DETECTOR RECONSTRUCTION: HOW TO FIND A POSITRON

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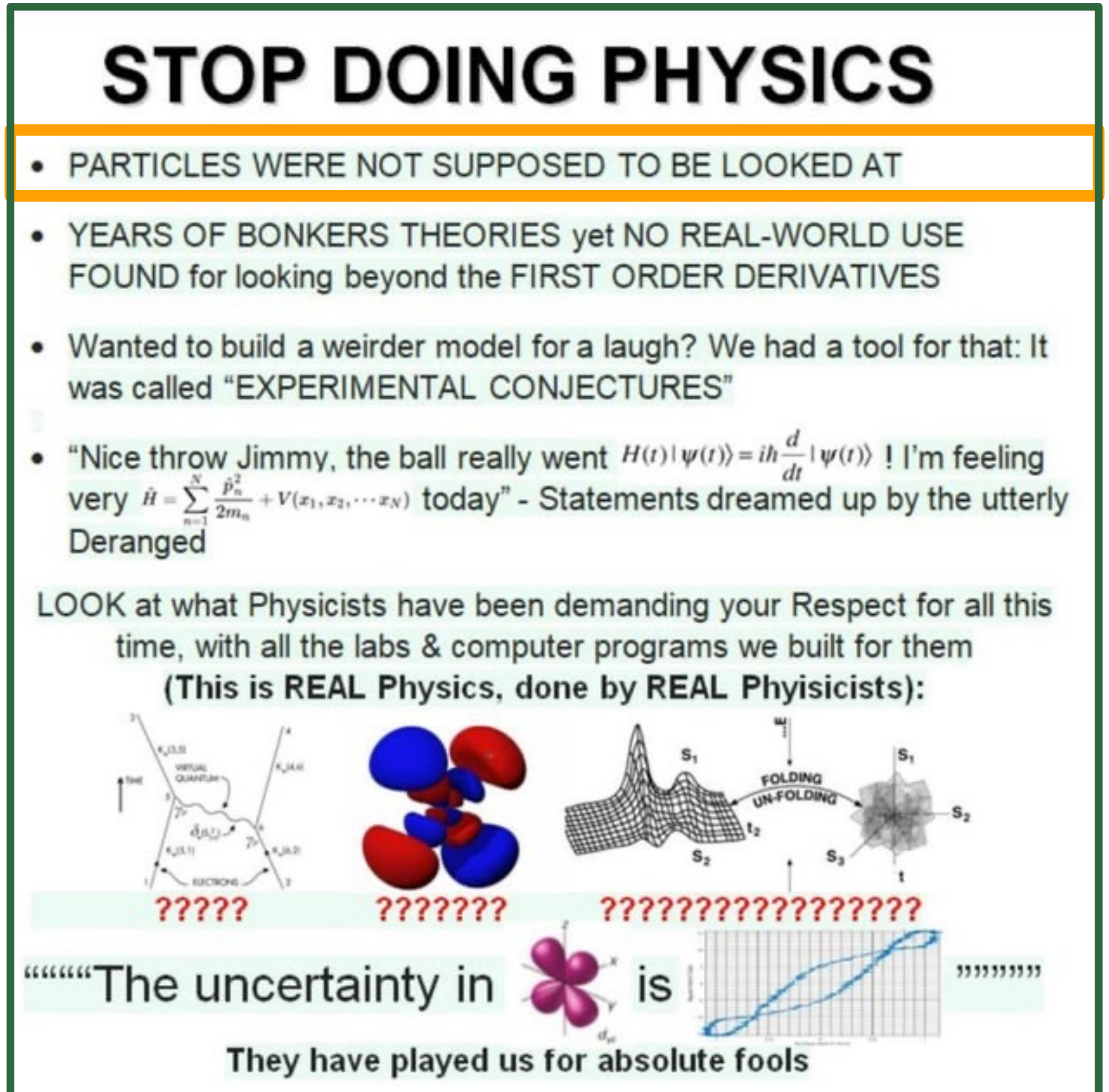
Outline

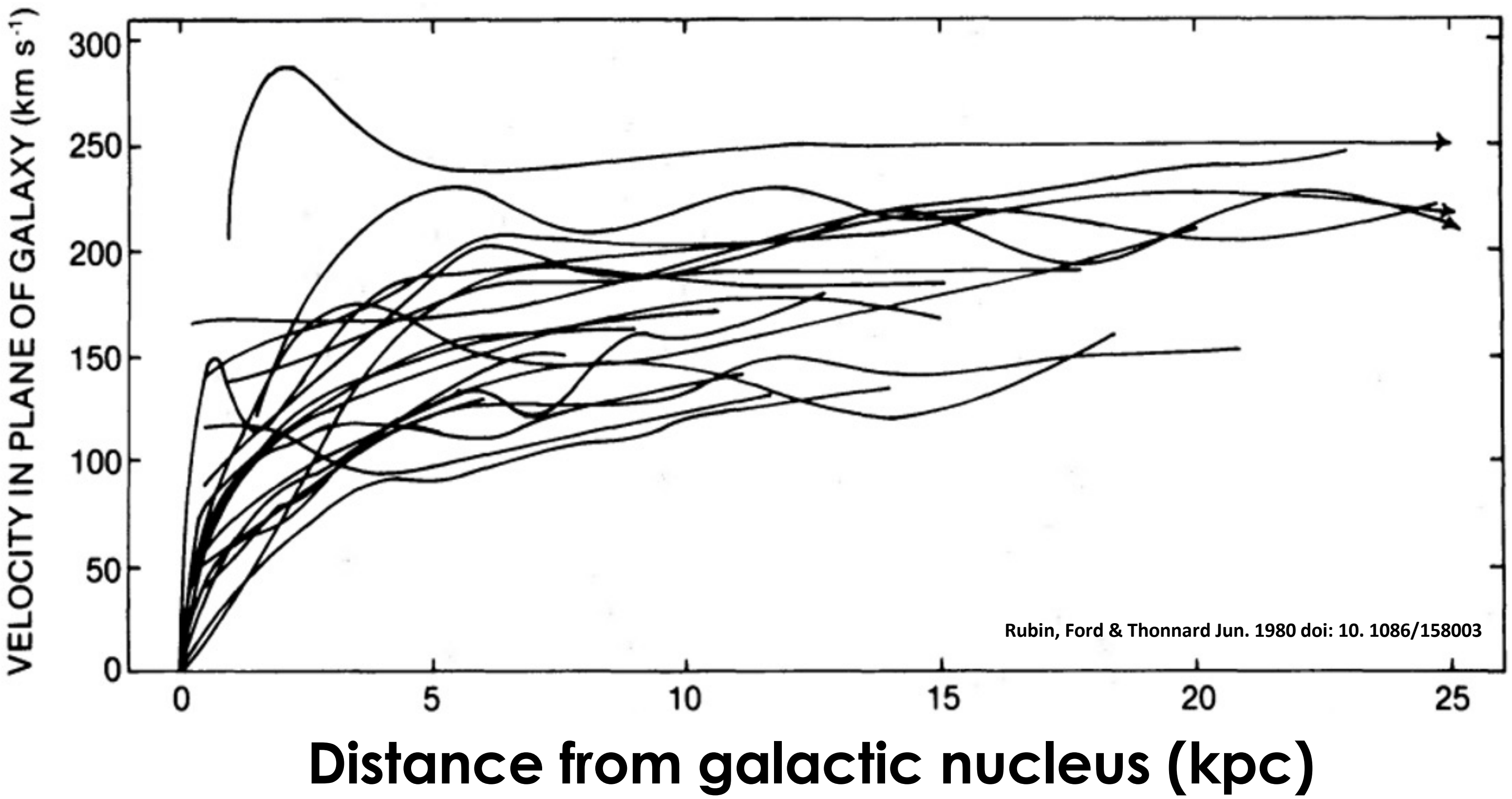
- The physics case
- The PADME setup
- The vetoes
- (Re)construction of physical quantities
- Conclusion



u/BWY9

The dark matter problem

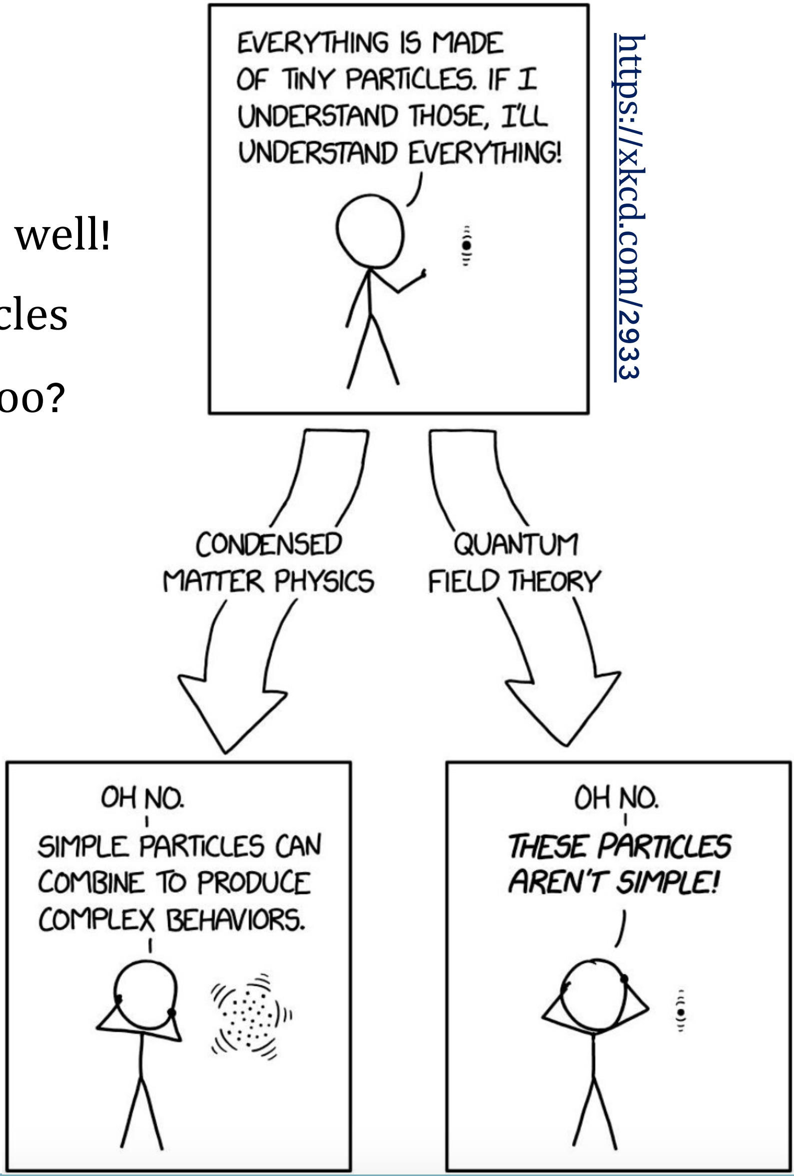
- In 1930s studies of galaxy clusters Zwicky found **no clear mapping** between angular velocity and mass
- By the 1980s there was a large body of evidence showing the same effect



A particle physicist's reasoning

DARK FERMIONS???

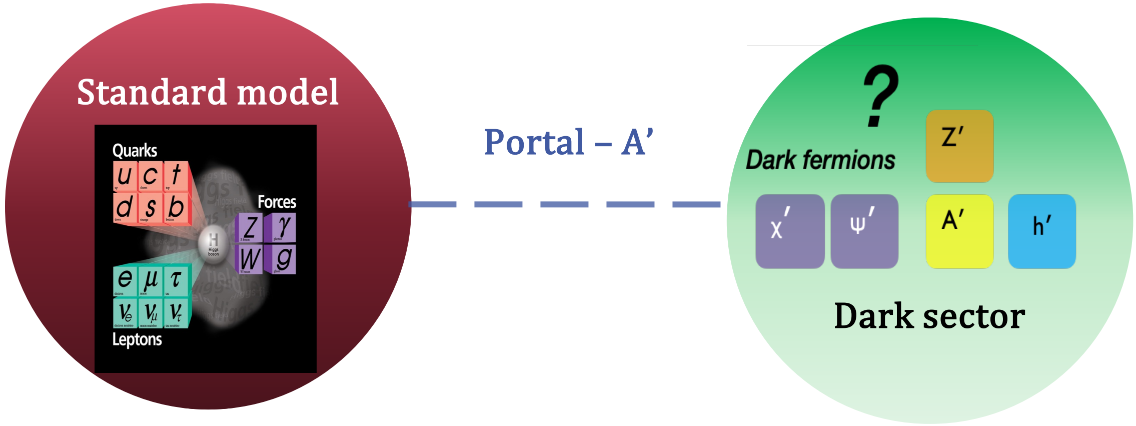
- The standard model works really well!
- Everything (that matters) is particles
- What if dark matter is particles too?



https://xkcd.com/2933

The dark sector

- Assume dark matter exists in secluded “dark sector”
- Interacts with standard model only through exchange of massive “portal particle”
- If the particle has spin 1, it’s known as “**dark photon**” - “$A'/X/\cdots$”
- SM-A' coupling $\epsilon \ll 1 \Rightarrow$ hidden

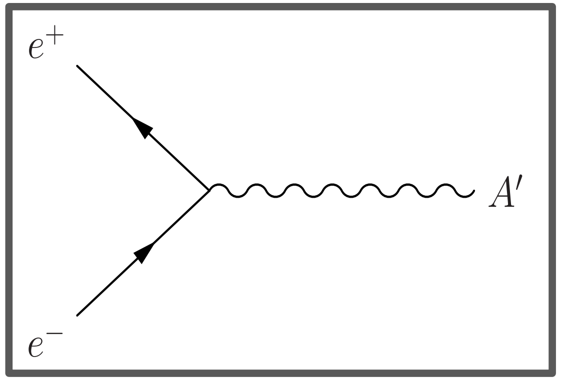


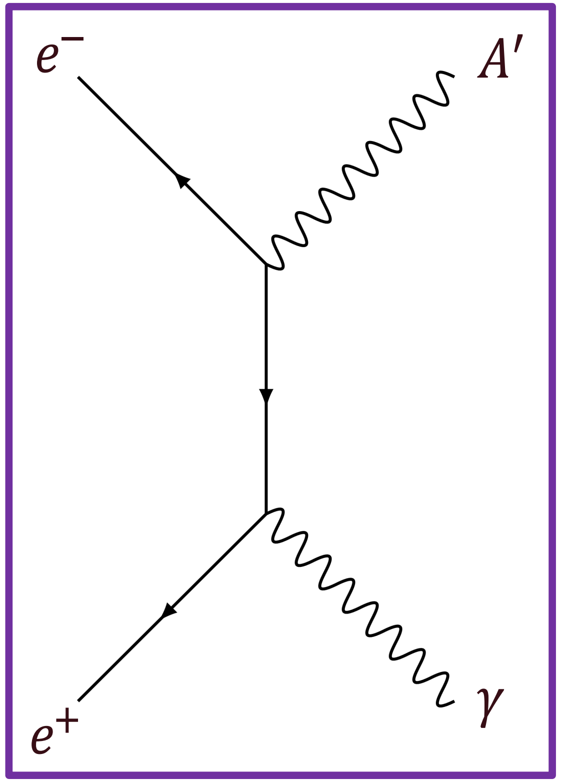
PADME production mechanisms

Assuming production Positron Annihilation

Centre of mass energy $\sqrt{s} \approx 20$ MeV

- Vector portal production at PADME:
  - **Resonant annihilation:**
    $e^+e^- \to A'$
    - Increased production when $\sqrt{s} \approx M_{A'}$
    - Only useful if you know $M_{A'}$
  - **Associated production:**
    $e^+e^- \to \gamma A'$
    - Useful if you don't know $M_{A'}$

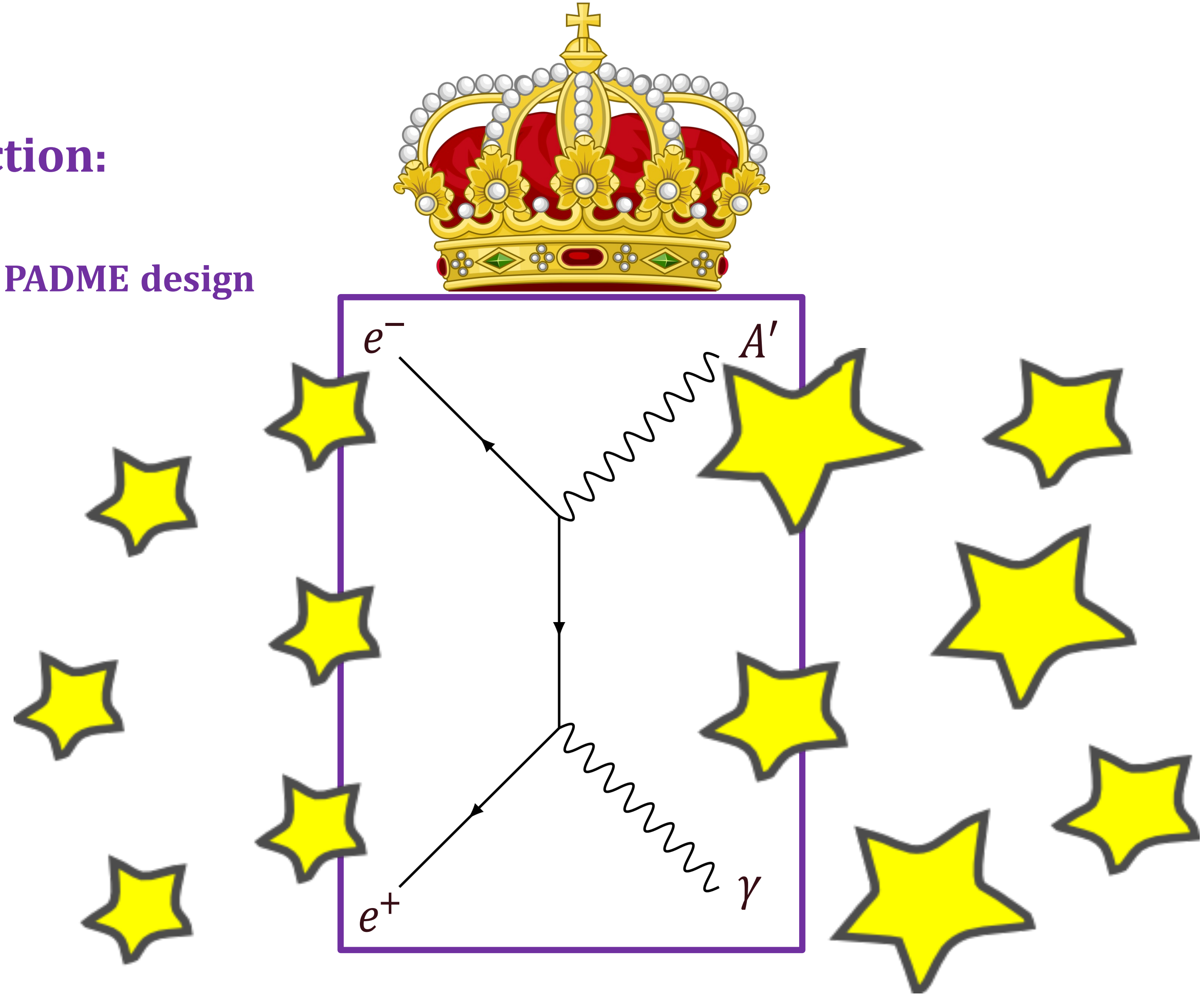




PADME production mechanisms

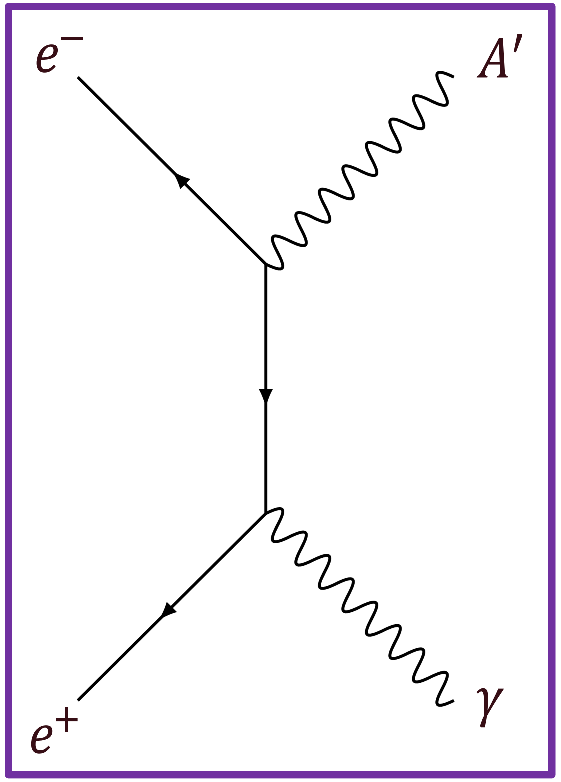
The winner:

- **Associated production:** $e^+e^- \to \gamma A'$
  - **Nominal process for PADME design**



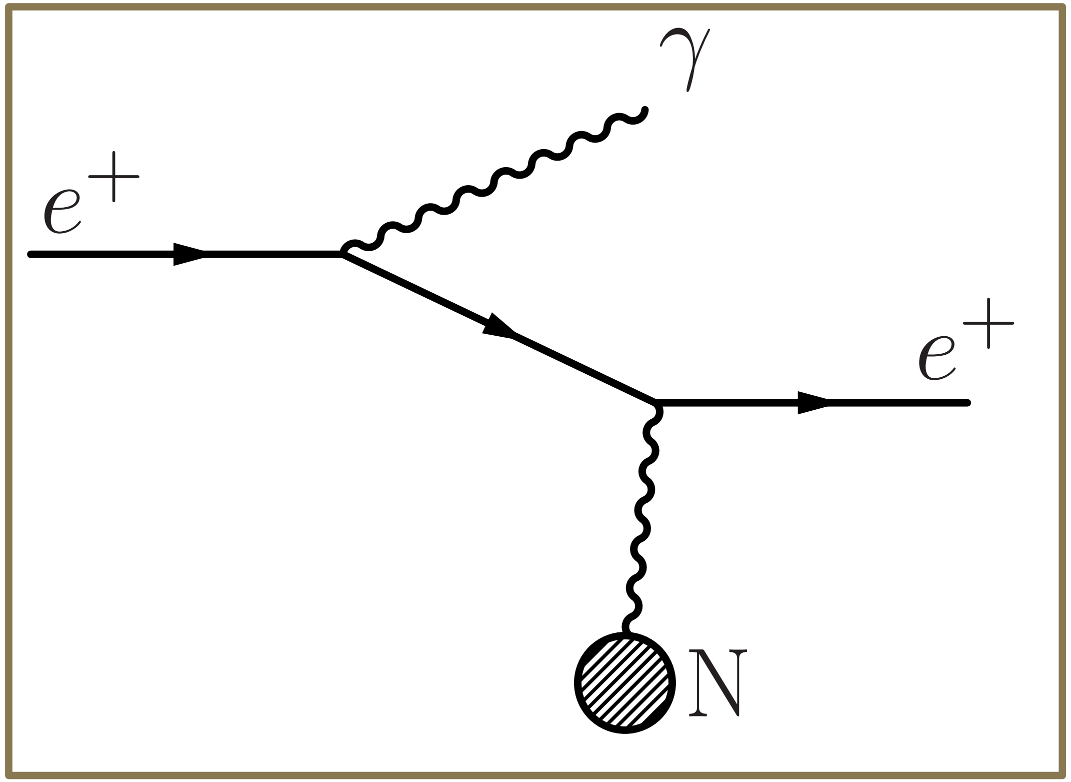
Every rose has its thorn

- Rose = signal ❤️ ❤️ ❤️ ❤️ ❤️
- $e^+e^- \rightarrow \boldsymbol{\gamma} + (undetectable\ stuff)$



- More e^+ undergo **Bremsstrahlung** than any other process
- e^+/γ not necessarily distinguishable

- Thorn = background 😭 😭 😭 😭 😭
- $e^+ + Nucleus \rightarrow e^+\boldsymbol{\gamma}$



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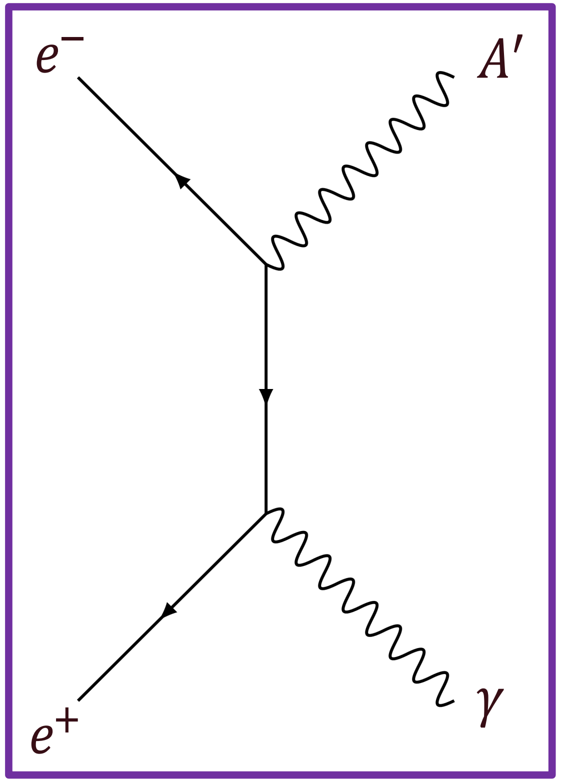

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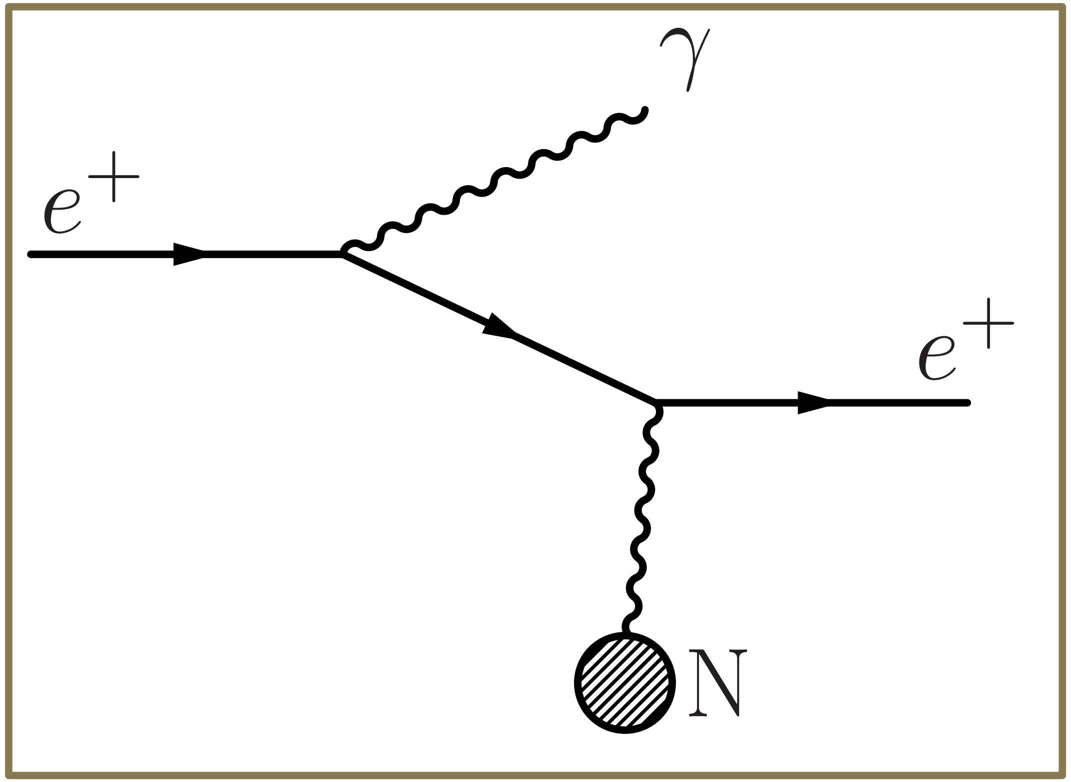
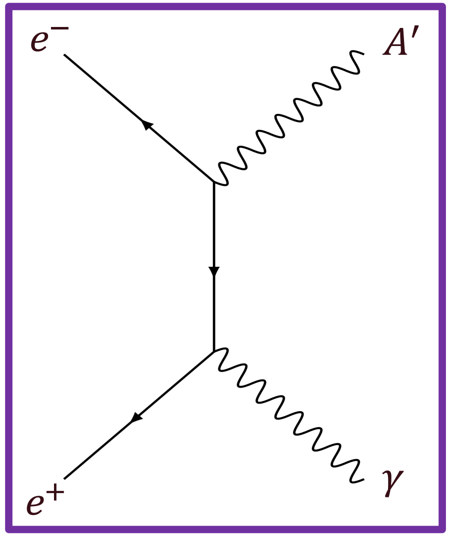
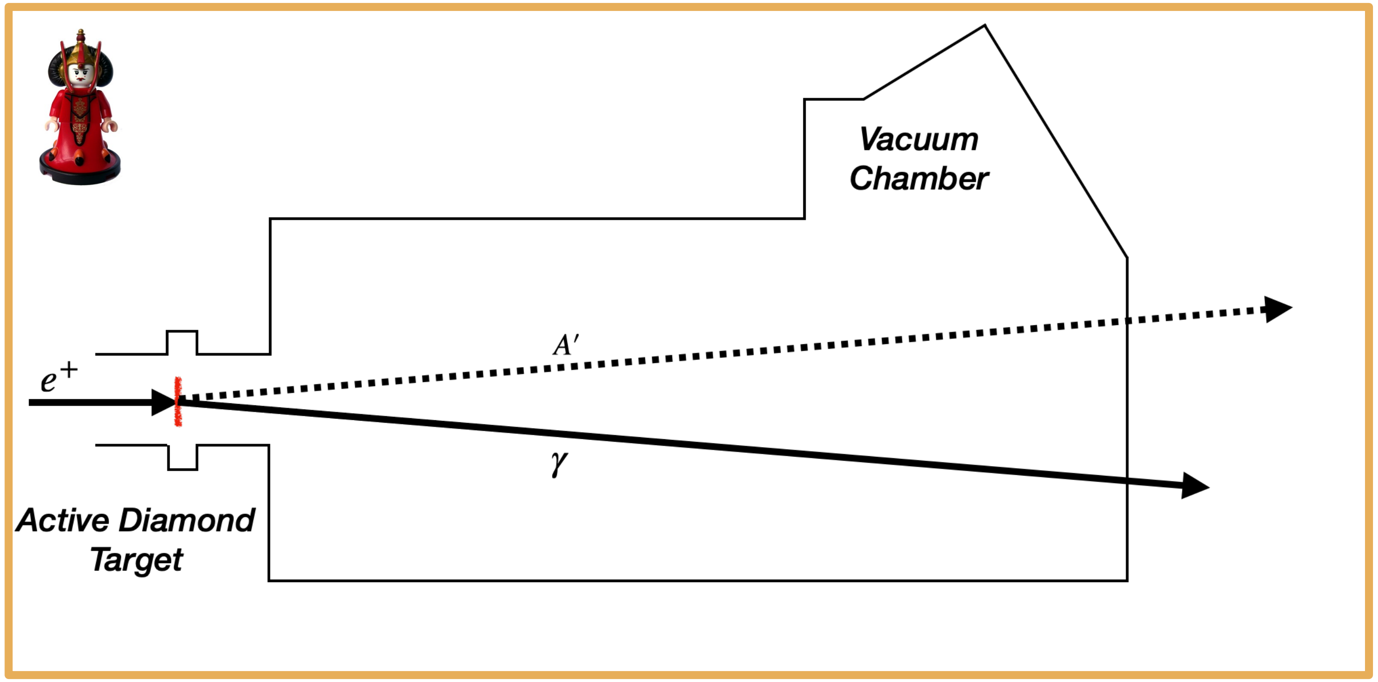


Luckily, this is a "reducible" background!

Designing the experiment

- **Target**



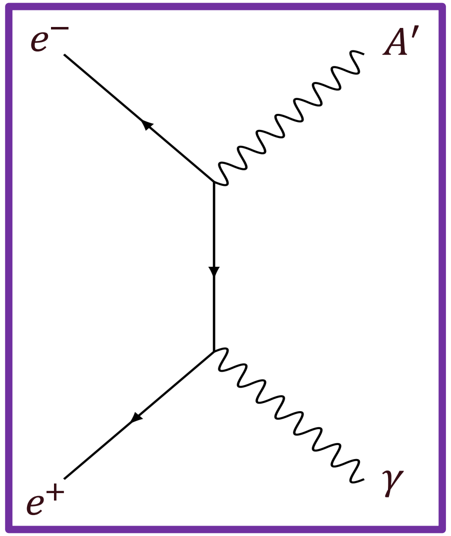


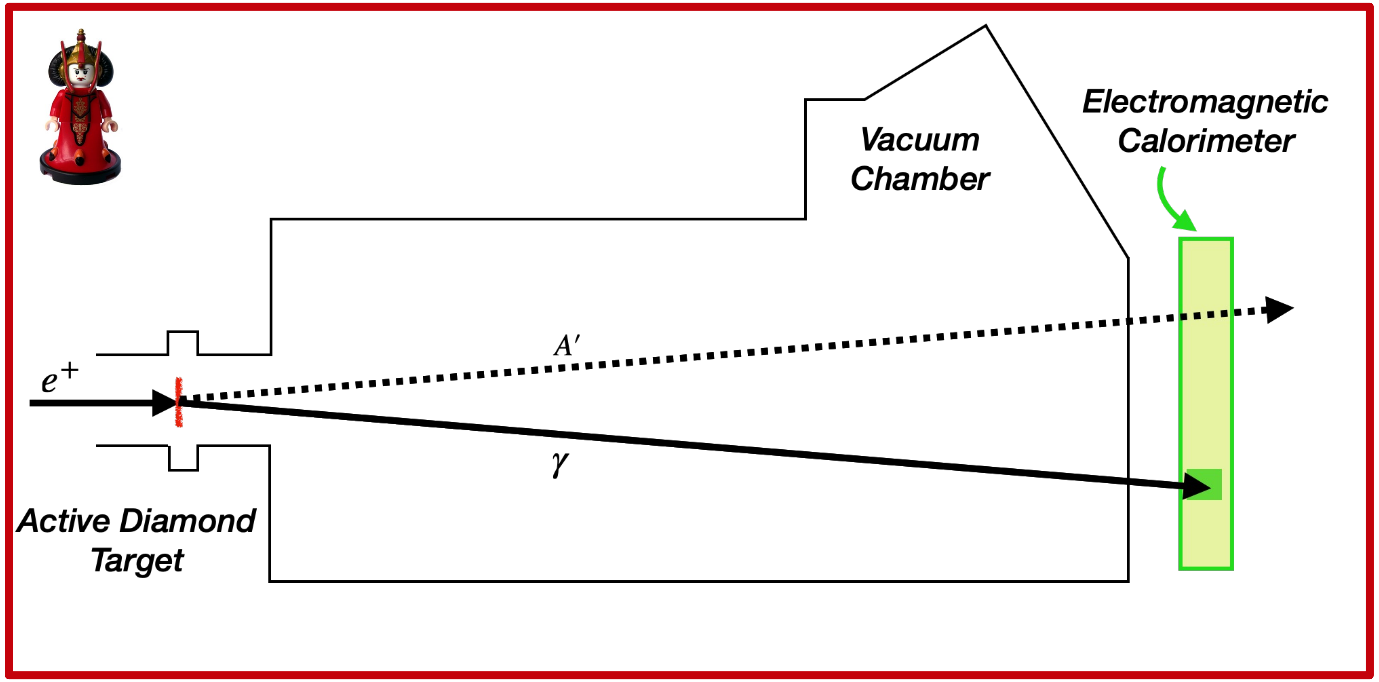
Designing the experiment

- **Target**
- **Nominal A' signal**: 1 γ & nothing else => **ECal**

Thanks Wiki

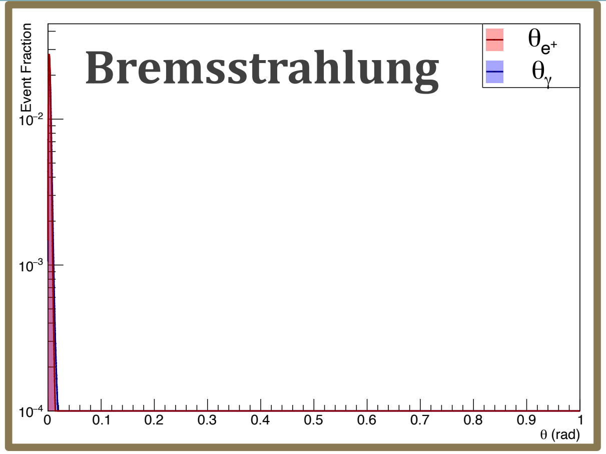
- Electromagnetic Calorimeter (ECal): a **calorimeter** is a type of detector that measures the energy of particles.
  An **electromagnetic calorimeter** (ECAL) is one specifically designed to measure the energy of particles that interact primarily via the electromagnetic interaction such as electrons, positrons and photons.

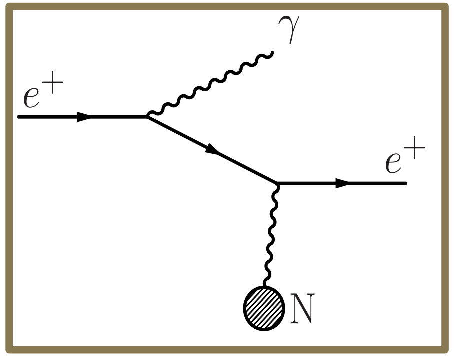


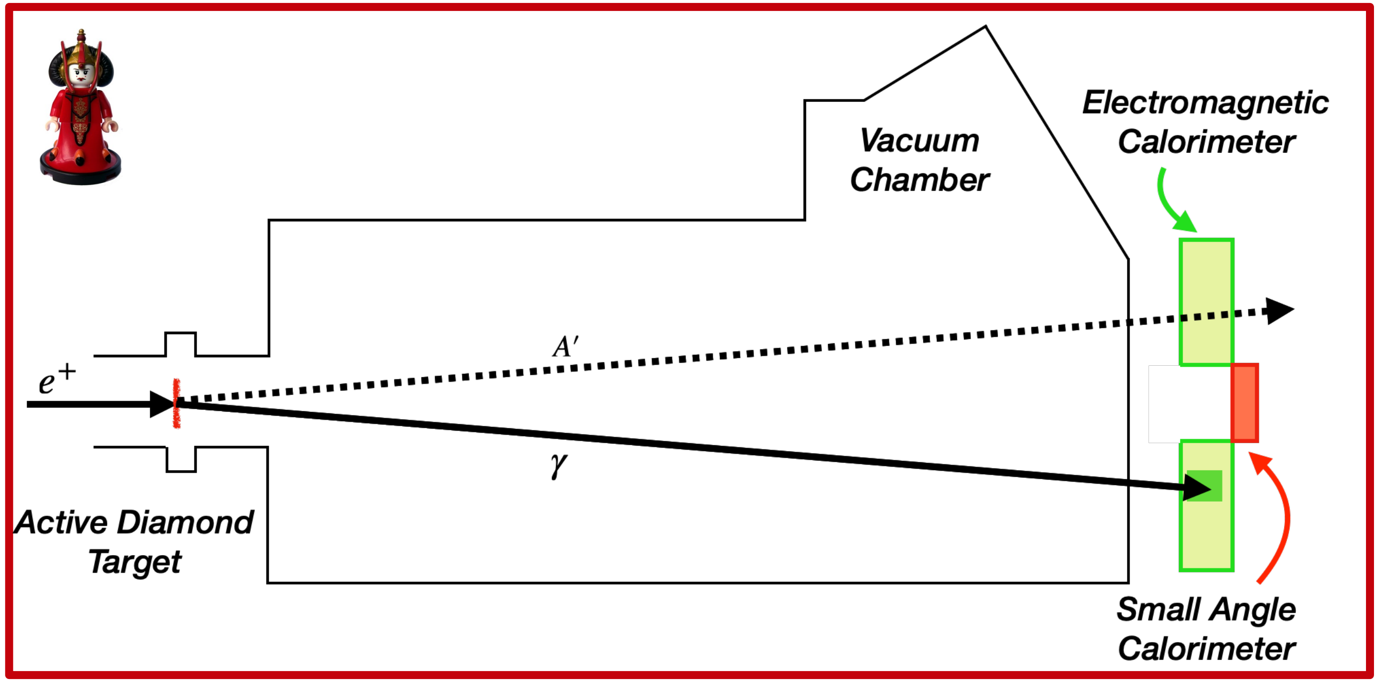


Designing the experiment

- **Target**
- **ECal** (with central hole)
- **Small Angle (electromagnetic) Calorimeter (SAC)**

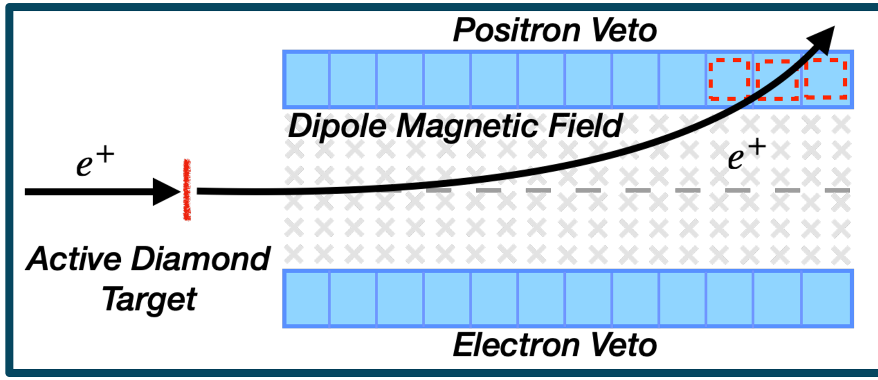




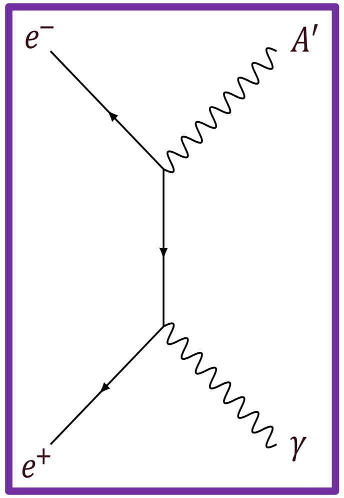


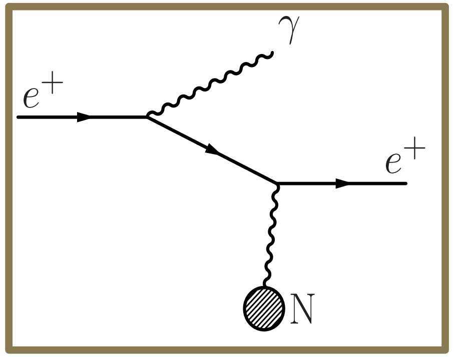
Designing the experiment

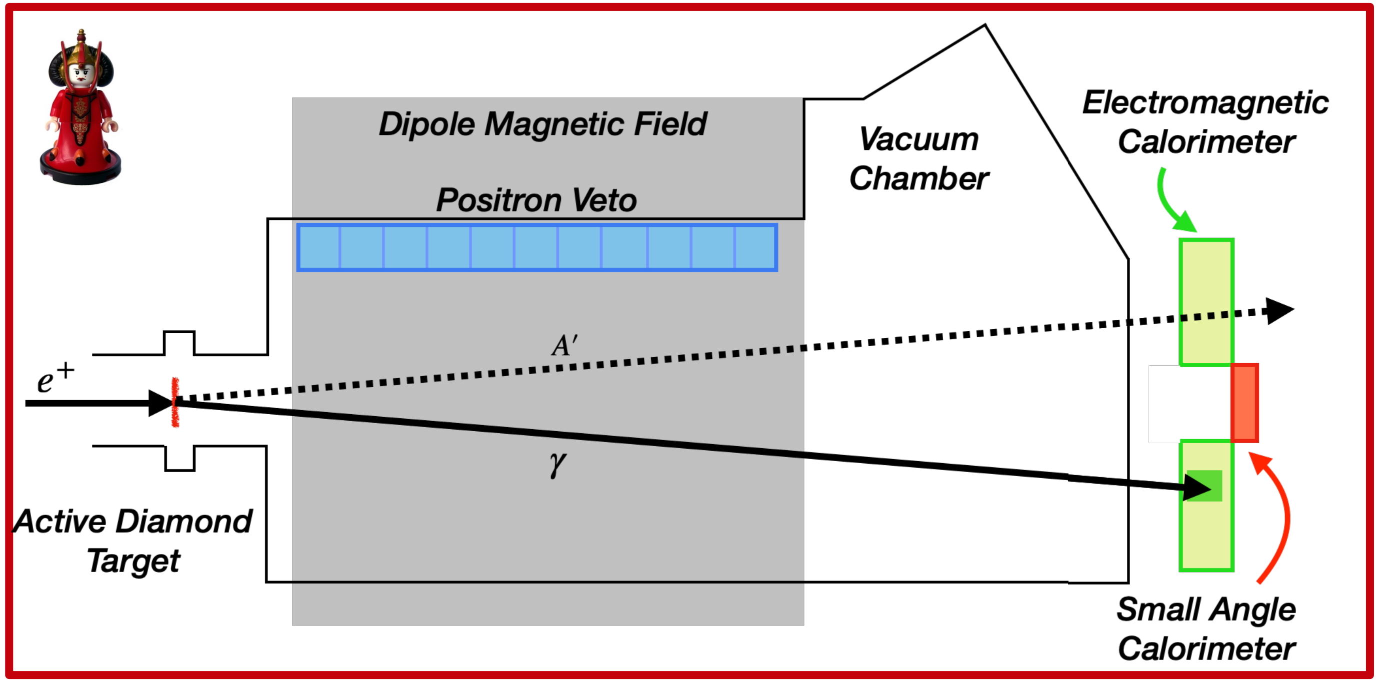
- Target
- ECal (with central hole)
- Small Angle (electromagnetic) Calorimeter (SAC)
- Dipole Magnetic Field (0.4 T)
- Positron Veto (PVeto)



$$\vec{F} = q\vec{B} \wedge \vec{v} \Rightarrow$$
$$r = \frac{p}{2B}$$







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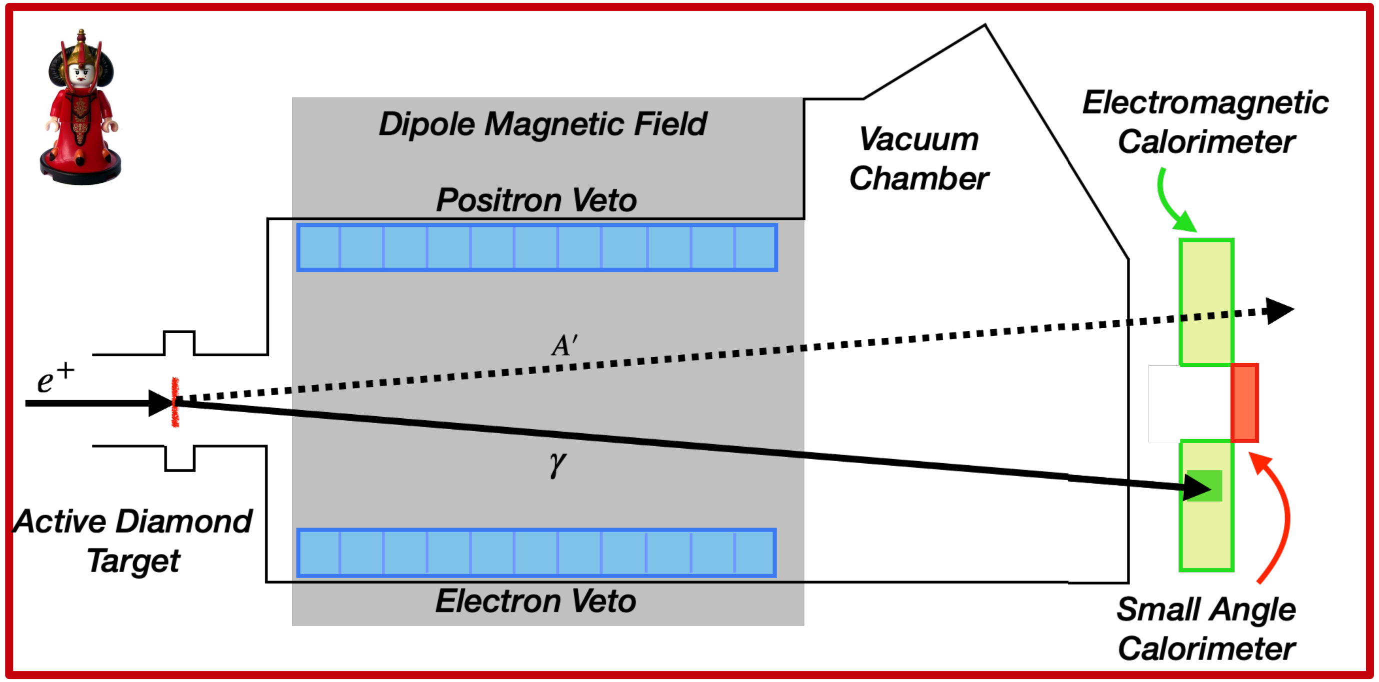
- For fun, **Electron Veto (EVeto)**



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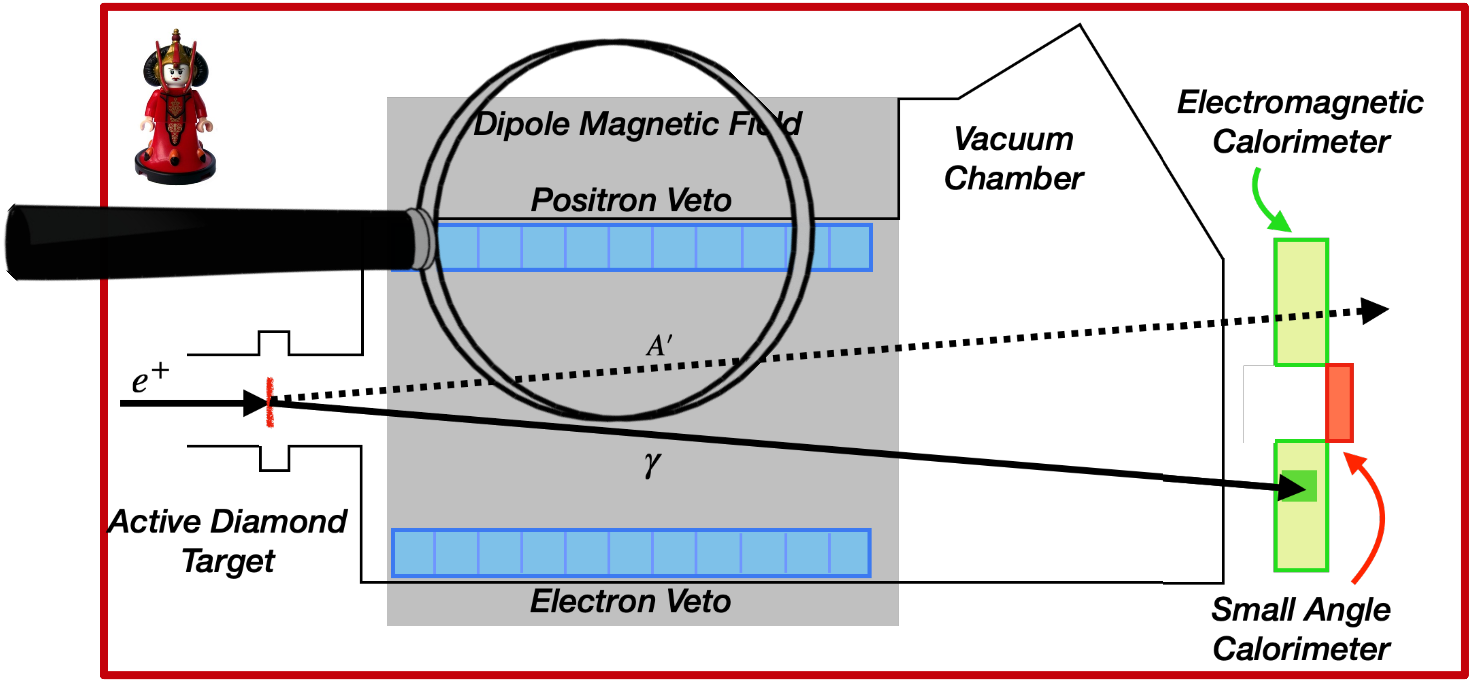
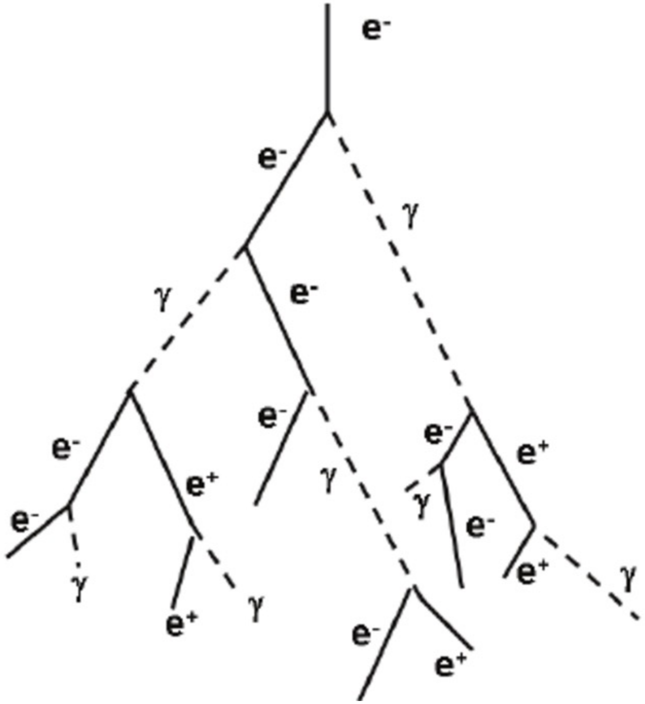
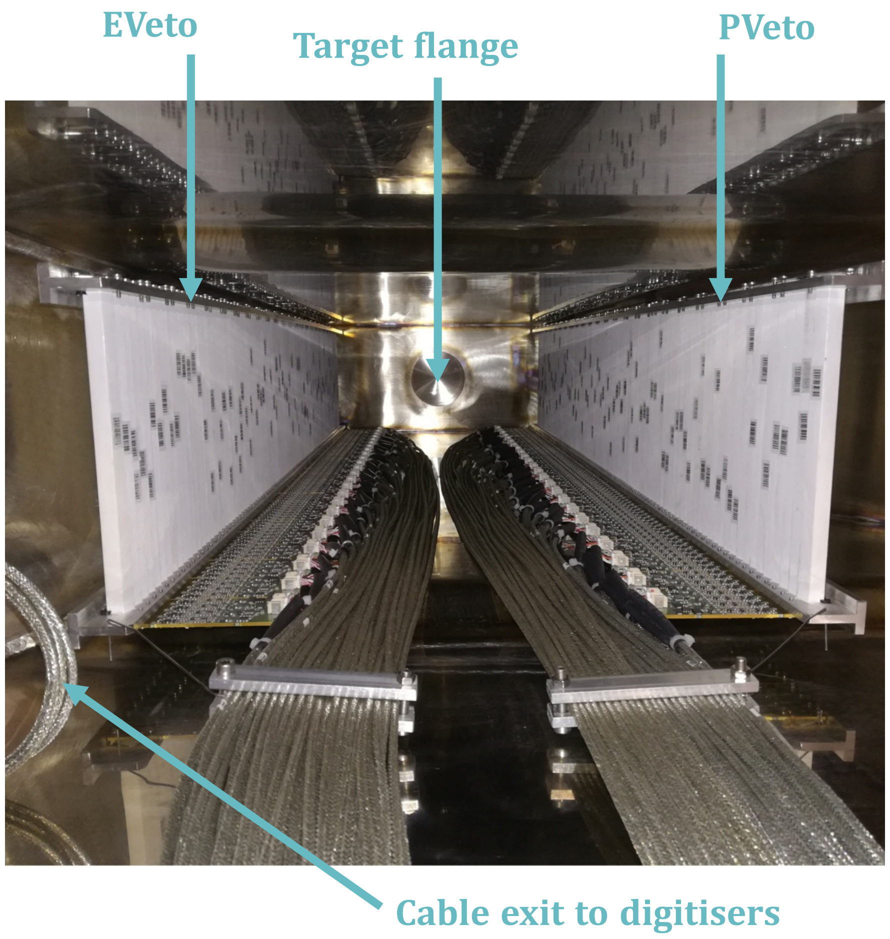


Designing the detector

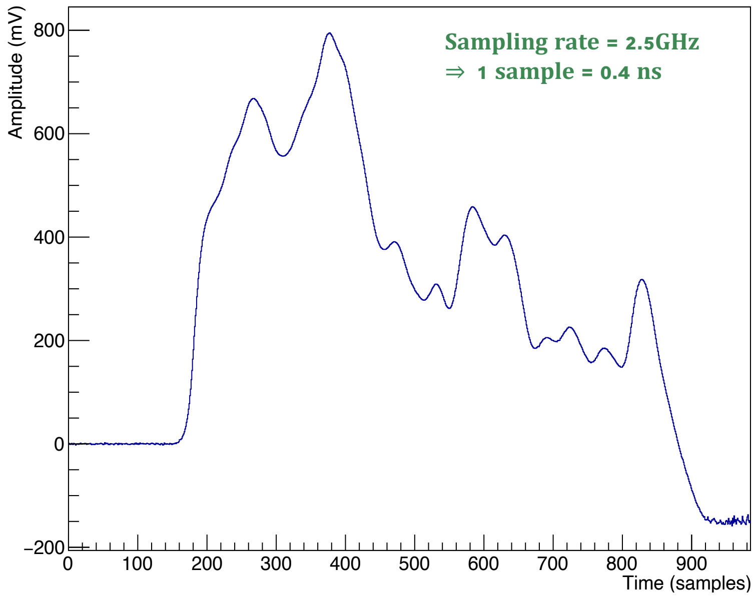
- Plastic scintillator bars
  - Particle enters, causes electromagnetic shower
  - Photons from shower captured by photomultiplier tube
  - Photomultiplier tube produces electrical pulse, passed to a digitizer and saved

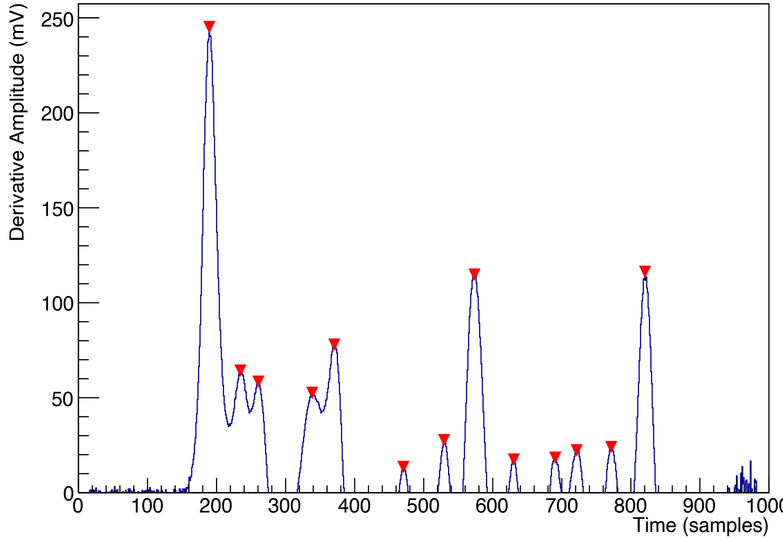




The digitised signal

- Worst case scenario on the right
- Identifying peaks even by eye is tricky!
  - Perform "derivative":
    - $SignalDerivative[s] = Signal[s] - Signal[s - 15]$
  - Fit the derivative recursively, looking for gaussian peaks
  - Define **time** as centre of gaussian fit
  - Define **energy** as amplitude of peak after subtracting tails of previous peaks
    - Was it a positron, a photon or just noise?
- Now you have:
  - **Time** of particle
  - **Particle ID** (from energy in detector)
  - Position of impact -> energy
- Job done!! Your positrons are ready to use!





Conclusions

- When you're building your particle physics experiment ask yourself:
  - What's my signal?
  - What's my background?
- Once you've built your detector ask yourself:
  - What are the physical quantities I care about?
  - How do I get access to them?