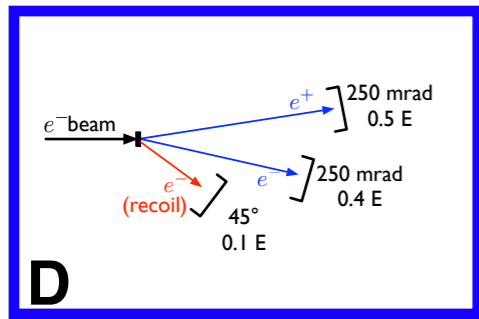
Conclusions

Heavy Photon Searches

Two Thumbs Up

Peter Fisher:
“People will look back and point to this workshop as the place where something big started”

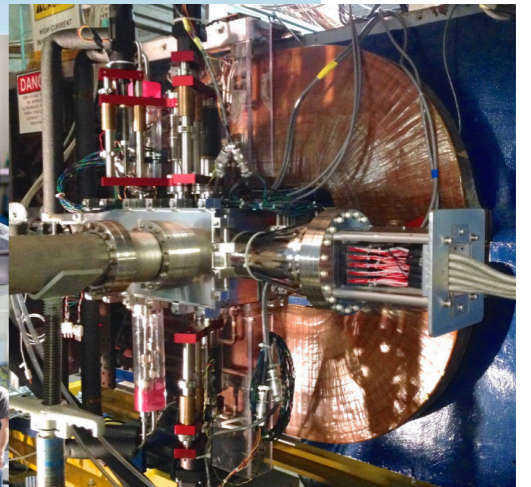
From the back of an envelope to the beamline...



APEX



HPS



Bj's infectious enthusiasm for this science played a major role in getting these program off the ground, and his model of going out and talking about it broadly inspired us to do the same.

He gave us valuable advice, both technical and political, as we became co-spokespeople with Bogdan Wojtsekhowski of the APEX experiment at JLab and connected John Jaros and Stepan Stepanyan to work on HPS.

A long tail

Rouven, Philip and I have continued to think about new directions for experiments, and work closely with experimentalists to realize them.



BEST was on the leading edge of a much broader movement towards theorists' creative engagement with new experiments.

Snowmass2021 Theory Frontier: Theory Meets the Lab

[arXiv:2203.10089](https://arxiv.org/abs/2203.10089)

Rouven Essig^a, Yonatan Kahn^{b,c,d}, Simon Knapen^{e,f}, Andreas Ringwald^g, and Natalia Toroⁱ

Basic Research Needs for Dark Matter Small Projects New Initiatives

P5 To preserve this agility, the panel recommends that the Department of Energy (DOE) create a new, competitive program named **Advancing Science and Technology through Agile Experiments (ASTAE)** to support a **portfolio of small-scale and agile experiments**.

Another amusing theory-experiment connection

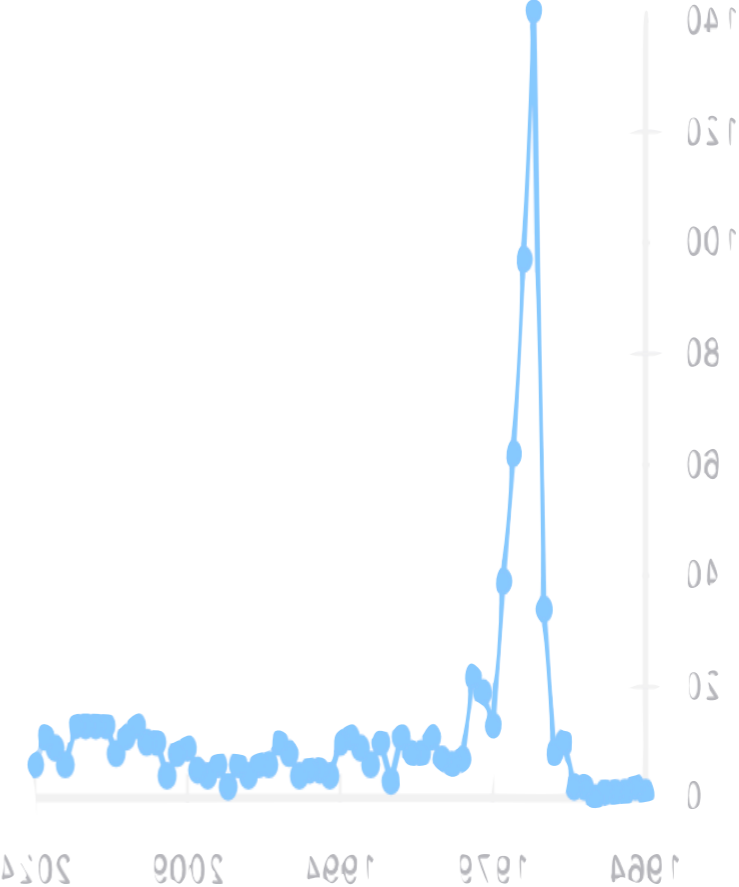
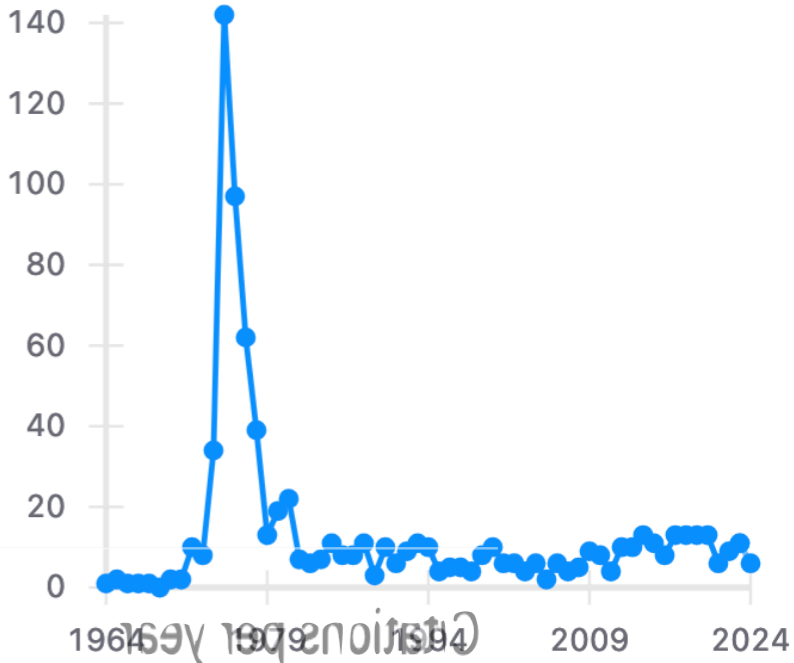
Elementary Particles and SU(4)

J.D. Bjorken (Bohr Inst.), S.L. Glashow (Bohr Inst.)
1964

3 pages
Published in: *Phys.Lett.* 11 (1964) 255-257
DOI: [10.1016/0031-9163\(64\)90433-0](https://doi.org/10.1016/0031-9163(64)90433-0)
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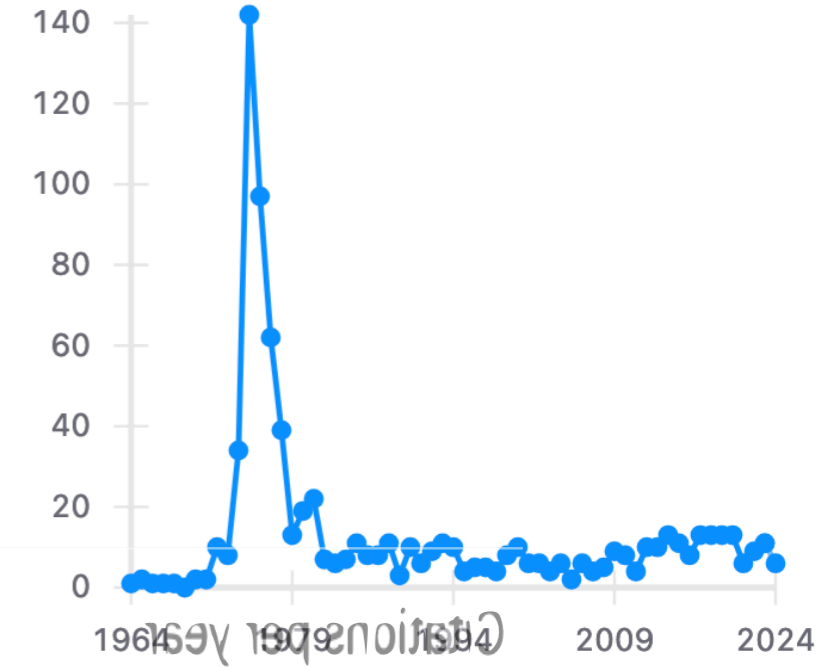
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PHYSICAL REVIEW LETTERS

2 DECEMBER 1974

Experimental Observation of a Heavy Particle J^{\dagger}

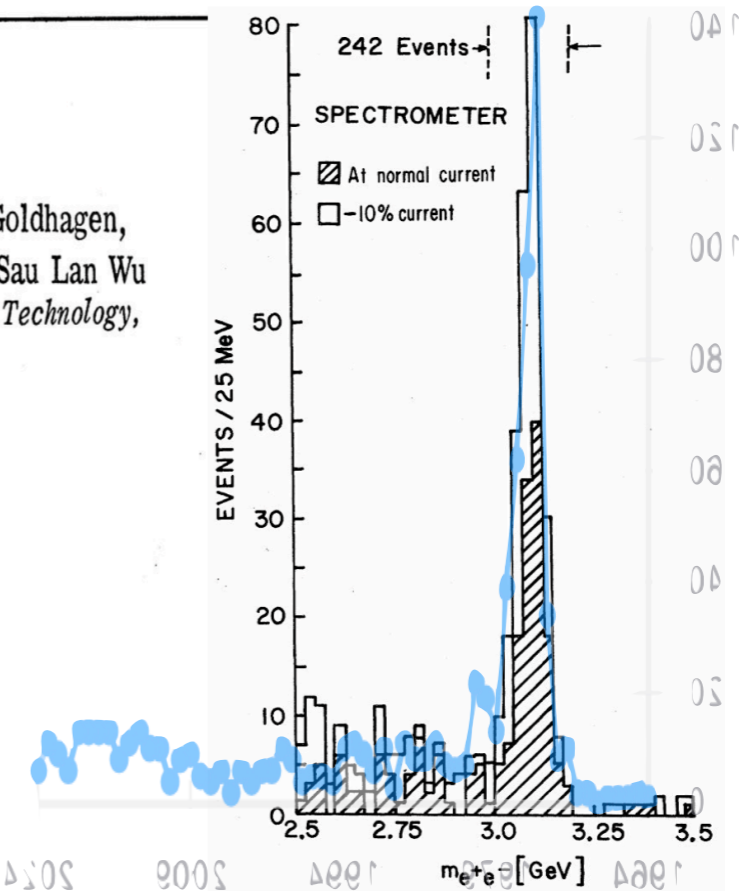
J. J. Aubert, U. Becker, P. J. Biggs, J. Burger, M. Chen, G. Everhart, P. Goldhagen, J. Leong, T. McCorrison, T. G. Rhoades, M. Rohde, Samuel C. C. Ting, and Sau Lan Wu
Laboratory for Nuclear Science and Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

and

Y. Y. Lee

Brookhaven National Laboratory, Upton, New York 11973

(Received 12 November 1974)



A long tail

Bj's approach influenced each of us – and how we do physics.

It was from bj that I learned the great value of talking about physics ***especially*** across perspectives and domains of expertise.

I learned from bj's example that “theorist” and “experimentalist” (and subspecies thereof) ***are best thought of as labels of what we bring to the table, not as boundaries on what we can work on.***

His broad intellectual legacy is a testament to these lessons.