MUON COLLIDER WORKSHOP

SUMMARY

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HISTORY AND PROPHESY

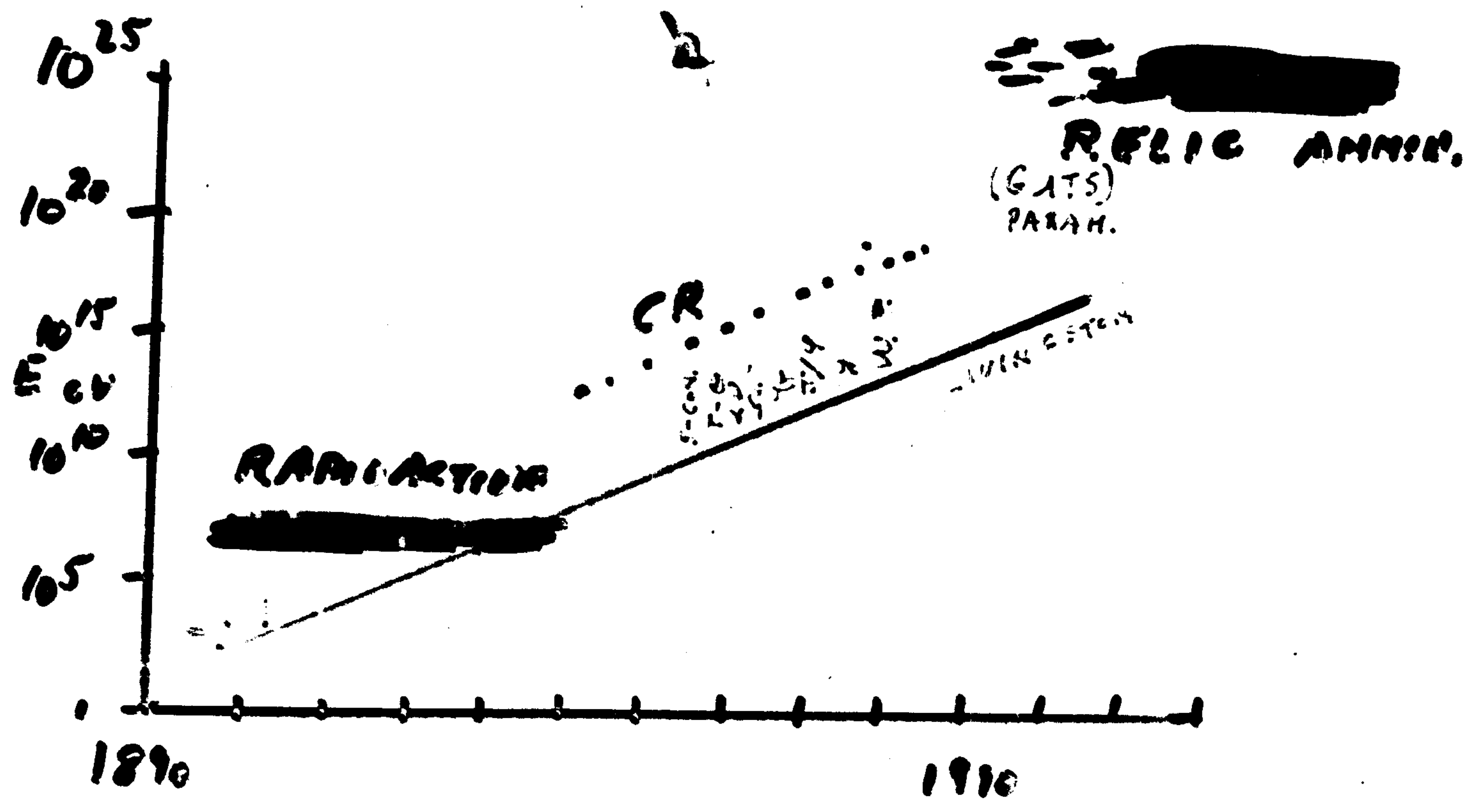
- Prophesy is based on History, of course
- Here is a 1981 prophesy snapshot:

- Comments:
  - we are keeping on the "Auger curve"
  - we risk to get behind on the "Livingston curve"
  - have we started to see New Physics from cosmic rays?
    - Some people think so...

Anyway, the moral applies that competition does not wait for you!

[illegible]

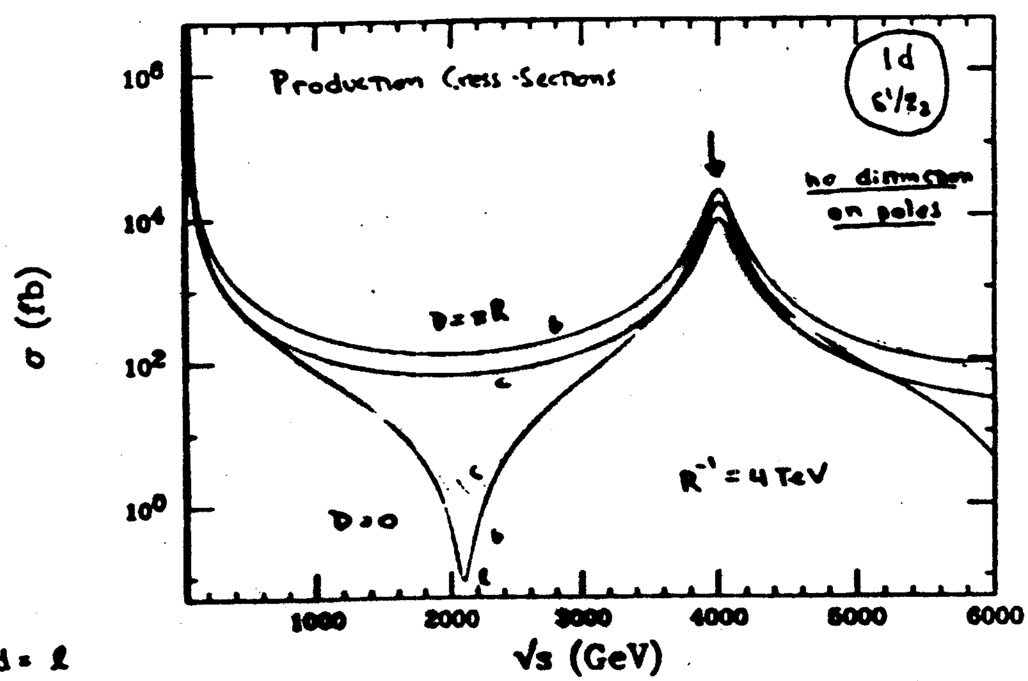
SOME NEW MASS-SCALE PARTICLES MAY BE STABLE; IF SO, FIND SOME. ANNIHILATE THEM: GET ENERGY 10^5–10^{16} GeV. HISTORY



GOOD NEWS: POWERFUL NEW TOOLS ALWAYS FIND SOMETHING.

MAYBE: 1. NUMBER OF NEW PART???!
2. MANY RESONANCES
3. QM IS WRONG.
4. NEW BIG GLORRY THINGS FORMED.
5. ???? → MAKE NEW [illegible]!
6. ..

$\mu^+\mu^- \to f\bar{f}$ collider

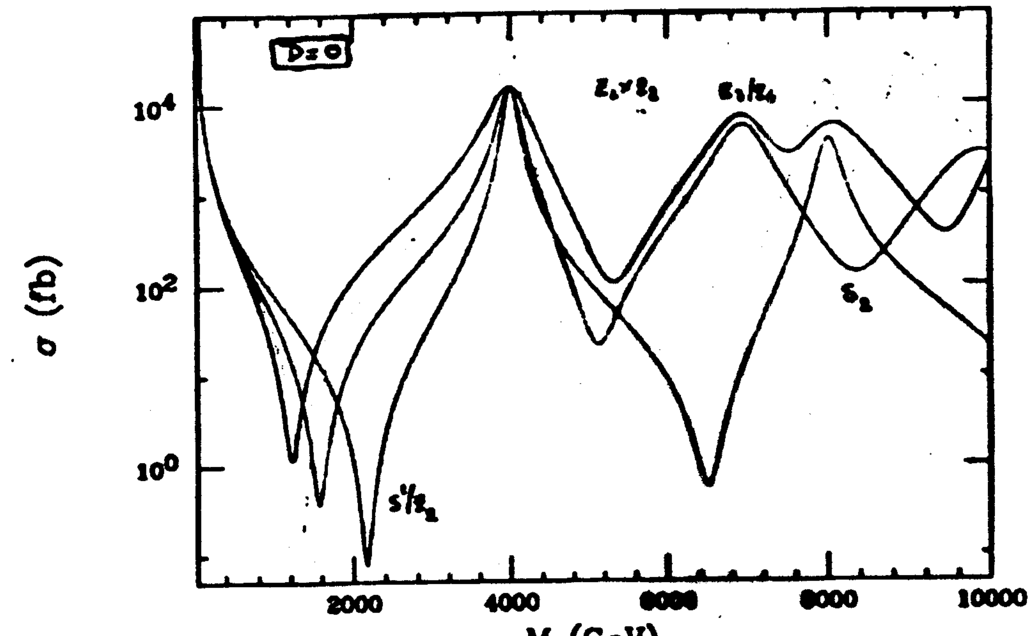


red = l
green = b
blue = b [A-A s]
magenta = c [A-A s]
cyan = c

KK excitation pattern

$\mu^+\mu^- \to e^+e^-$

$M_1 = 4$ TeV
$n_{max} = 5$



More than one extra dimension ??

Model of compactification ??

Keeping on "Livingston curve"

- Generally, discoveries come from more energy
- What is needed next to stay on the curve?
- LHC "reaches" to about 5 TeV.
- We usually increase by factor π
- The next machine should be at 15 TeV (for p-p about 25+25 TeV)
- Luminosity depends on physics, LHC should point the way
- (If no signposts at LHC, maybe hard to sell)

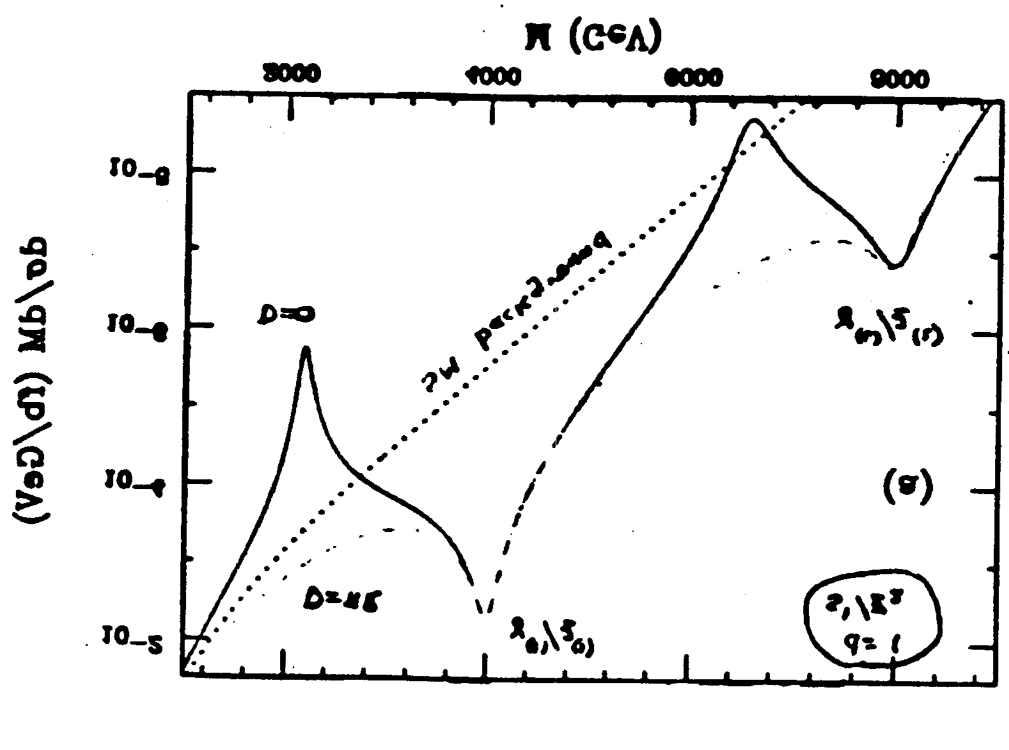
What did we learn from Physics?

- I learned a lot
- Often we have been helped out of a tight spot by Nature, usually in the form of new particles with nice properties:
  - stable and negative
  - just stable
  - long enough lived to move
  - at least forming narrow resonances
  - with characteristic decays
  - more point-like in production than the competition
  - grouped to display evident symmetries
  - with properties important for other science or for society

If Nature is as kind as our (theoretical) physicists

- SUSY is already not bad, as we see in the amazing measurements at hadron machines like the LHC modeled by our theorists
- But they are on the track of new ideas that are particularly friendly to the accelerators:
  - Rizzo curves for Kaluza-Klein vector states
  - Huge cross sections near, as well as on, MultiTev peaks, big lepton decay rates

D = 'distance' between g's and Z's in 5th dimension { Arkani-Hamed, Grossman, Schmaltz



D = 'separation' of g's + Z's in 5th dimension

What do we know about a 15TeV Muon Collider?

- Quite a bit, but not <u>nearly</u> enough.
- Proton drivers can produce and catch lots of muons in a short bunch (maybe enough to get you into various kinds of trouble).
- They can be cooled to some degree by ionization, how much and to what charge density to be studied further.
- They can be stored for a 1000 turns, up to impressive charges.
- It seems that they can be cooled optically in short times and to a high degree. ★ (Zholents)

- **Maintaining 1000 turns in a ring with extreme focusing at an IR is not simple:**

  Carol Johnstone: “an accelerator physicist’s dream, but is it a workhorse?”

  Must we go to axisymmetric focusing?

  –Plasma (Cline)

  –Auxillary beams(Irwin)

  We need more study of these.

  How can we work with smaller beams?

  –Compensation? (Skrinsky)

  » Backgrounds? Collisions? Radiation?(Telnov)

Fresh Looks

- **Electron-positron colliders:**
  - use rings to accelerate if you can, cheaper than linacs
  - when there is too much radiation in the ring, shift to single pass collisions(Tigner/Richter)
  - radiation in the collisions is the next limit

  Muon Colliders:
  - introduced to gain 1000 turns in a ring, cheaper than a linac
  - when there is too much disruption at the collision (with small beams), shift to single pass collisions(Zimmermann)
  - works because less radiation at collision, go to high disruption for high $\mathcal{L}$

- **Trade offs in single pass(Zholents, Zimmermann)**
  - –we are still accelerating in the ring
  - –profit from small emittance by big disruption
  - –beamstrahlung not a problem for mu (until ?)
  - –small number of particles:
    - •much less background and neutrino radiation
    - •perhaps compensation is ok
      - –less background
      - –single pass, insensitive to brems
      - –small current, collisions not important
    - •same story for focus with plasma or beam, but quads are easier too!
    - •Proton driver can make lots of bunches, get $\mathcal{L}$ up that way too
- **Catch is that lots of laser pulses are needed, so laser cost is an issue (cost *can* come down on this one).**

Real world Scenarios

- We have learned that even though "$1G is not what it used to be" (Bunker Hunt, asked how it felt to lose $4G) it is not so easy to get many $G for a HEP project.
- A very dull story from the LHC is both unexpected a a very poor start on the next machine.
- Rizzo, for example, has given us a very fine scenario: a massive resonance (if not KK, then Z') with 10^4 events per fb^{-1} on the mu-mu peak. If we know that, we can build a 10^{33} machine and upgrade later. Still go for 15 TeV!! That is how we could get in business in a finite time.

Conclusions

- Most of us learned a lot
- Some new ideas came up
- Lots of juicy problems were identified
- The physics ideas look very lively and promising
- The pace of study must be accelerated to settle questions that really can be settled in time to keep the work efficient
- I think it particularly important to move on a demo of the optical stocastic cooling