Accelerator Operational Gradient Margin

The challenge!
(and some personal observations)

Nick Walker

Why are we discussing this?

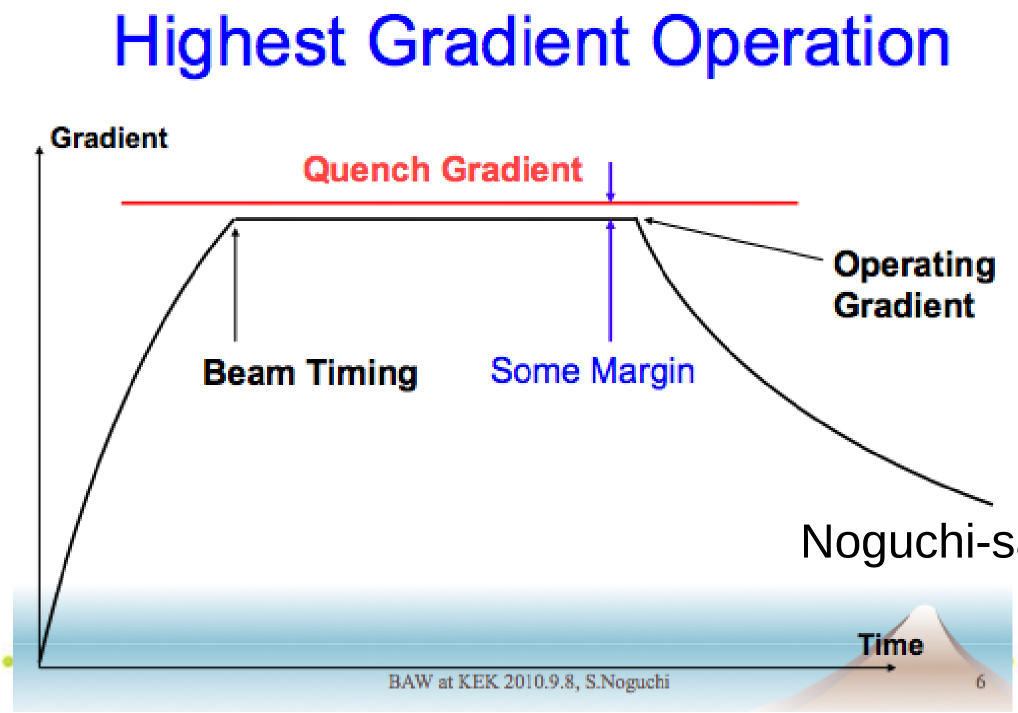
- **Cost of 1% accelerating gradient: ~34 MILCU**
- **Cost of 1% additional RF power: ~10 MILCU**
- ***Gradient is cost premium, trade against RF power***
  - rationale for adoption of 'gradient spread'

Operational Gradient

- **Historically (Snowmass 2007) assumed a ~10% de-rating from VT (35 MV/m) to operational gradient (31.5 MV/m)**
- **This margin included**
  - de-rating allowed for CM fabrication
  - control headroom (margin for LLRF feedback)
  - (division was not specified)
- **Our primary goal is to construct an accelerator with an average accelerating gradient of 31.5 MV/m**
  - primary cost driver

Dividing up the Pie

VT Observed Gradient Limit		35.0 MV/m avg
CM Observed Gradient Limit	3%	34.0 MV/m avg
Operation Gradient Limit	1.5 MV/m	32.5 MV/m avg
Controls margin	3%	31.5 MV/m avg



Noguchi-san

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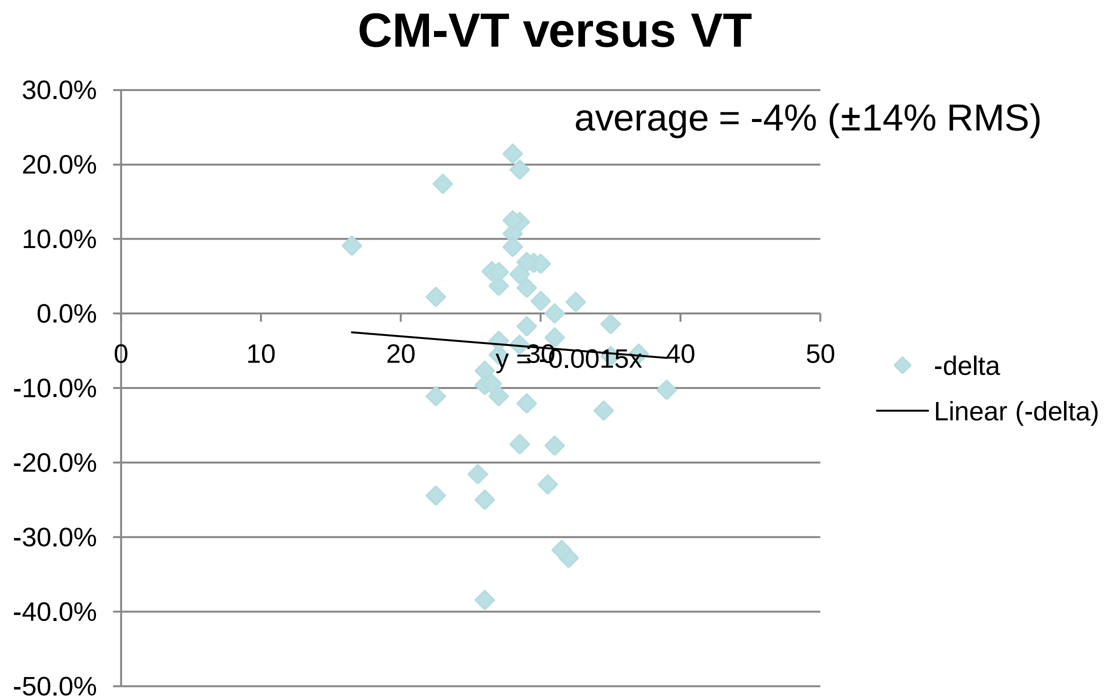
Data from FLASH modules



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$$V = \sqrt{P_{for}\left(\frac{r}{Q}\right)Q_{ext}} - I_b\left(\frac{r}{Q}\right)Q_{ext}$$

gradient "slopes" within 3%

1% change in gradient

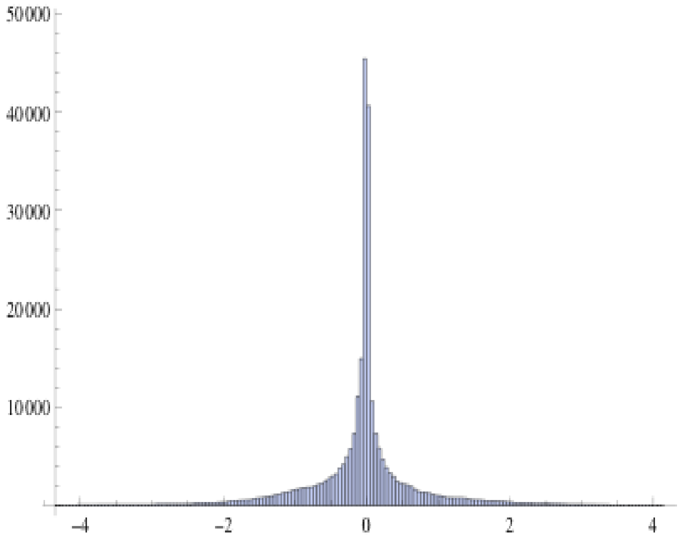
$\Delta P_{for}/P_{for}$	2%
$\Delta Q_{ext}/Q_{ext}$	2%
$\Delta I_b/I_b$	1%
Δf	15 Hz

Controls Issues
-calibration!

Major R&D challenge (but impossible?)

Beam Dynamics Constraint

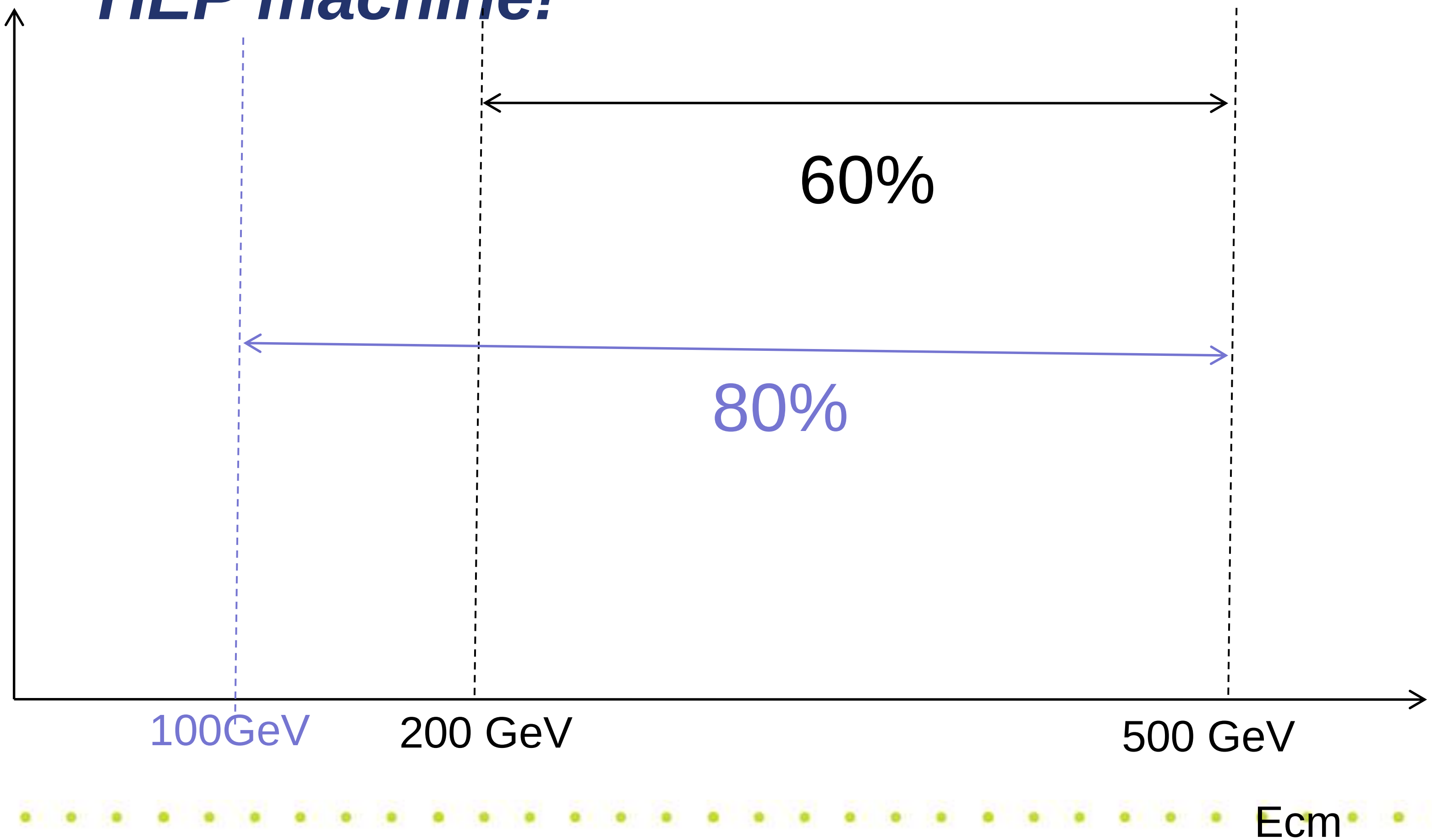
- **3% pk to pk is 1% RMS**
  - Already at specified tolerance
  - Kicks to do not give gaussian distribution
  - RMS a poor measure of performance (?) (possible overestimate)



- **Attempt to get control levels first, then fix remaining effect (if necessary) with additional feedback in linac**

Pushing the Envelope!

- **It's what we do ☺ *in an energy frontier HEP machine!***



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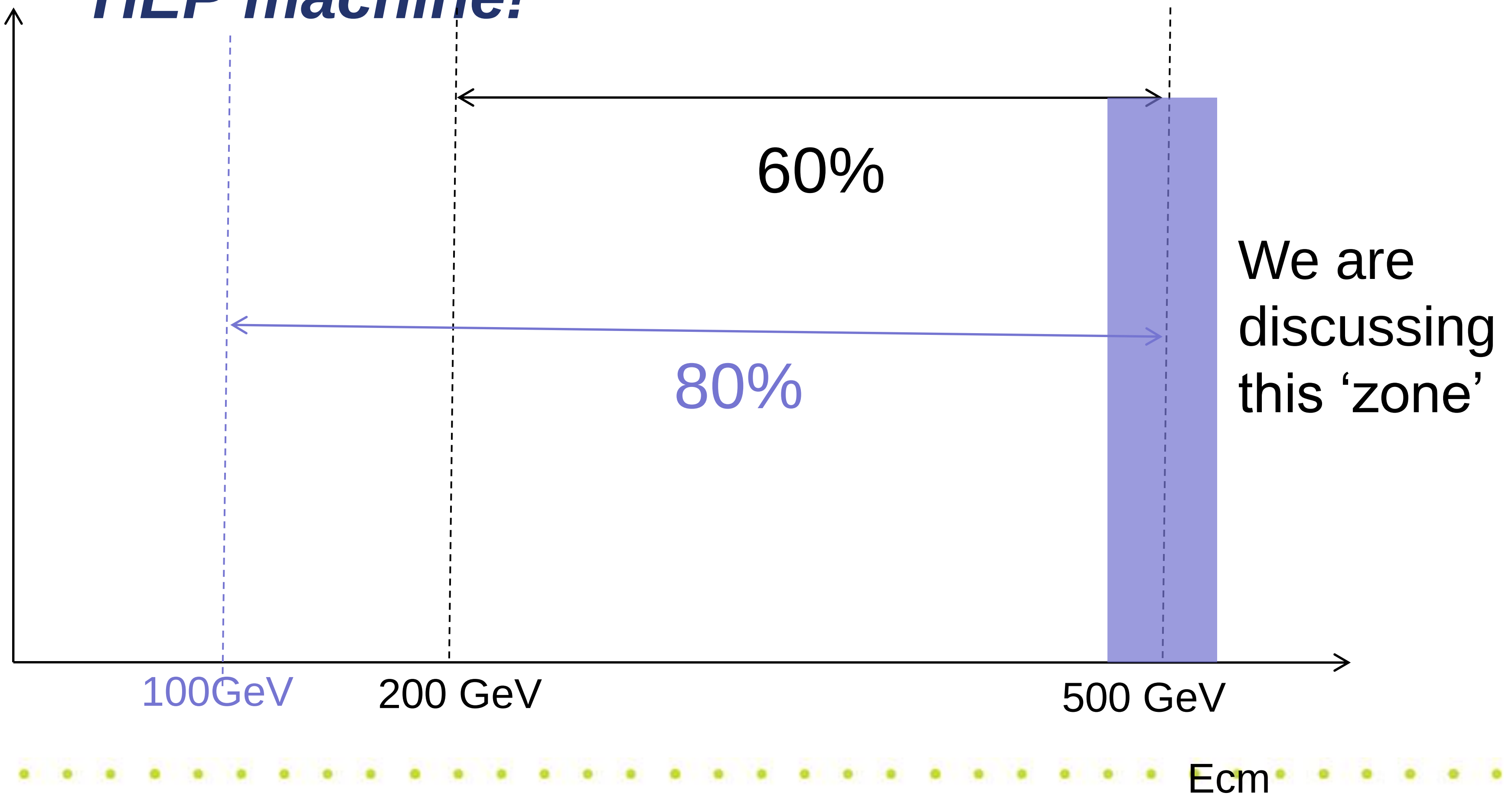

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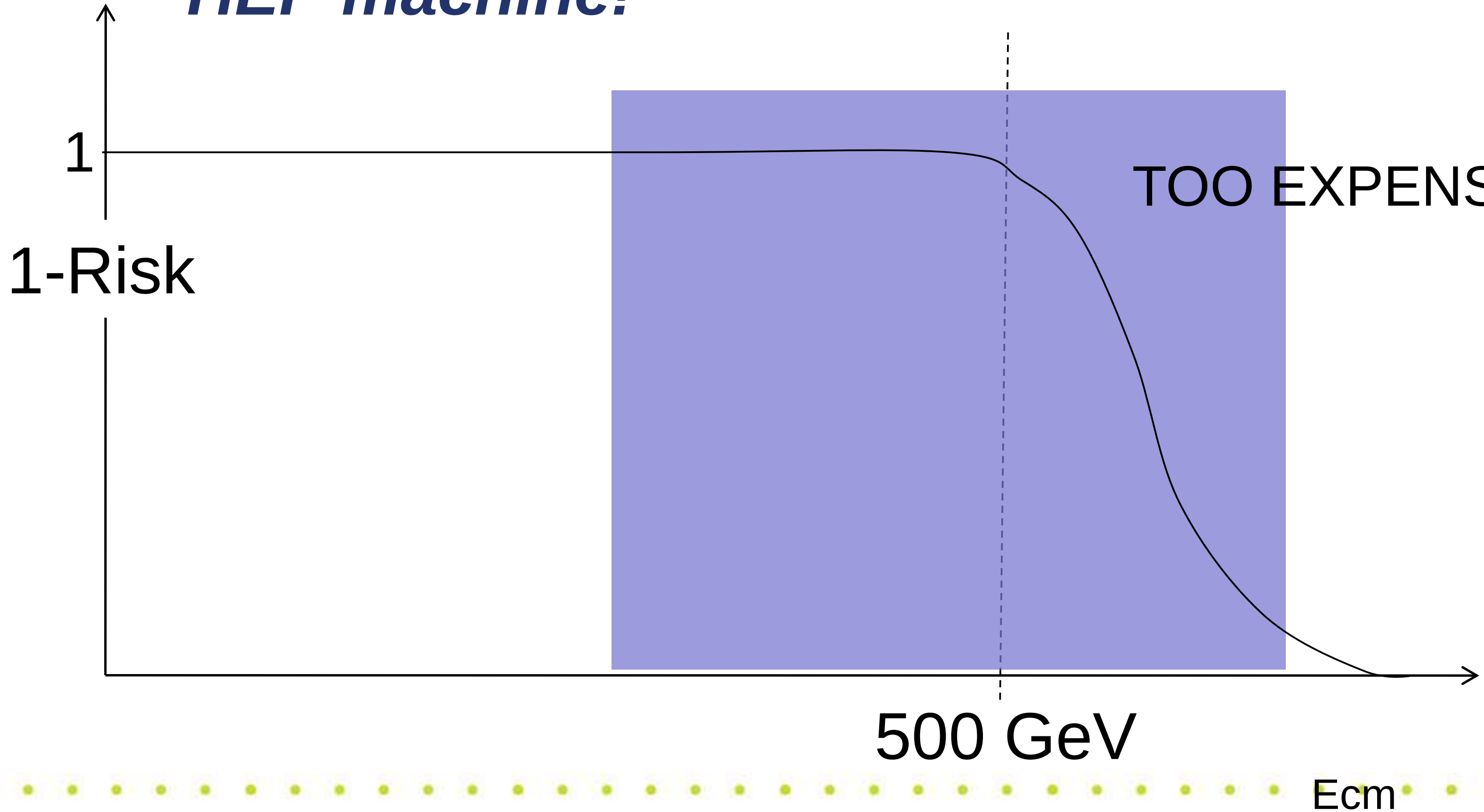

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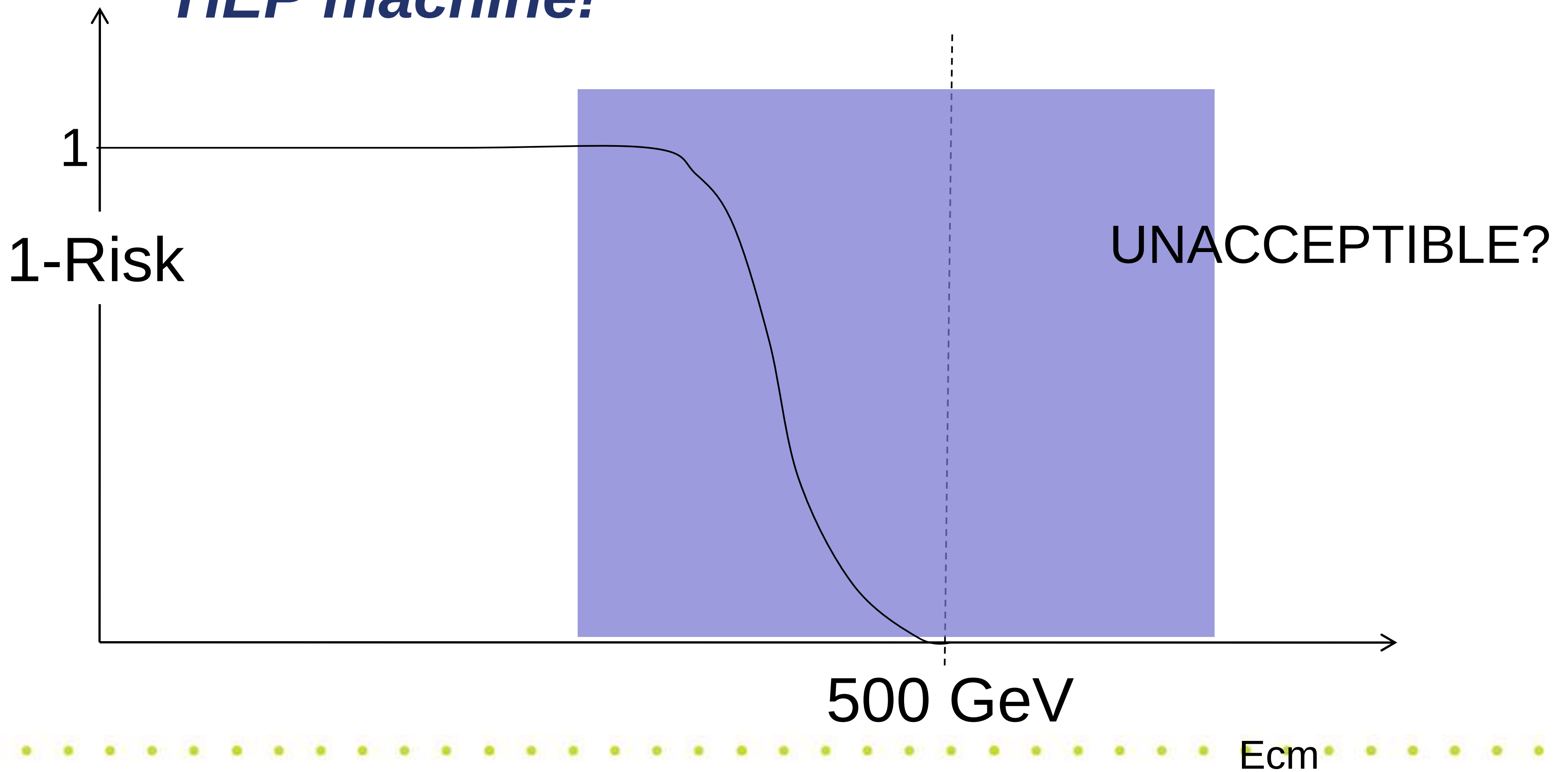

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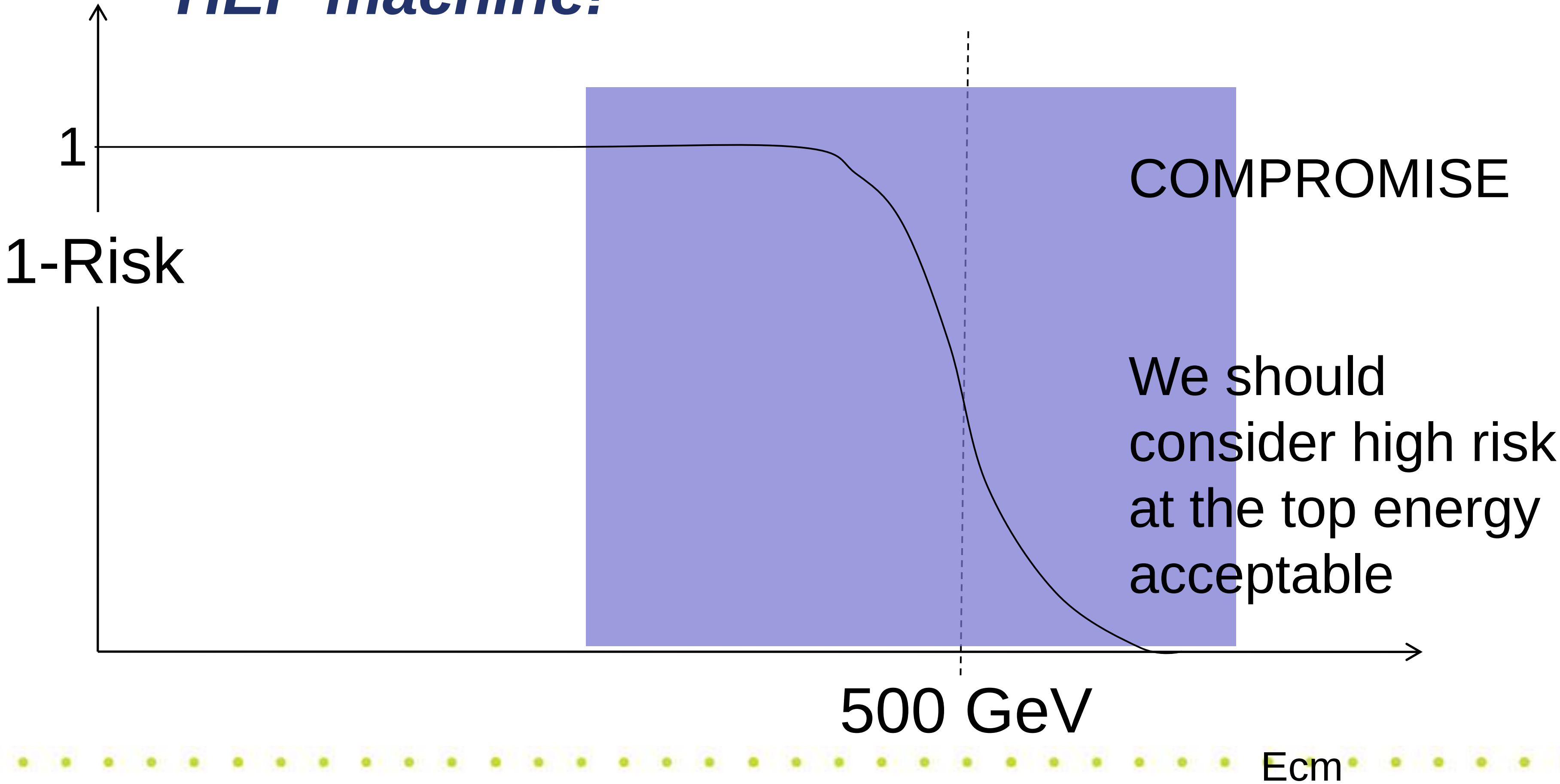

In Conclusion

- **Focus R&D Plans are needed to give us more confidence**
  - goals are “aggressive” but not impossible
  - Thinking “out-of-the-box” may be required

- **Two primary areas need attention**
  - (gradient yield.)
  - VT → CM (difficult because statistics are poor)
  - S2 for LLRF control margins
    - FLASH 9mA test and S1g, more simulation work
    - Longer term: STF2 and NML