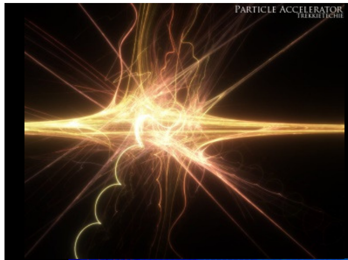


Toward a second detector for CepC

Franco Bedeschi

IAS-HEP conference,

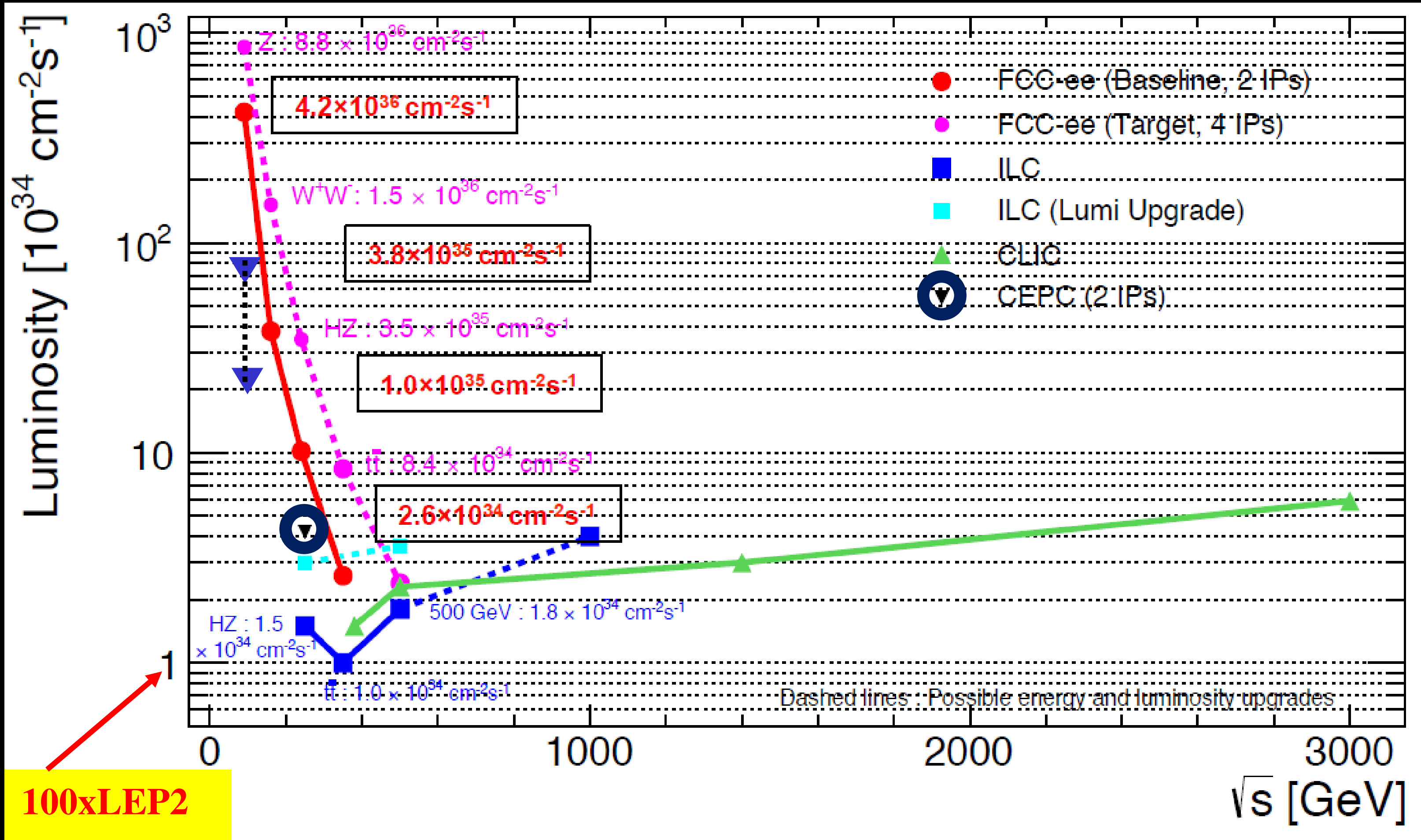
Hong Kong, January 2017

OUTLINE

- Basic requirements
- Potential «new» concept
- Conclusions

e+e- operation modes

❖ Wide range of running conditions FCC ~ CepC ≠ ILC



e+e- operation modes

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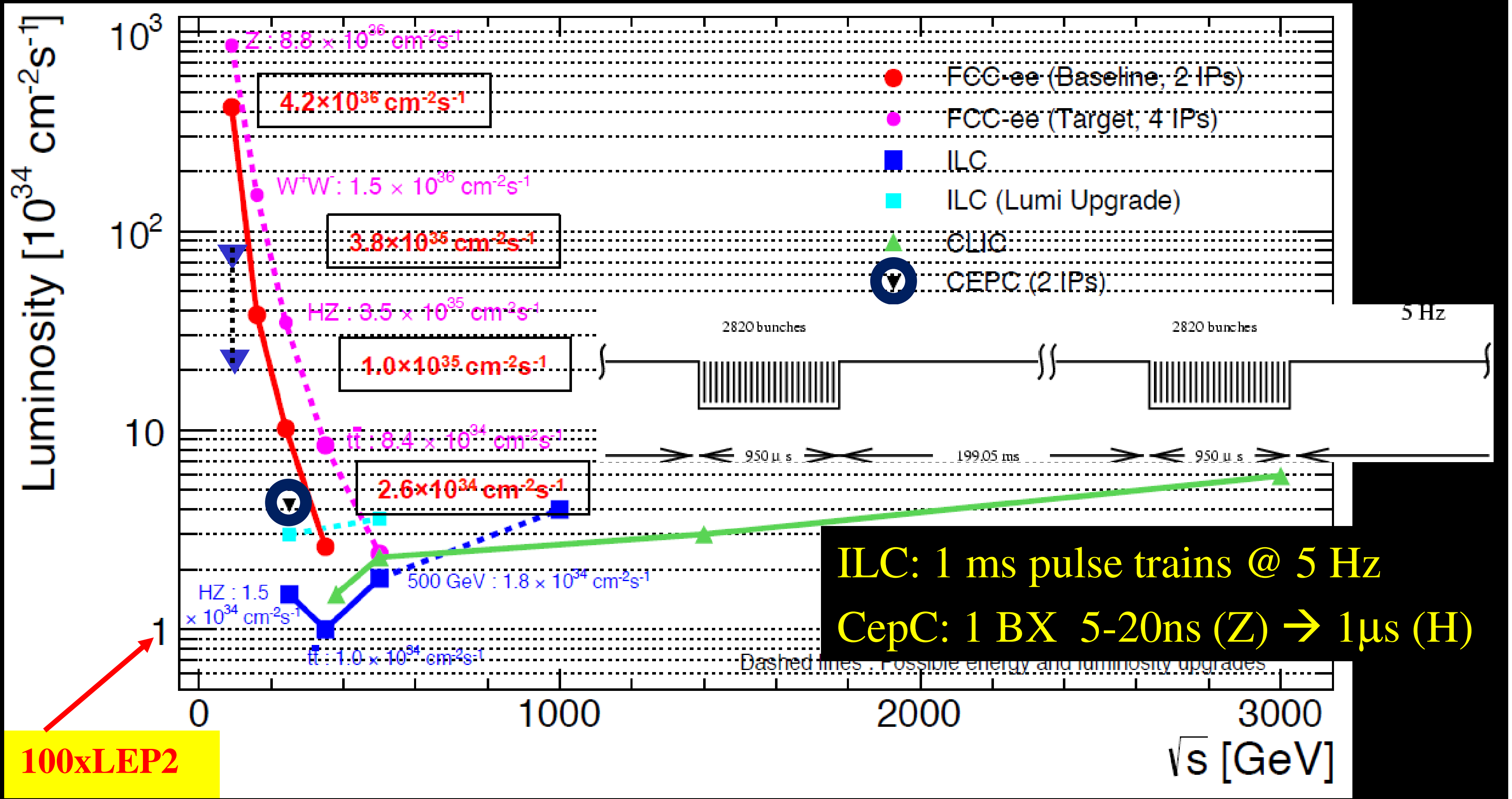


ILC: 1 ms pulse trains @ 5 Hz

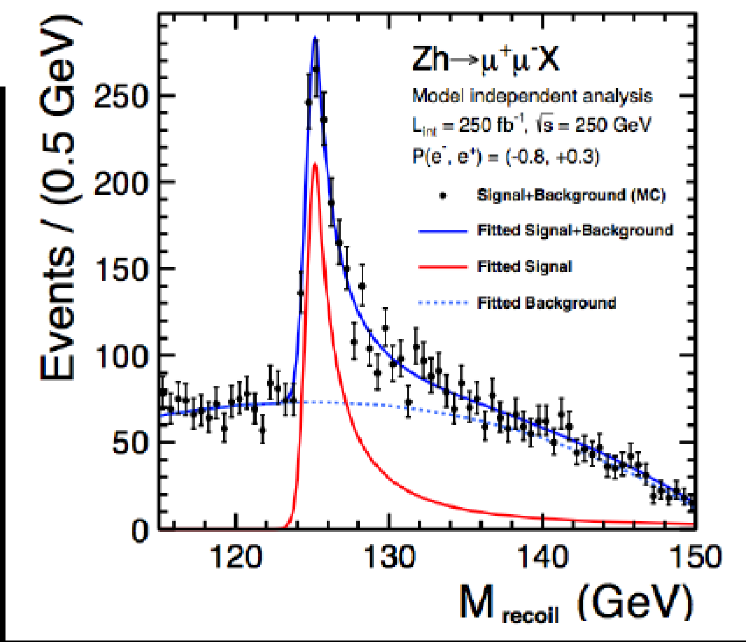
CepC: 1 BX 5-20ns (Z) → 1μs (H)

e+e- →HZ physics constraints

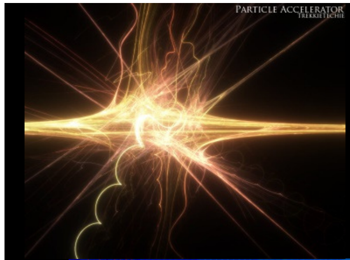
- Vertex detector:
  - c/τ besides b
  - Light and small pixels

e+e- →HZ physics constraints

$$m_{\text{recoil}}^2 = \left(\sqrt{s} - E_Z\right)^2 - \left|\vec{p}_Z\right|^2$$



- Vertex detector:
  - c/τ besides b
  - Light and small pixels
- Tracker:
  - Fit M_{recoil} from Z→μμ
  - H→μμ mass resolution (*)
  - Light and excellent resolution



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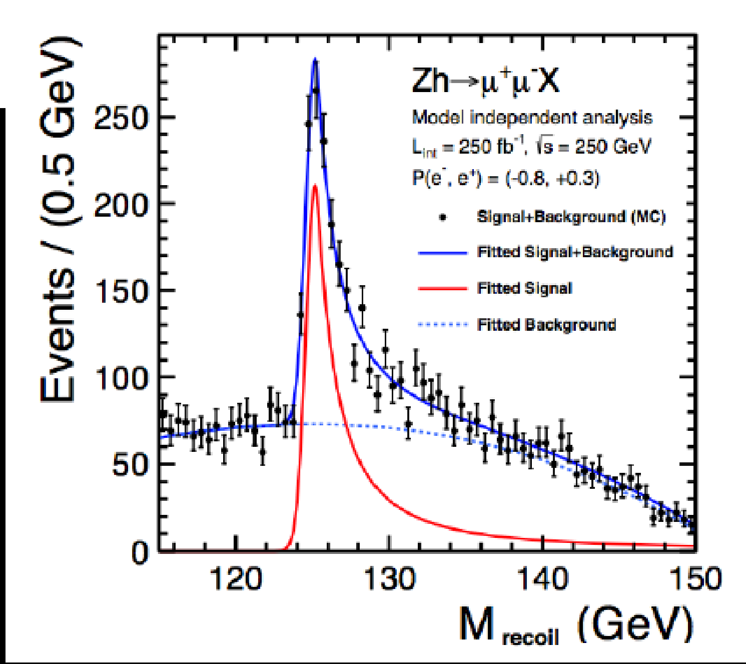

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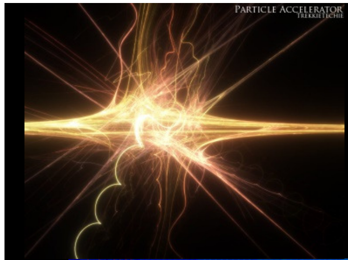
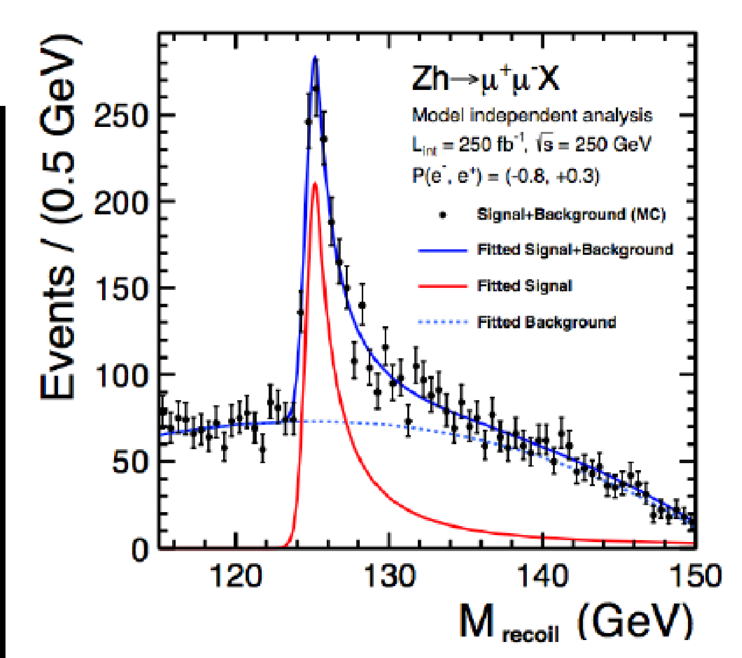
- Calorimeters:
  - H→γγ → ECAL resolution (*)
  - H→qq, VV → ECAL+HCAL resolution



e+e- →HZ physics constraints

$$m^2_{\rm recoil} = \left(\sqrt{s} - E_Z\right)^2 - \left|\vec{p}_Z\right|^2$$



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(*) LHC may observe these channels with similar ot better precision before CepC

e+e- →HZ physics constraints

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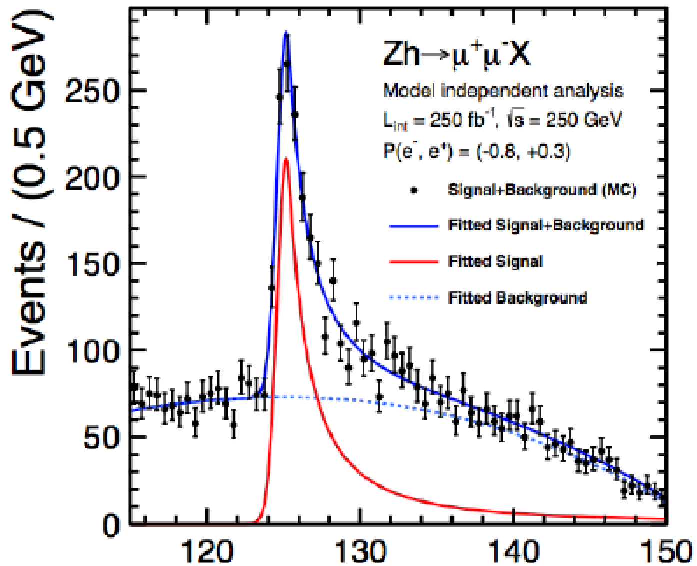


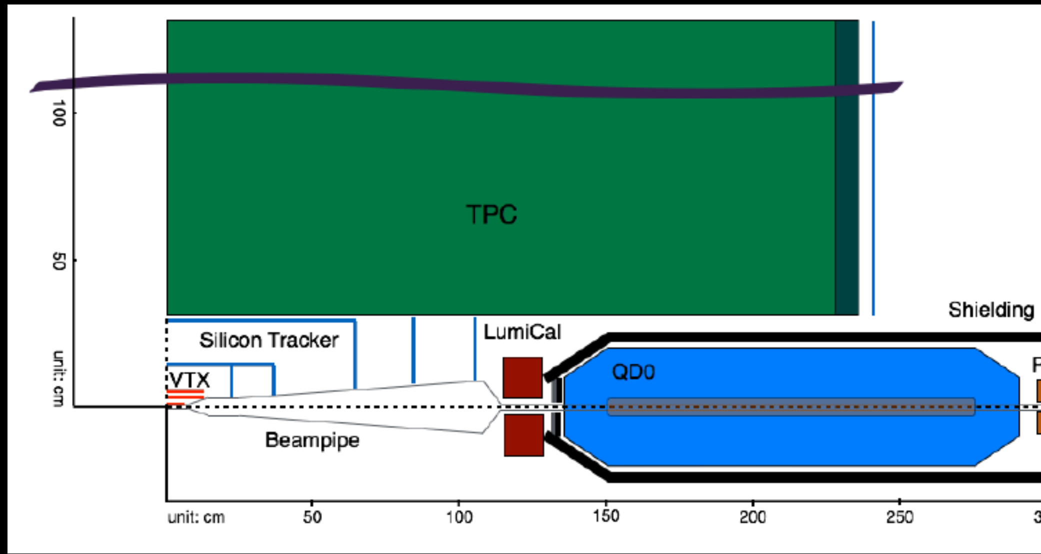
Physics Process	Measured Quantity	Critical Detector	Required Performance
$ZH \to \ell^+\ell^- X$	Higgs mass, cross section	Tracker	$\Delta(1/p_T) \sim 2 \times 10^{-5}$
$H \to \mu^+\mu^-$	$\text{BR}(H \to \mu^+\mu^-)$		$\oplus 1 \times 10^{-3}/(p_T \sin\theta)$
$H \to b\bar{b},\ c\bar{c},\ gg$	$\text{BR}(H \to b\bar{b},\ c\bar{c},\ gg)$	Vertex	$\sigma_{r\phi} \sim 5 \oplus 10/(p \sin^{3/2}\theta)\ \mu\text{m}$
$H \to q\bar{q},\ VV$	$\text{BR}(H \to q\bar{q},\ VV)$	ECAL, HCAL	$\sigma_E^{\text{jet}}/E \sim 3-4\%$
$H \to \gamma\gamma$	$\text{BR}(H \to \gamma\gamma)$	ECAL	$\sigma_E \sim 16\%/\sqrt{E} \oplus 1\%$ (GeV)

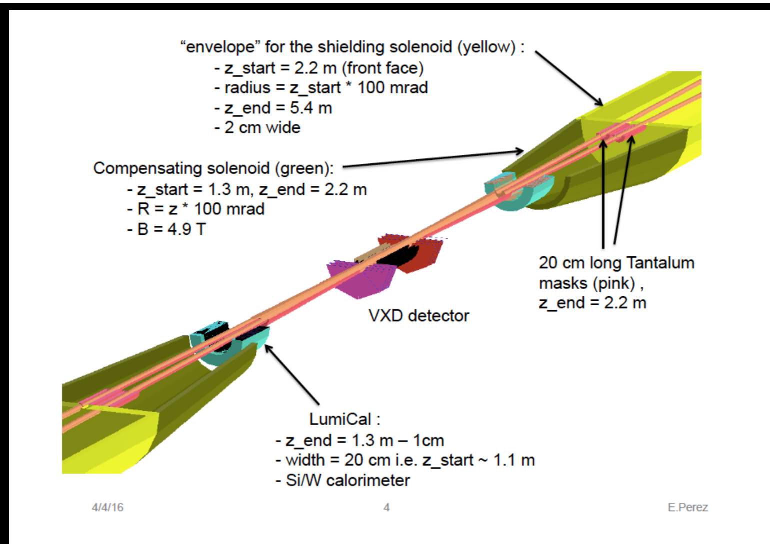
e+e- →Z/WW physics constraints

- Additional EW physics drivers:
  - High precision acceptance determination
  - Good e/γ/π^0 discrimination

Accelerator constraints

- Final focus
  - QD0 forw. Acceptance
    - Coverage up to ~10°
  - Beam pipe R ~ 2 cm
  - B_{max} < 2 T (FF optics)
    - From FCC-ee MDI





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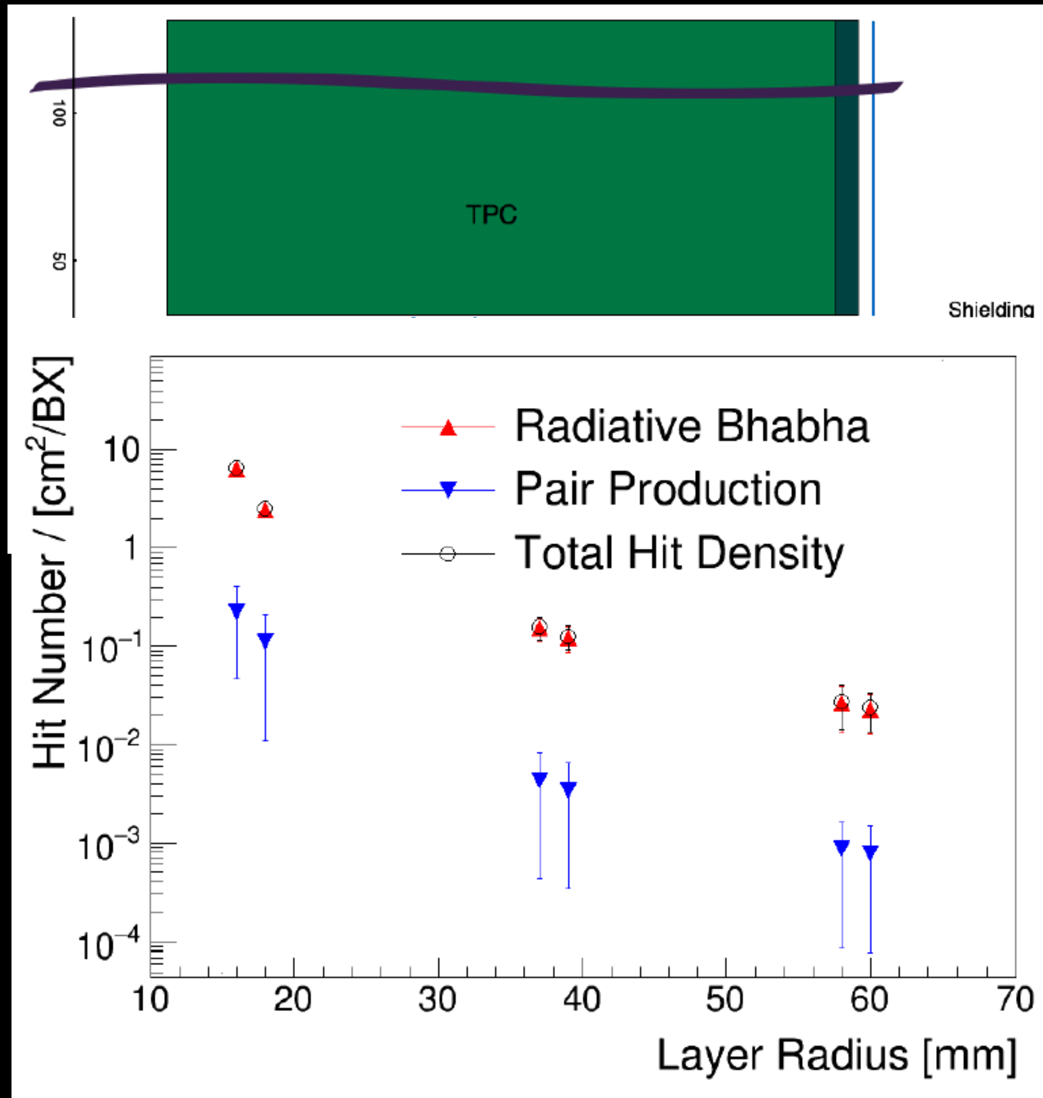
- Final focus
  - QD0 forw. Acceptance
    - Coverage up to ~10º
  - Beam pipe R ~ 2 cm
  - B_{max} < 2 T (FF optics)
    - From FCC-ee MDI
- Backgrounds:
  - Radiative Bhabha, SR
  - @R = 1.6 cm
    - NIEL: <10^{12}neq/cm^2/yr
    - TID: <300 krad/yr



Options

- Can use ILC detectors as starting point
  - ILD (baseline): Pixels, TPC, particle flow calorimeter
  - SiD: Pixels, Si microstrips, particle flow calorimeter
  - 4° concept: Pixels, DCH, DR calorimeter, Dual Solenoid

- Any of these works well for HZ (....at ILC)
- Additional requirements may be needed for Z operation
  - Eg. Preshower, particle ID, ...
- Some requirements may be looser after HL-LHC
  - E.g. $H \rightarrow \gamma\gamma$, $H \rightarrow \mu\mu$

ILD: current CepC baseline

❖ Large solenoid with calorimeter/tracker inside

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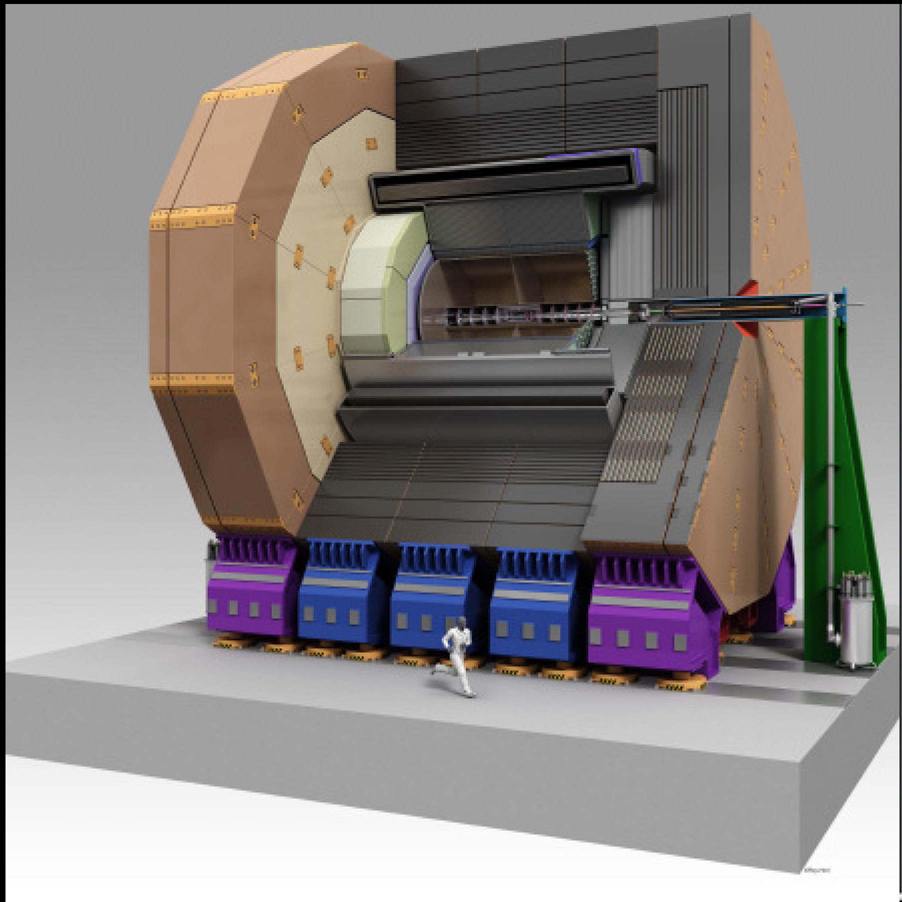
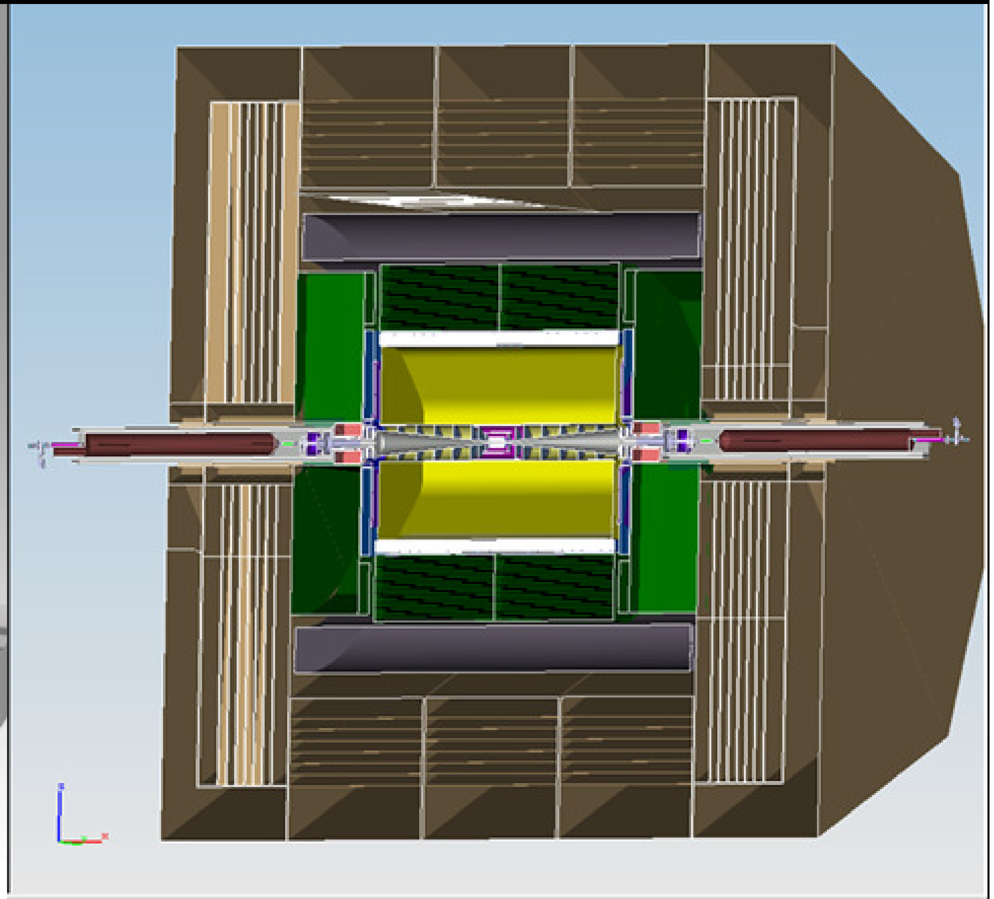
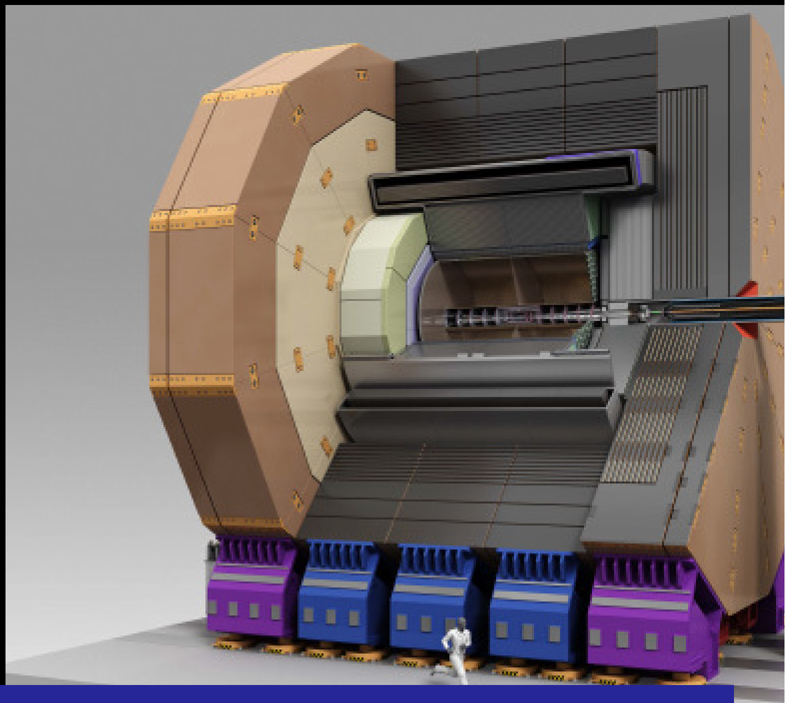
- Large solenoid with calorimeter/tracker inside





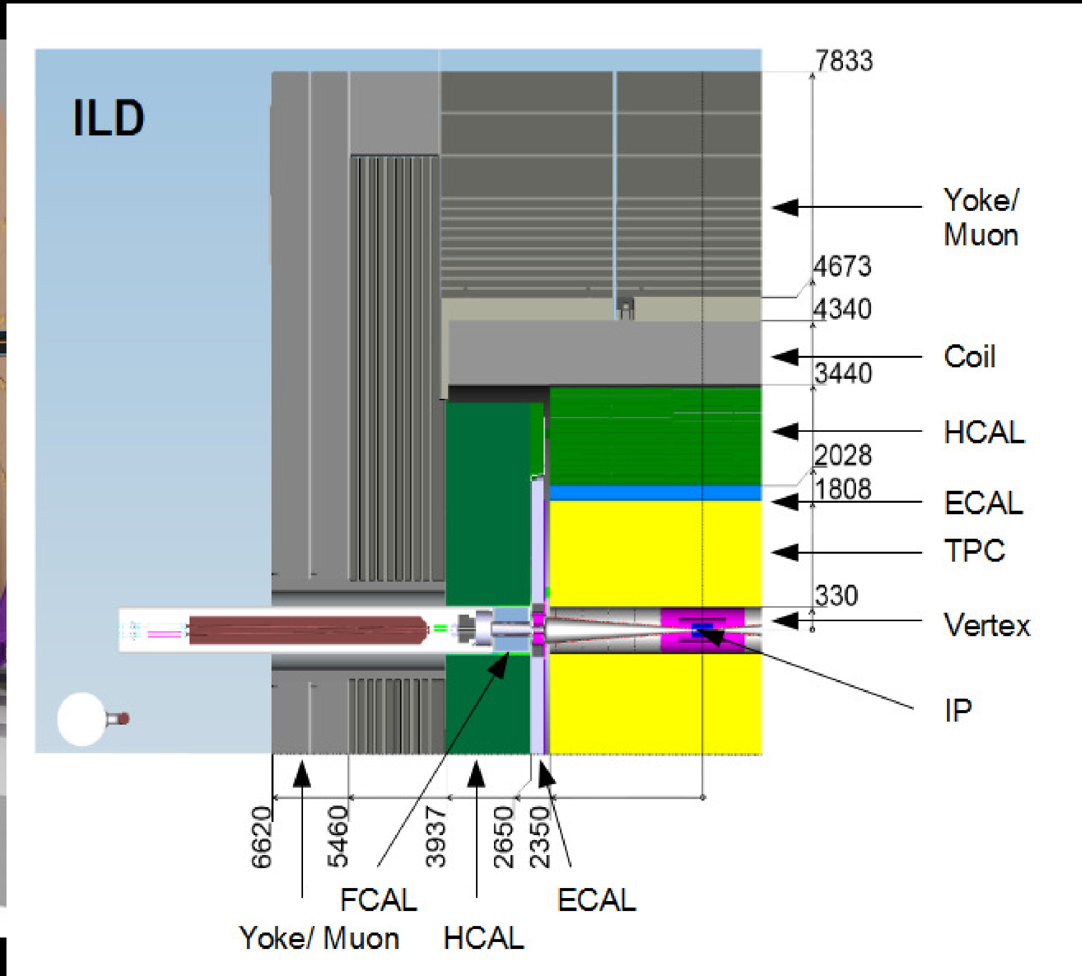
ILD: current CepC baseline

❖ Large solenoid with calorimeter/tracker inside



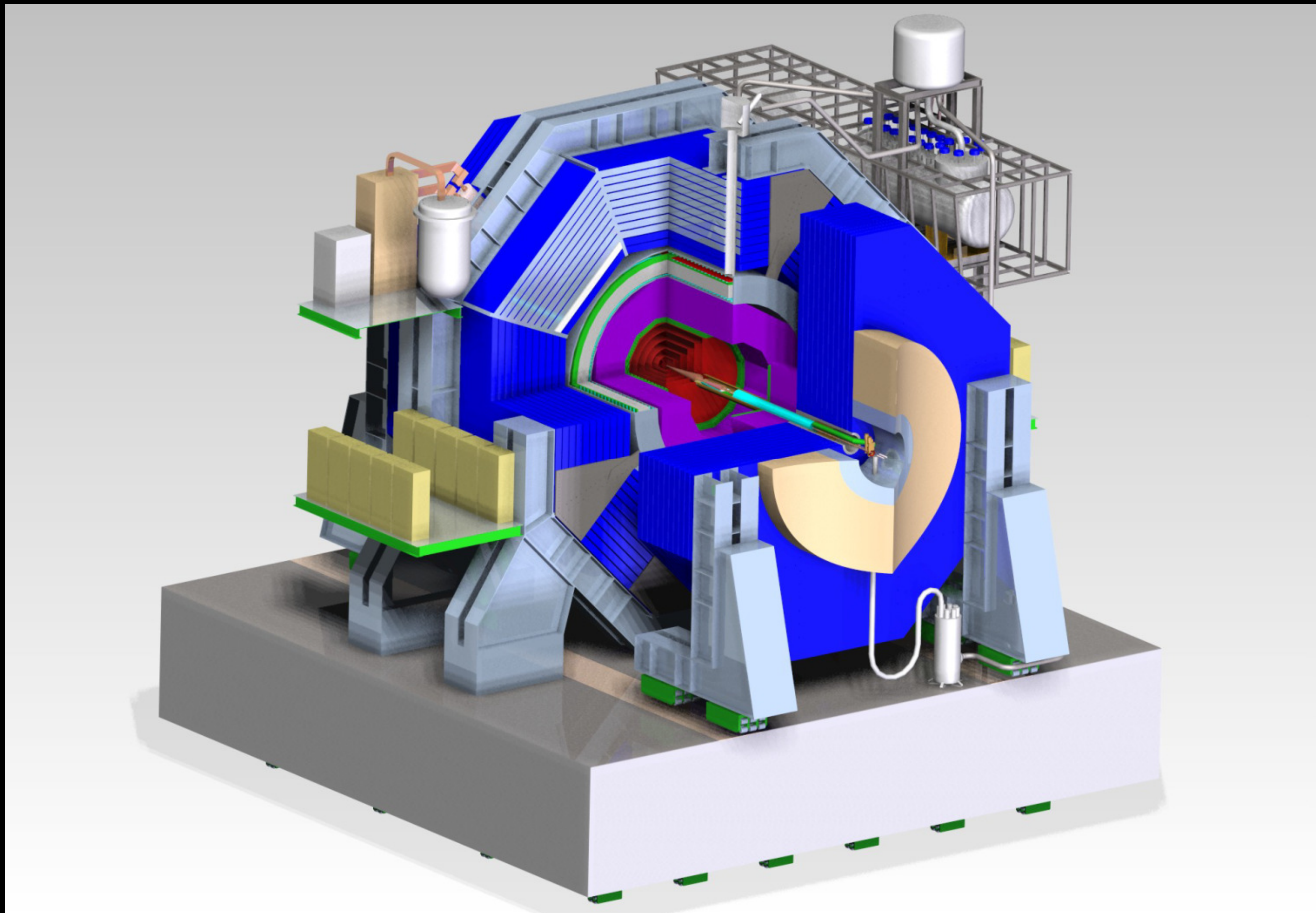
Solenoid B=4T, L~7m,

R_{min}=3.4m, ΔR=90cm



SiD

- ❖ More compact with Si tracker



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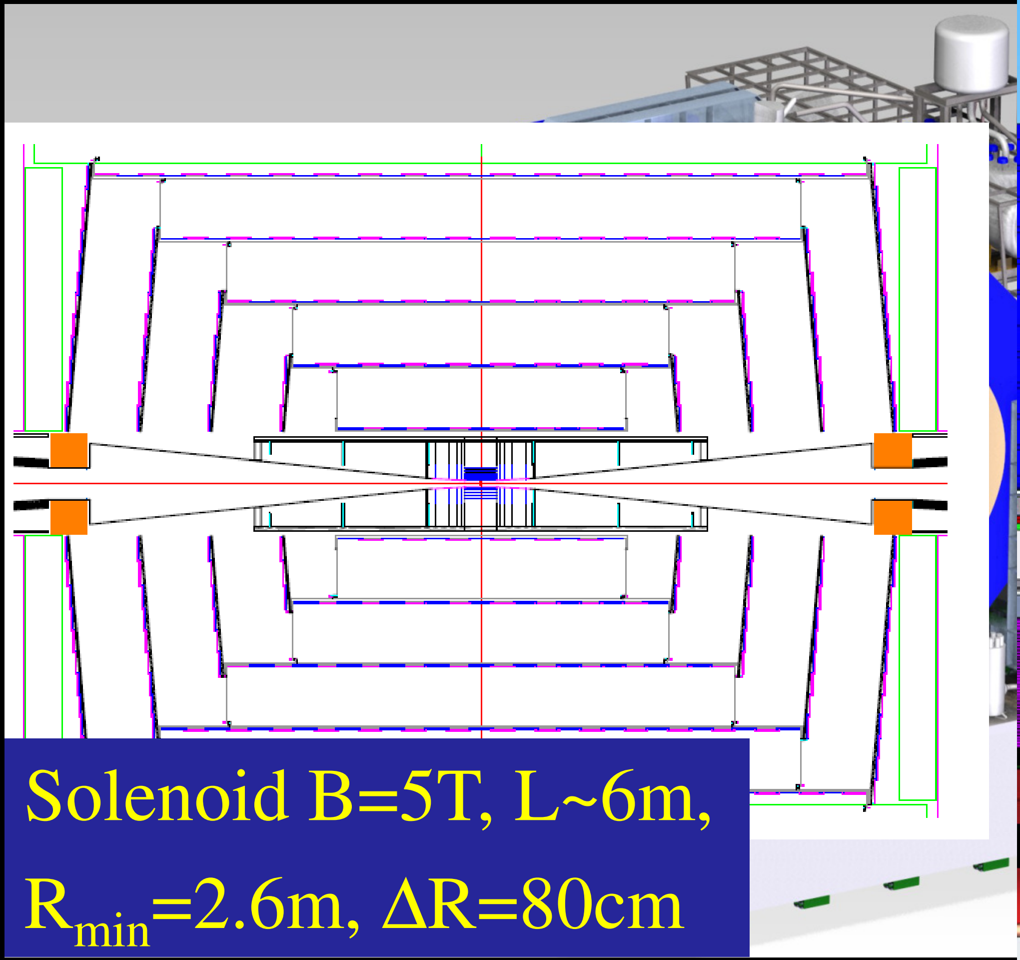
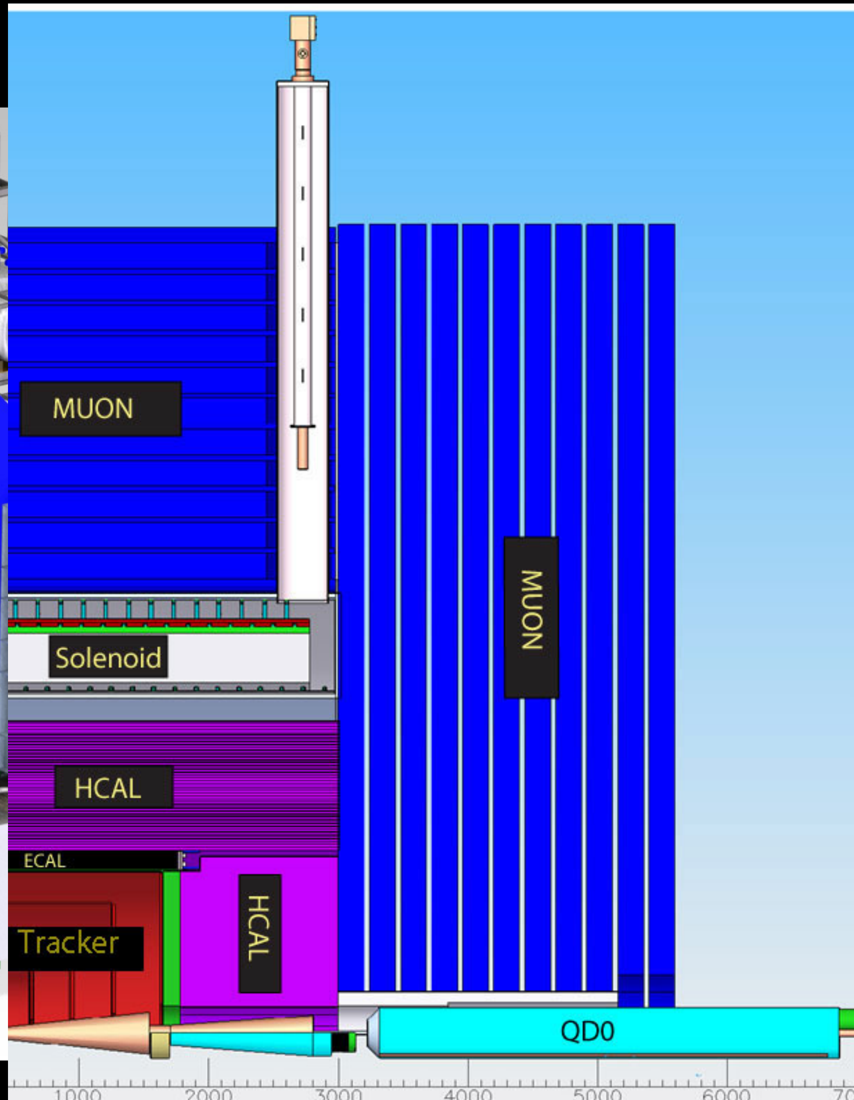


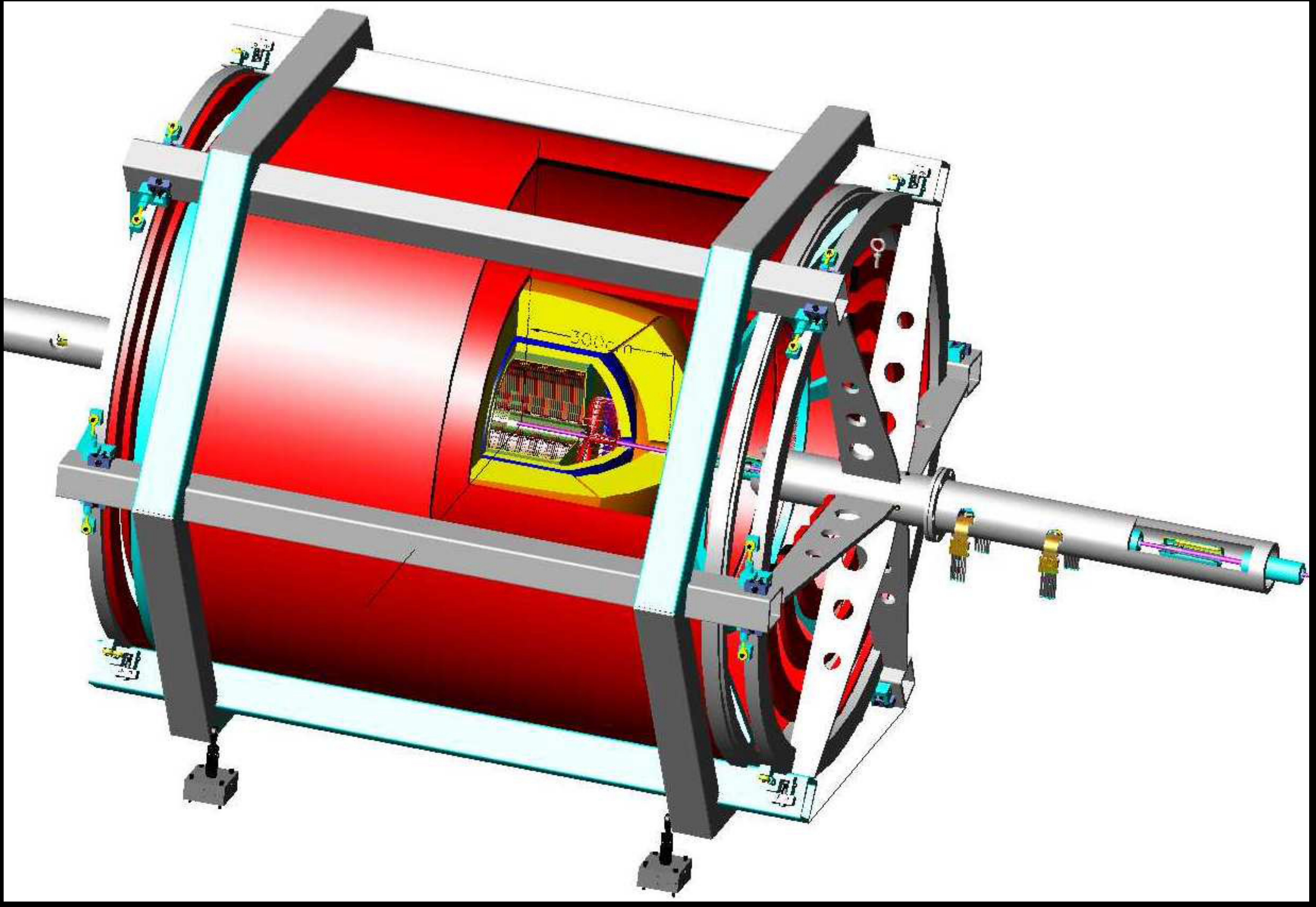
Solenoid B=5T, L~6m,

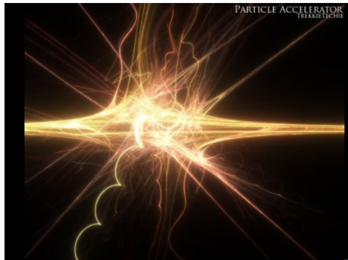
R_{min}=2.6m, ΔR=80cm



4° concept

❖ Dual solenoid, Drift chamber, Dual Readout



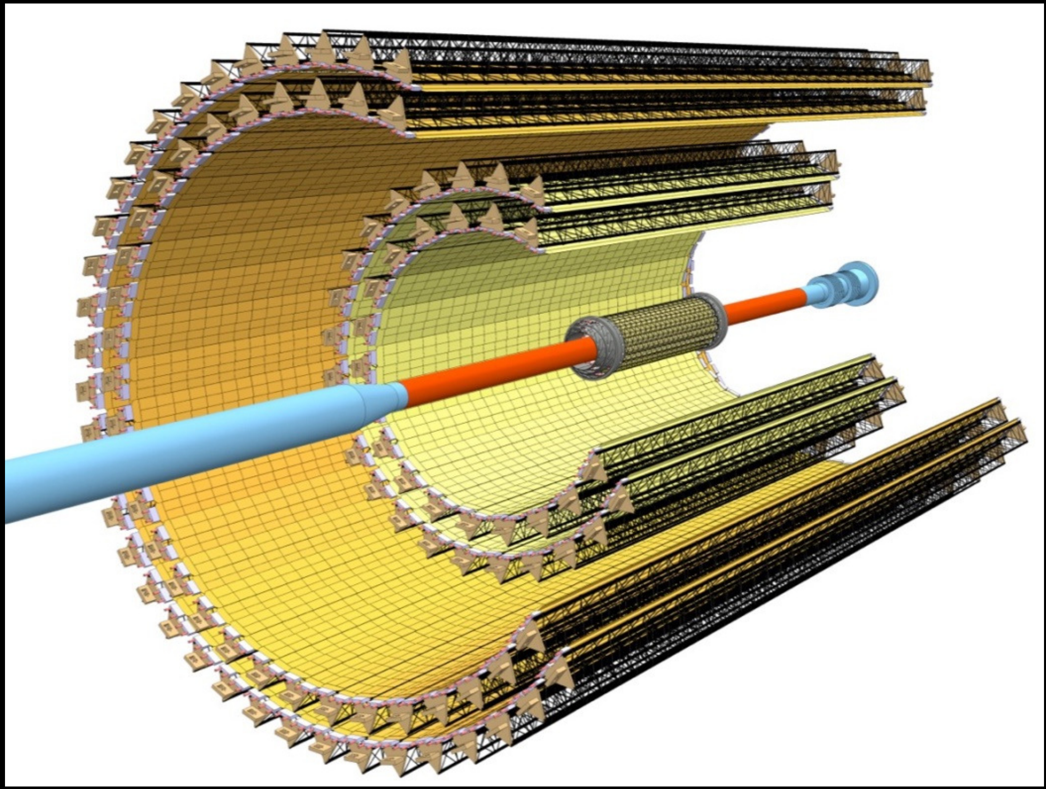


A second detector concept

- Usual elements:
  - Vertex detector
  - Tracker
  - (Preshower)
  - Calorimeter
  - Solenoid
  - Muon system

Vertex detector

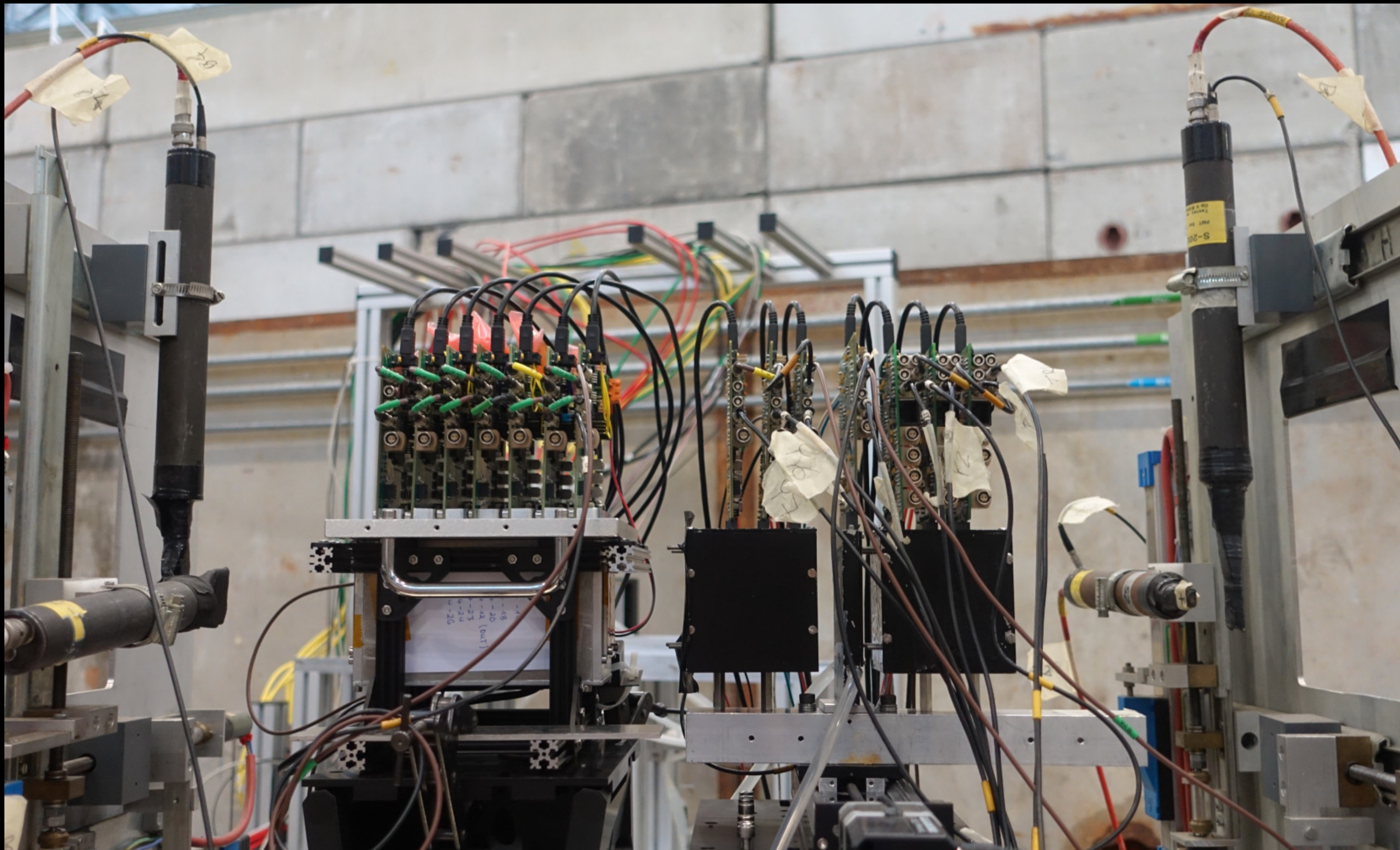
- Build on ALICE ITS technology
  - 30x30 μm MAPS
  - %X0
    - 0.3-1.0% (in-out)
  - Power:
    - 41-27 mW/cm2 (in-out)
  - Radiation hard
  - >100 kHz readout



- Optimize # layers

Vertex detector

❖ Impressive recent test beam results



Courtesy of ALICE J.W. van Hoorne

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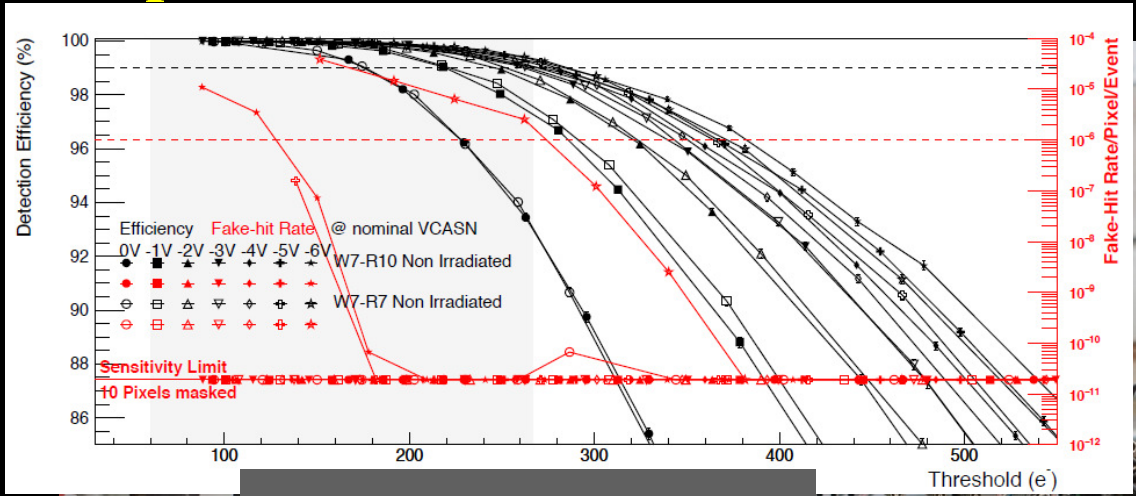
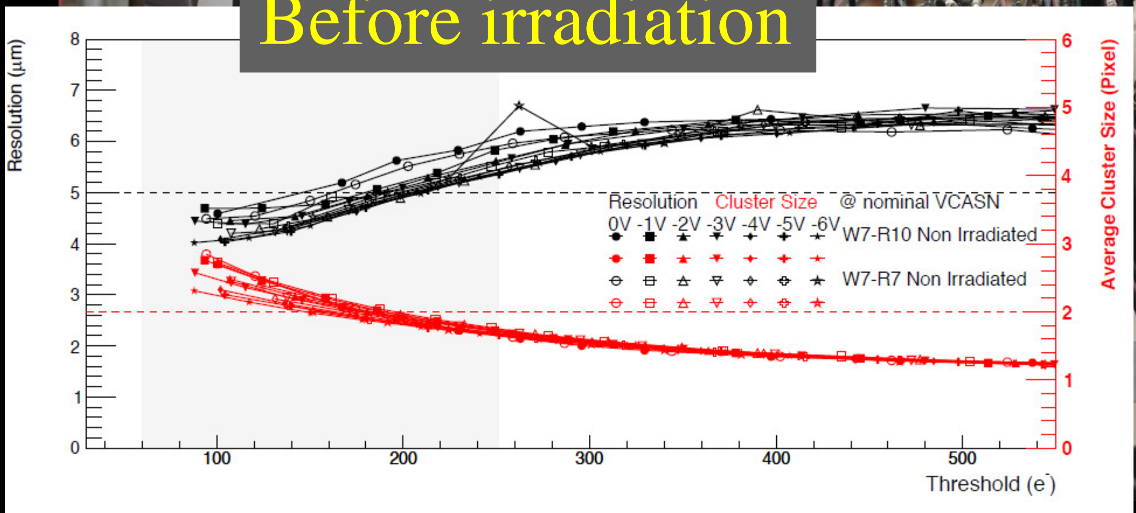


Before irradiation



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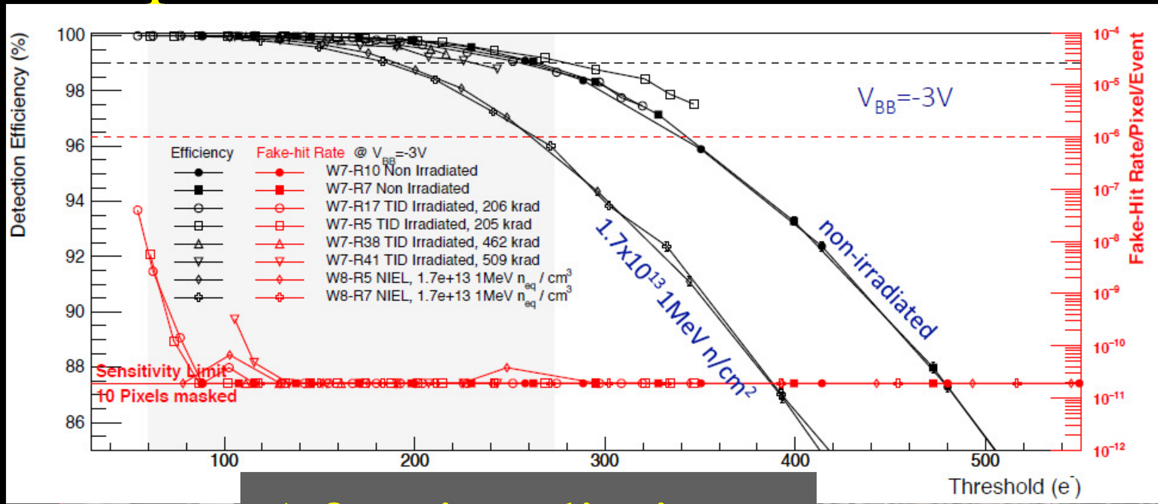

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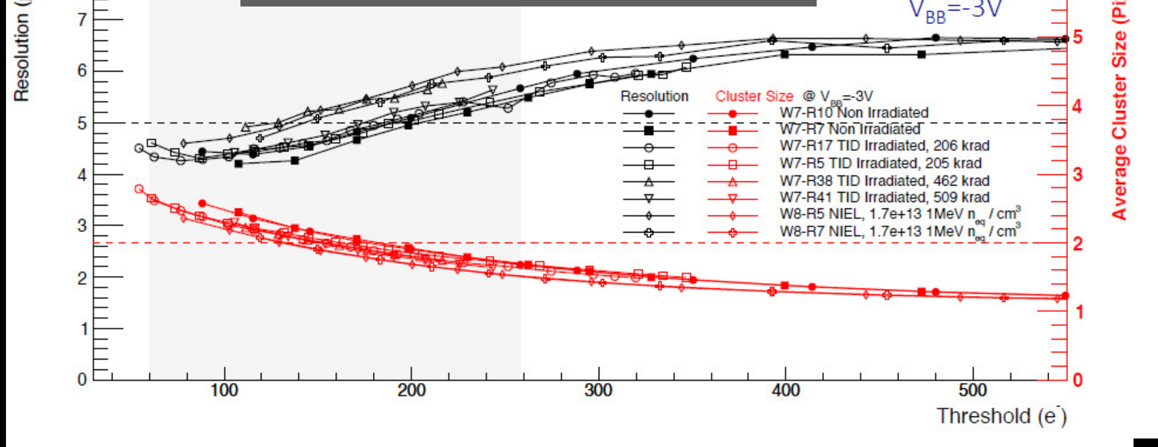

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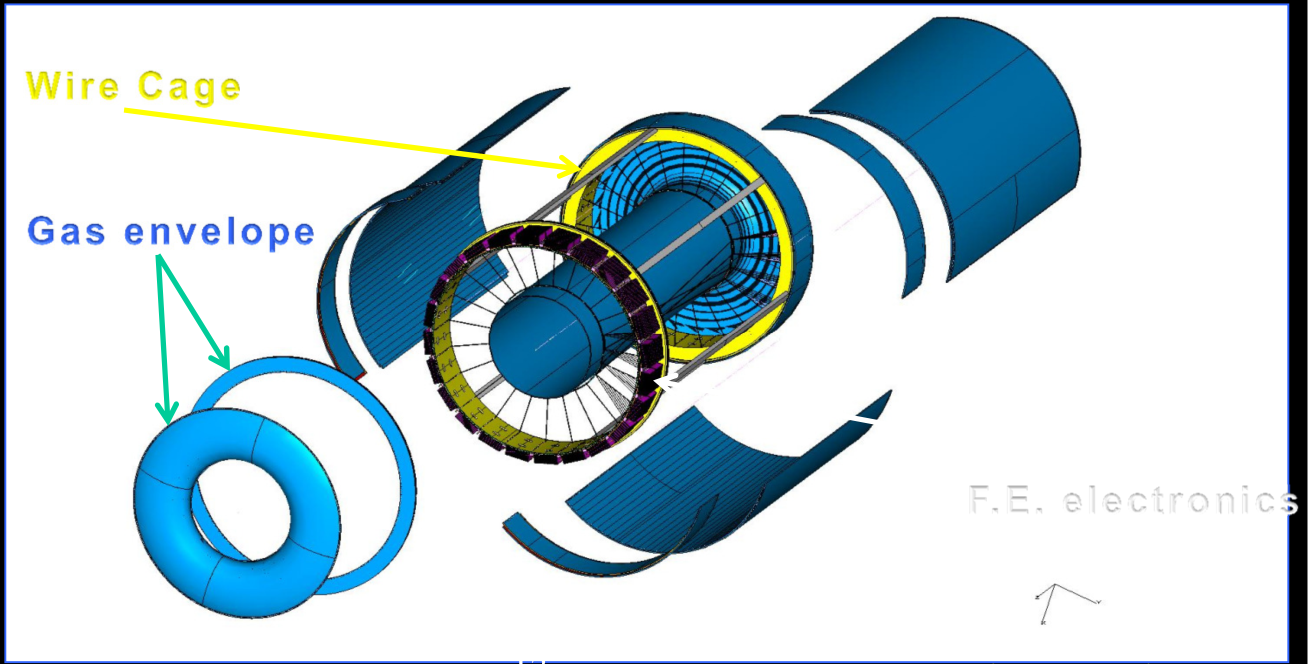
Tracker

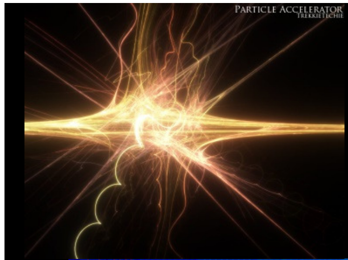
- Drift Chamber: fast, small ion buildup, good dE/dx
  - Ultralight chamber (<1% X_0) – gas: He 90% - iC_4H_{10} 10%
  - 4 m long, drift length ~1 cm, drift time ~150ns, σ_{xy} < 100 μm

$$\frac{\Delta p_\perp}{p_\perp} = \frac{8\sqrt{5}\sigma}{.3BL^2\sqrt{n}} p_\perp = 7.1\times10^{-5} p_\perp \, [GeV/c]$$

- B = 2 T
- L = 2 m
- N = 112



See talk of F. Grancagnolo



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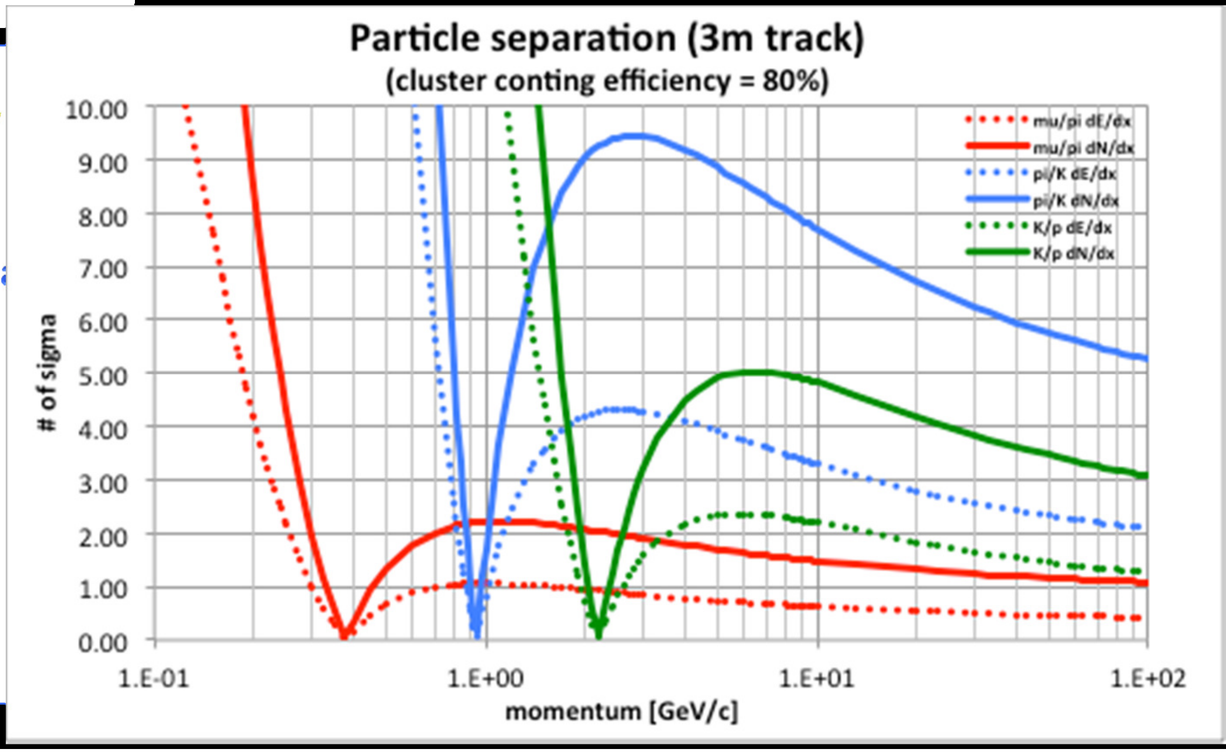
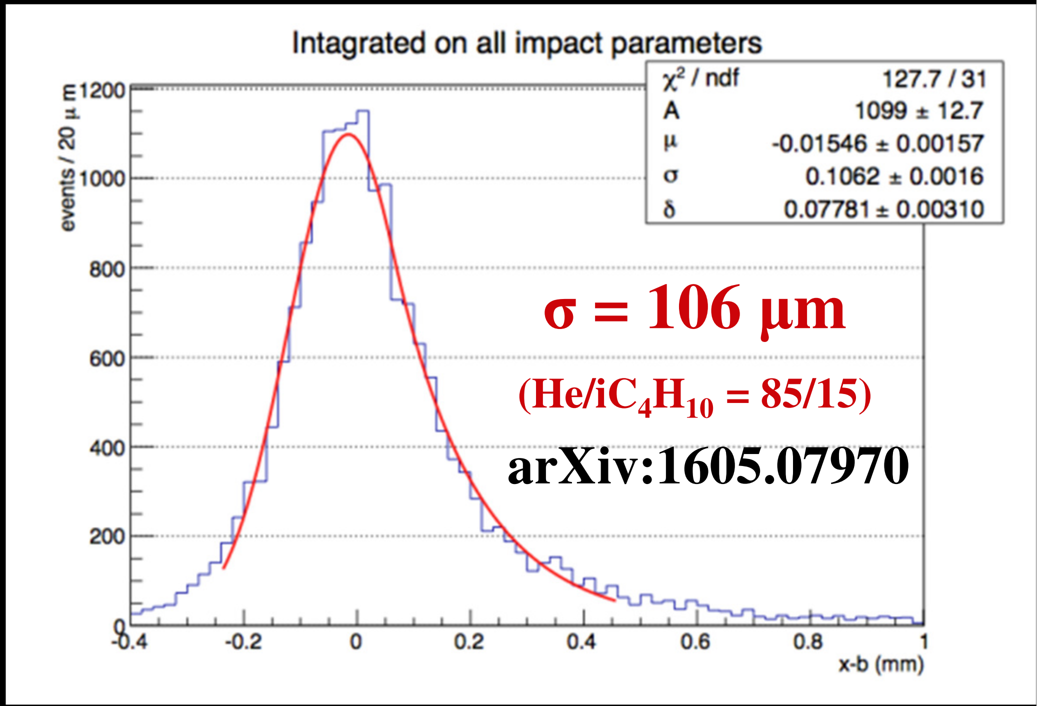
- dE/dx ~ 4%
- dN/dx ~ 2%

See talk of F. Grancagnolo



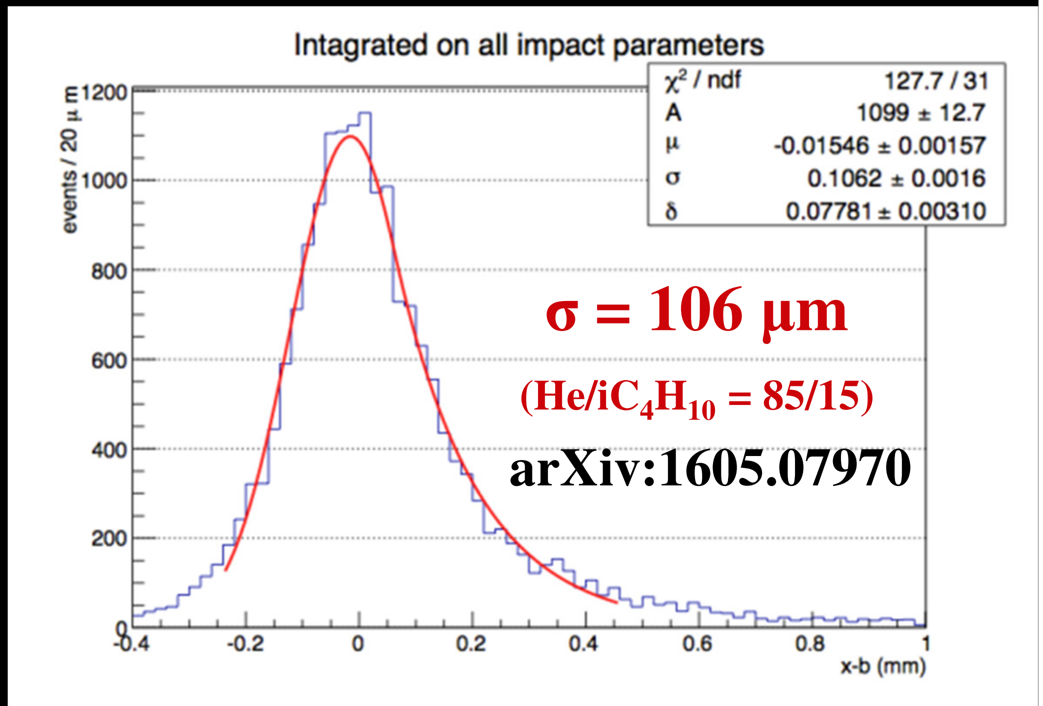
Tracker

❖ Minimal performance established (MEG-II prototype)



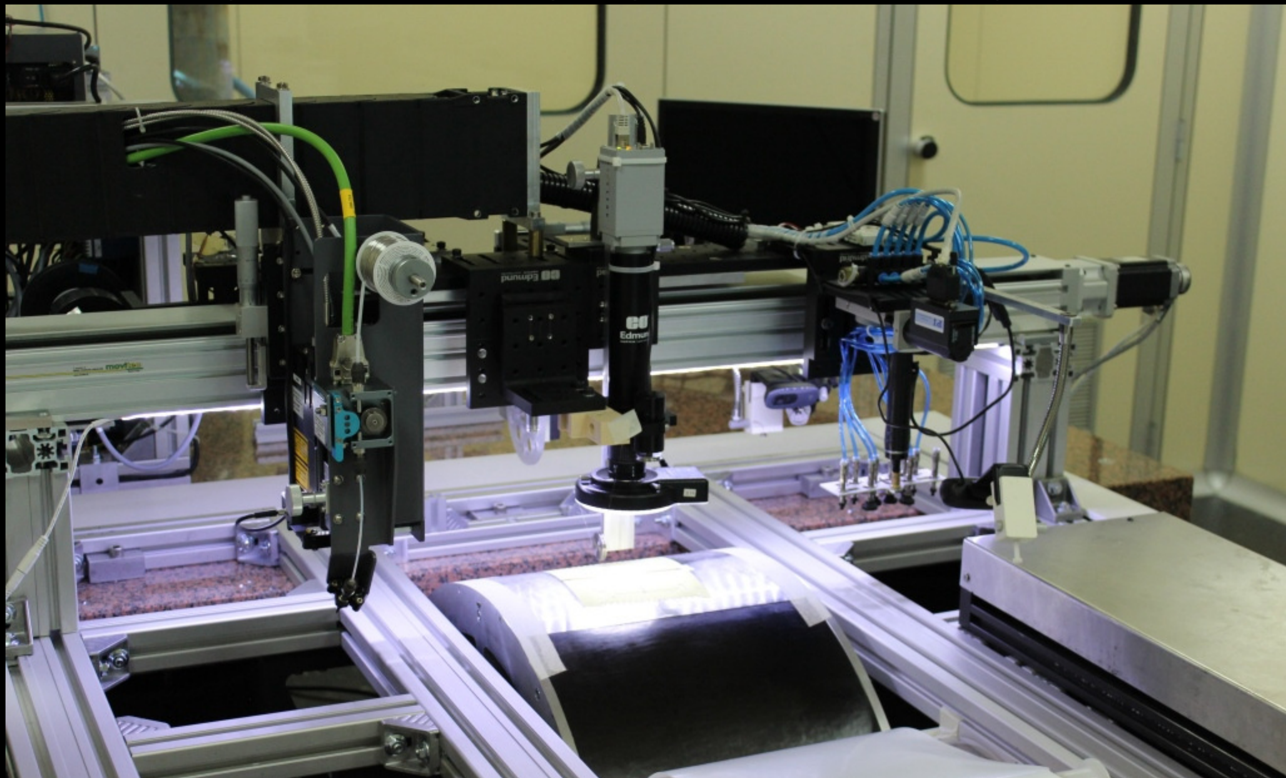
Tracker

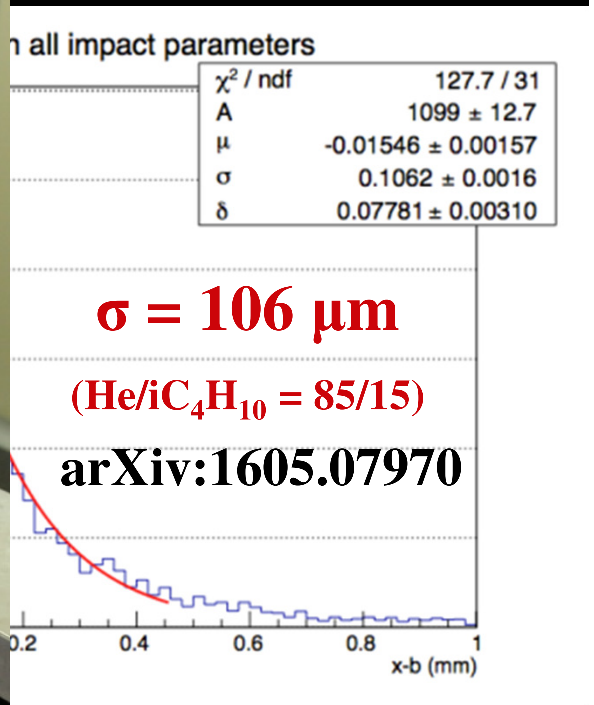
- Minimal performance established (MEG-II prototype)
- Technical solutions engineered (MEG-II)



Tracker

- Minimal performance established (MEG-II prototype)
- Technical solutions engineered (MEG-II)
  - E.g. Wire stringing and soldering machine





$\sigma = 106\ \mu m$

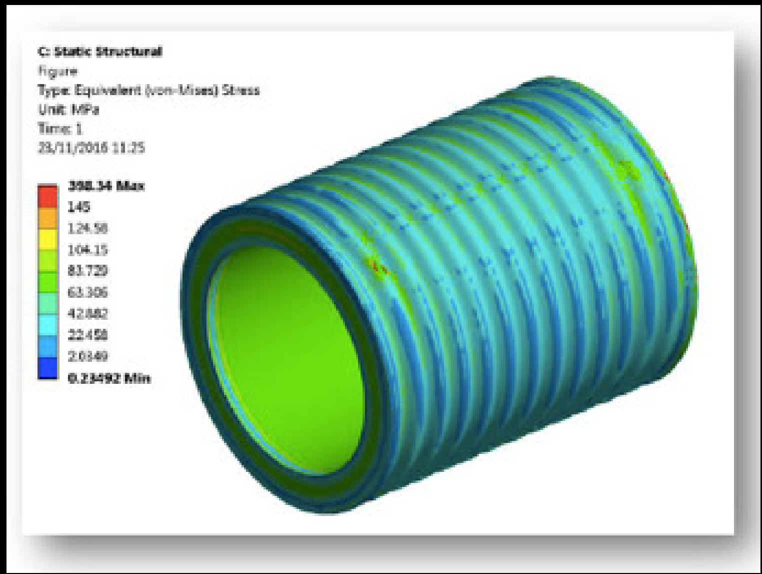
($He/iC_4H_{10} = 85/15$)

arXiv:1605.07970

2T solenoid

- Two options:
  - Large bore (R=3.7 m) – calorimeter inside
  - Smaller bore (R=2.2 m) – calorimeter outside
    - Preferred: simpler/ Extreme EM resolution not needed
      - Thick calorimeter
    - Thin (30 cm): total = 0.74 X_0 (0.16 λ) at $\theta = 90^\circ$

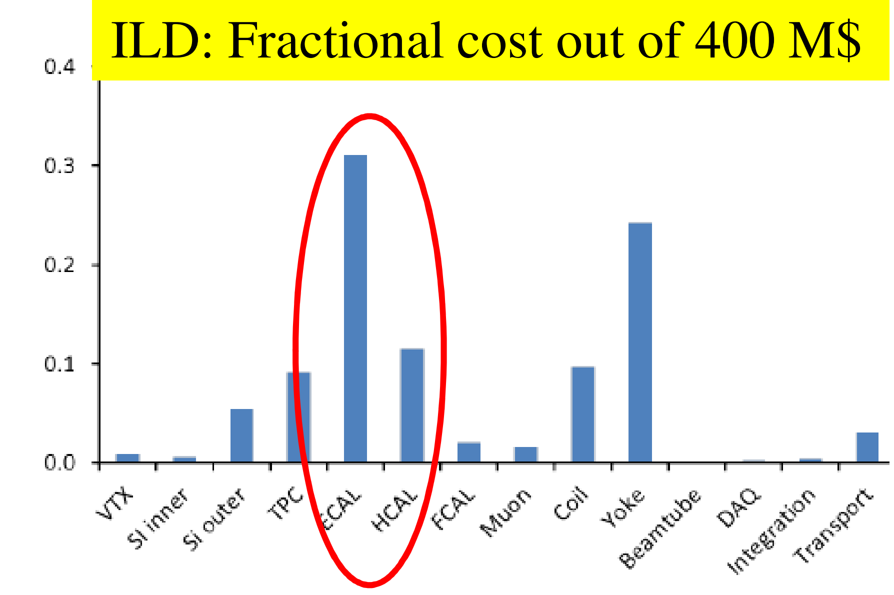
Property	Value
Magnetic field in center [T]	2
Free bore diameter [m]	4
Stored energy [MJ]	170
Cold mass [t]	8
Cold mass inner radius [m]	2.2
Cold mass thickness [m]	0.03
Cold mass length [m]	6

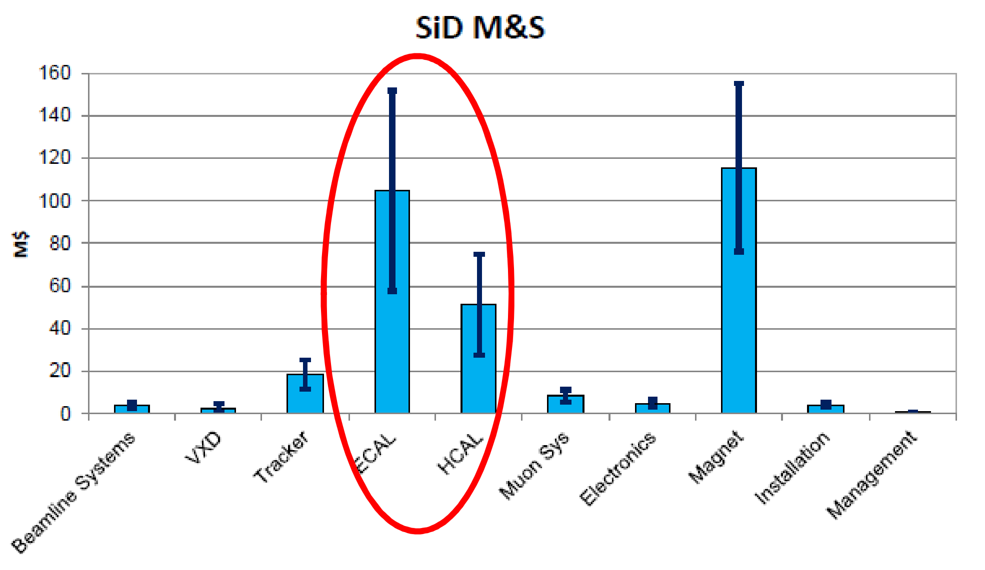


Courtesy of H. ten Kate et al.

Calorimeter

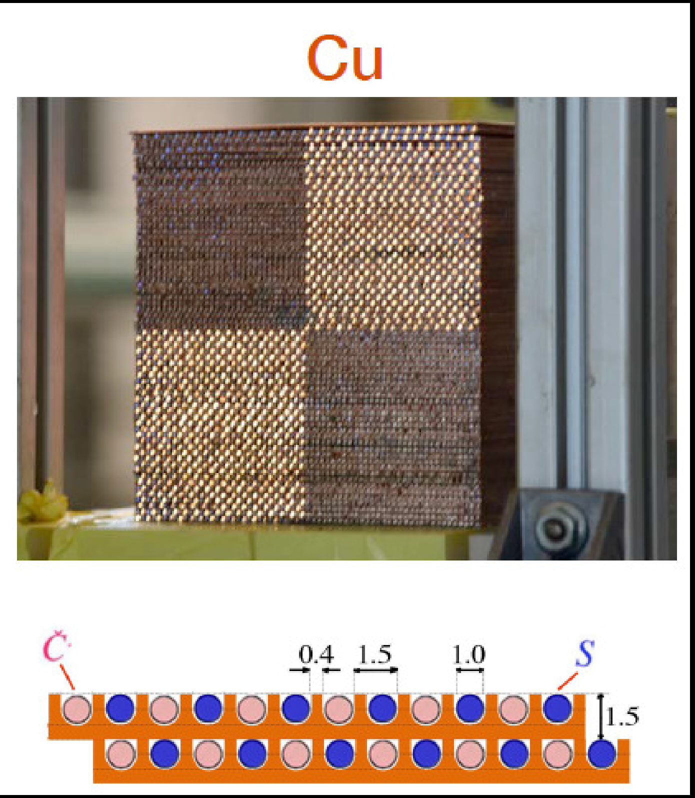
- Particle flow calorimeters are extremely expensive!
- Similar (or better) performances with dual readout
  - EM and HAD in same calorimeter
  - High transverse granularity





Calorimeter

- Copper dual readout calorimeter

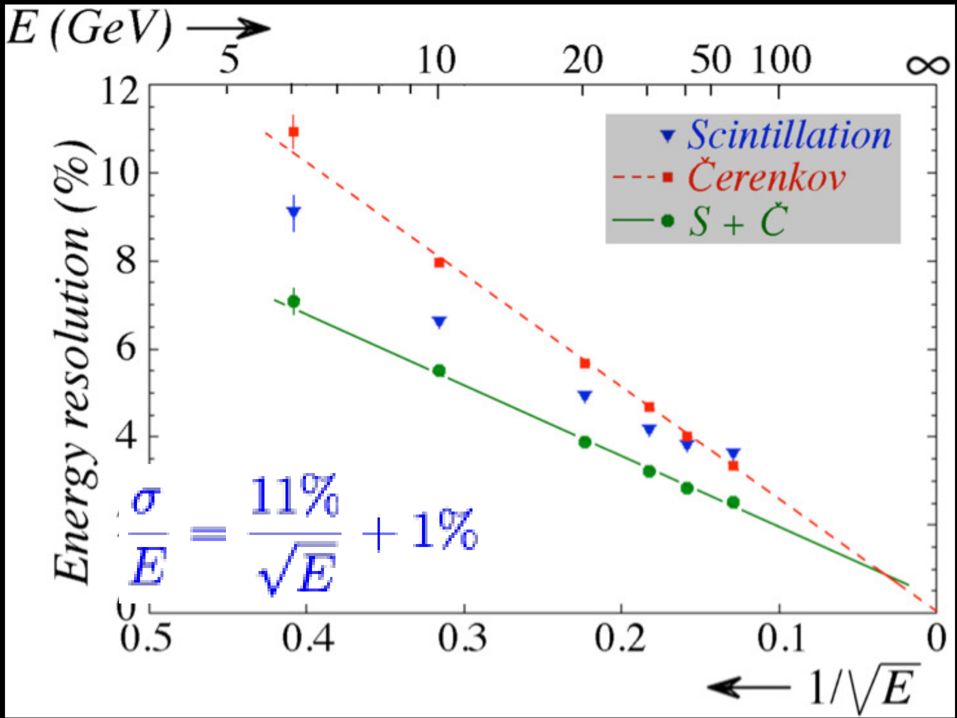


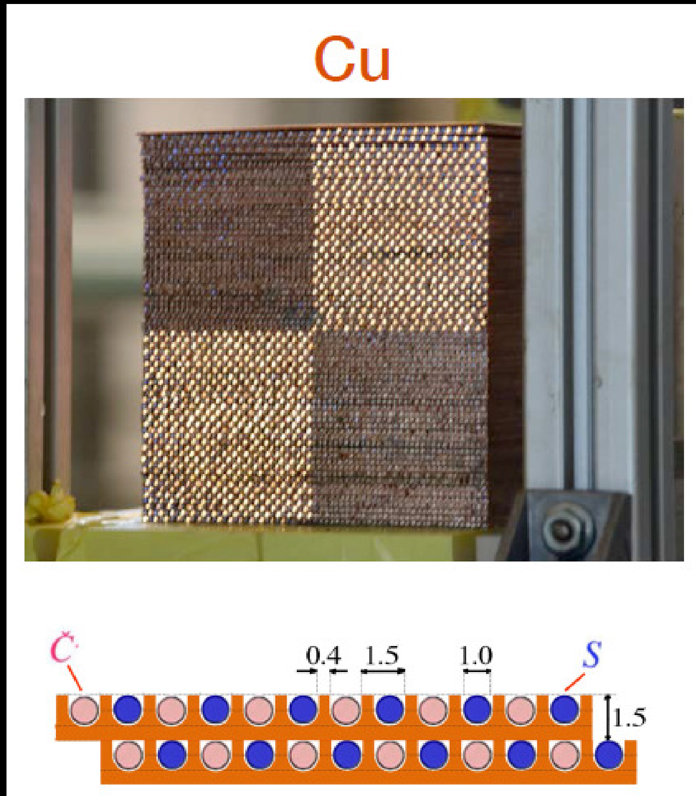
Courtesy of DREAM/RD52

Calorimeter

- Copper dual readout calorimeter
  - Demonstrated EM resolution

Courtesy of DREAM/RD52

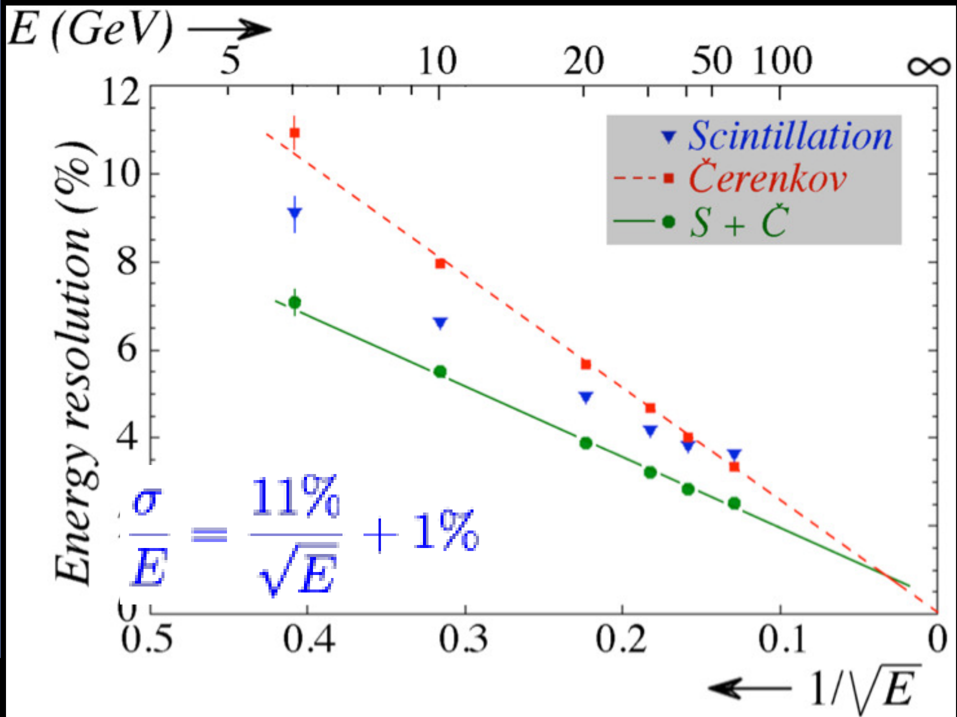


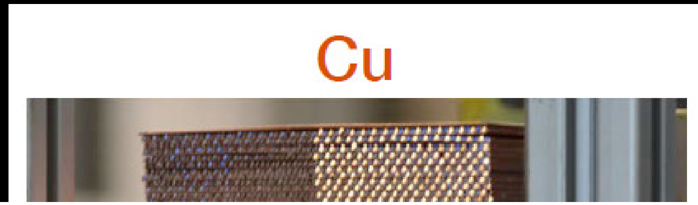


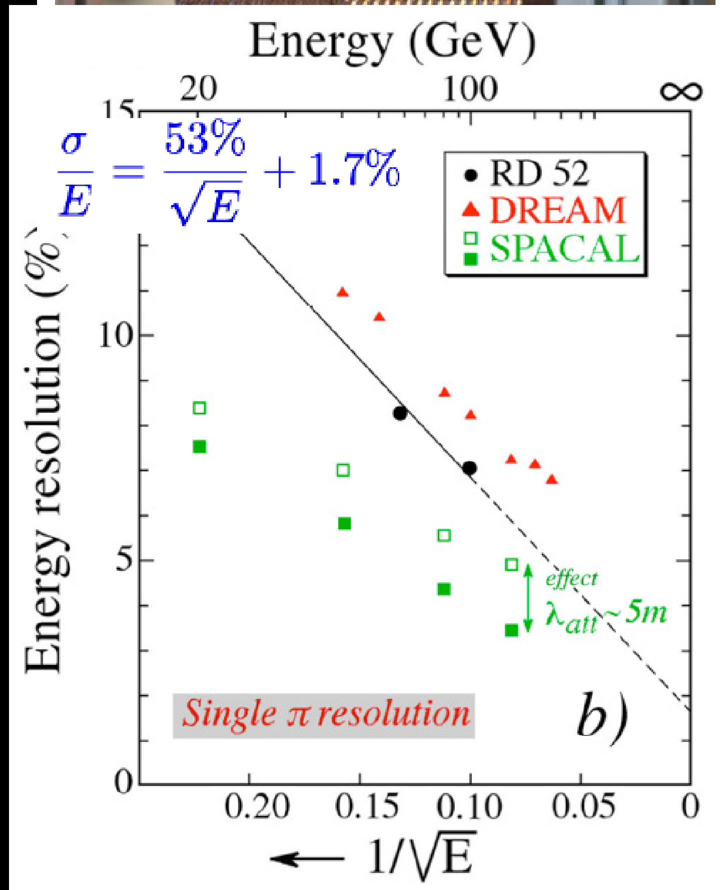
Calorimeter

- Copper dual readout calorimeter
  - Demonstrated EM resolution
  - Observed Had resolution dominated by lateral leakage (~6%)

Courtesy of DREAM/RD52







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  - Can improve with timing and lateral shape cuts
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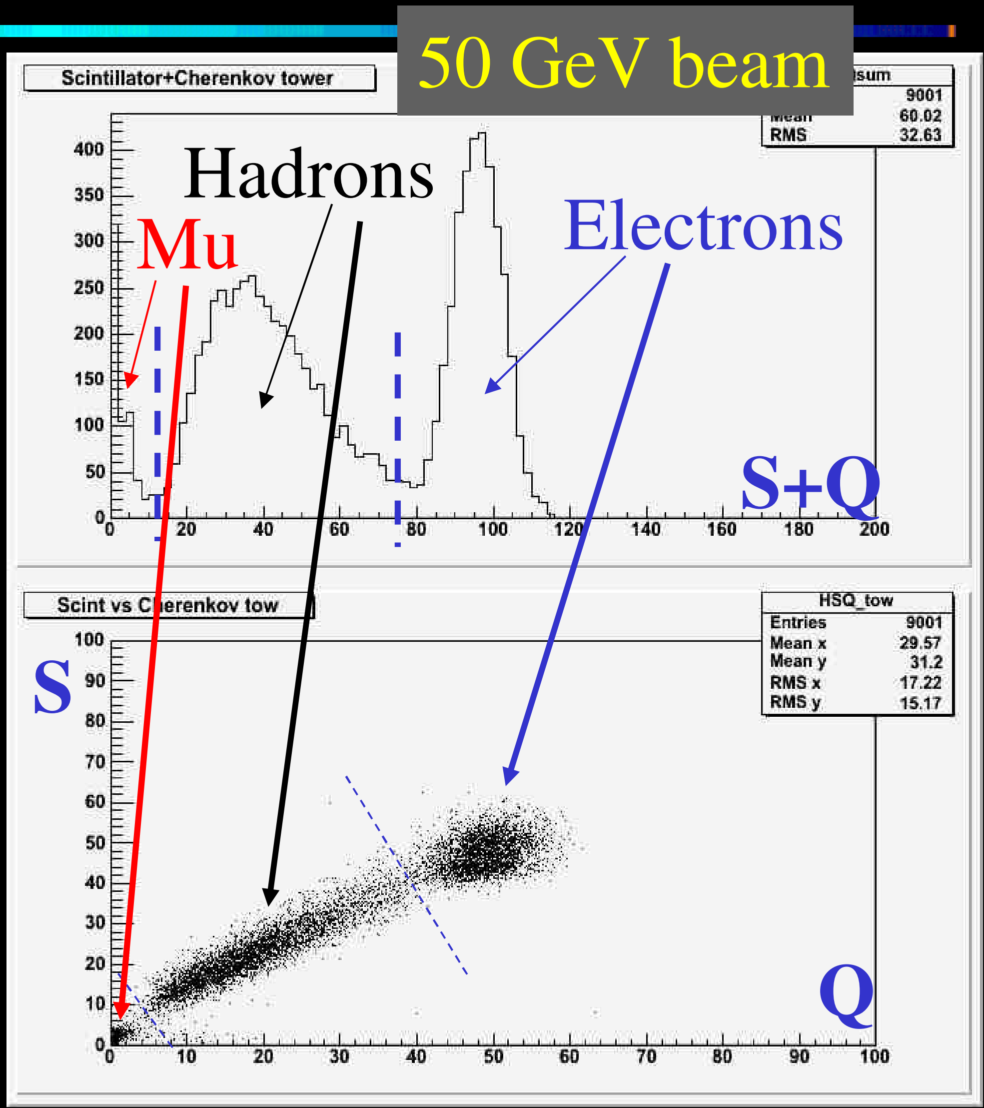

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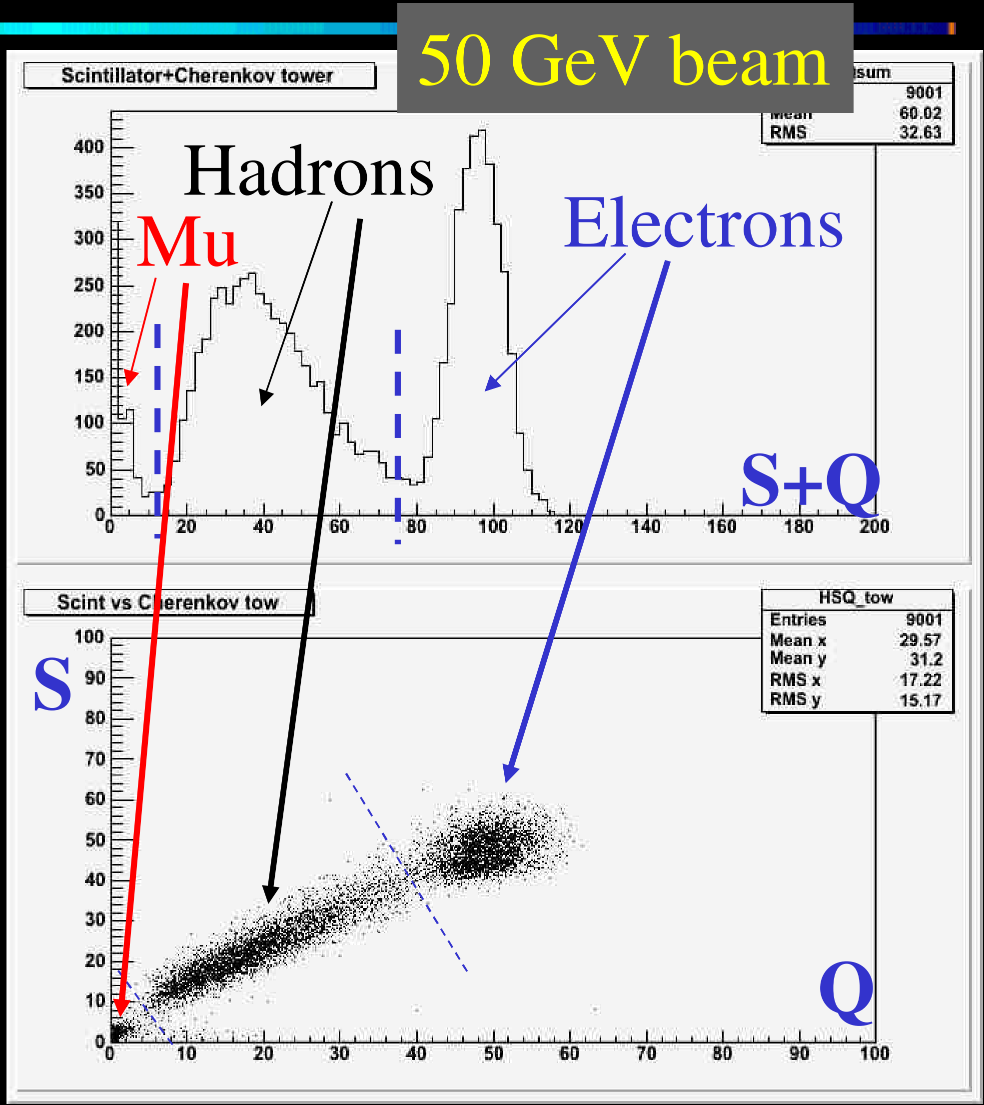
- Natural μ/π/e separation
  - Can improve with timing and lateral shape cuts
    - $\varepsilon_{el} > 99\%$, <0.2% π mis-ID
- Preshower (~2 X_0)
  - Acceptance determination e/γ /π^0 separation



Muons

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  - Vertex+DCH: ~ 0.5% @ 100 GeV

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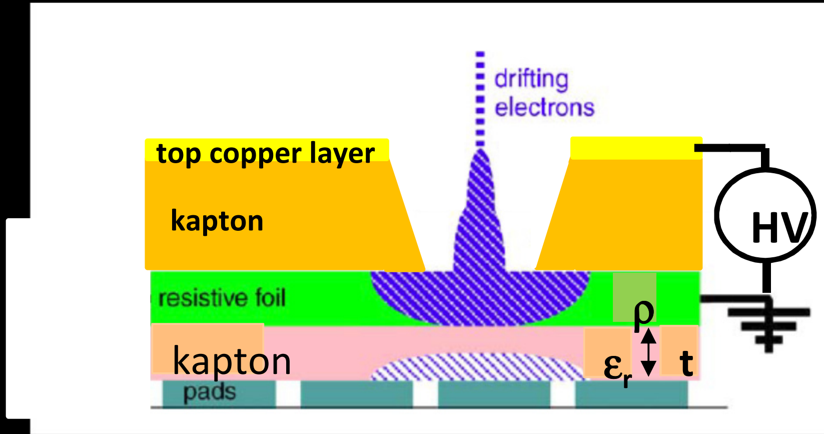
    - μ-RWELL low-cost technology already proven for low rate applications (CMS/SHiP)



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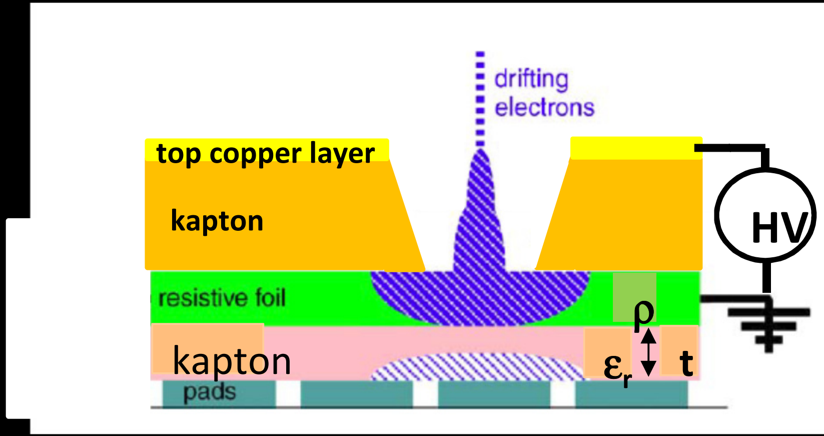
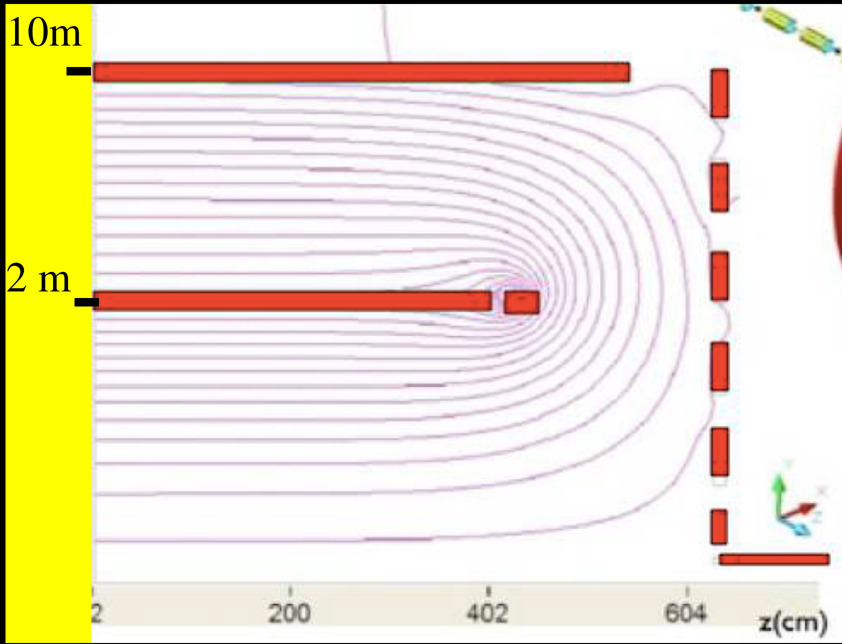
    - Iron yoke or partial yoke
  - Followed by additional chambers
    - μ-RWELL low-cost technology already proven for low rate applications (CMS/SHiP)
  - Potential outer solenoid
    - Flux return → reduced yoke
    - Muon tracking





Summarizing ....

- Beam pipe (R~2 cm)

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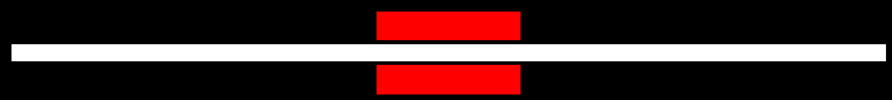
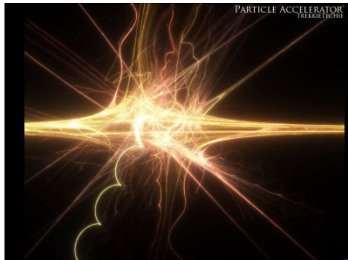
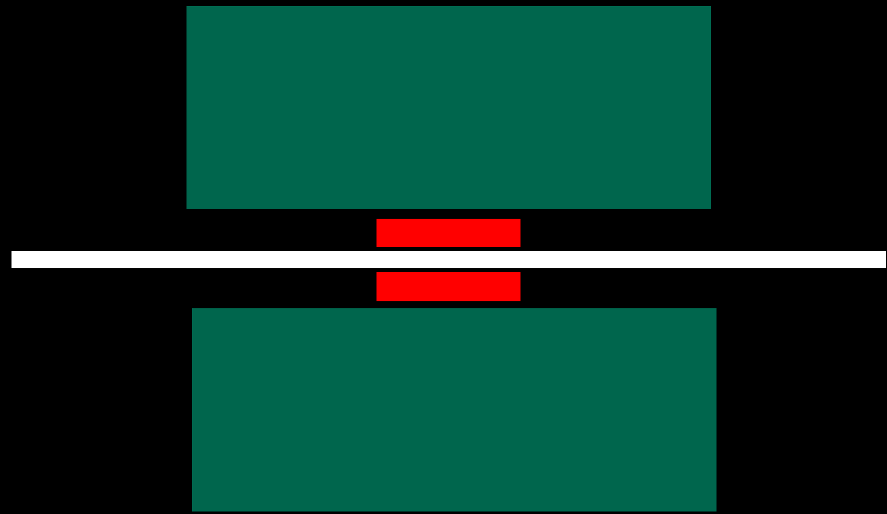
- VTX: 4-7 MAPS layers





Summarizing ....

- Beam pipe (R~2 cm)
- VTX: 4-7 MAPS layers
- DCH: 4 m long, R 40-200 cm



Summarizing ....

- Beam pipe (R~2 cm)
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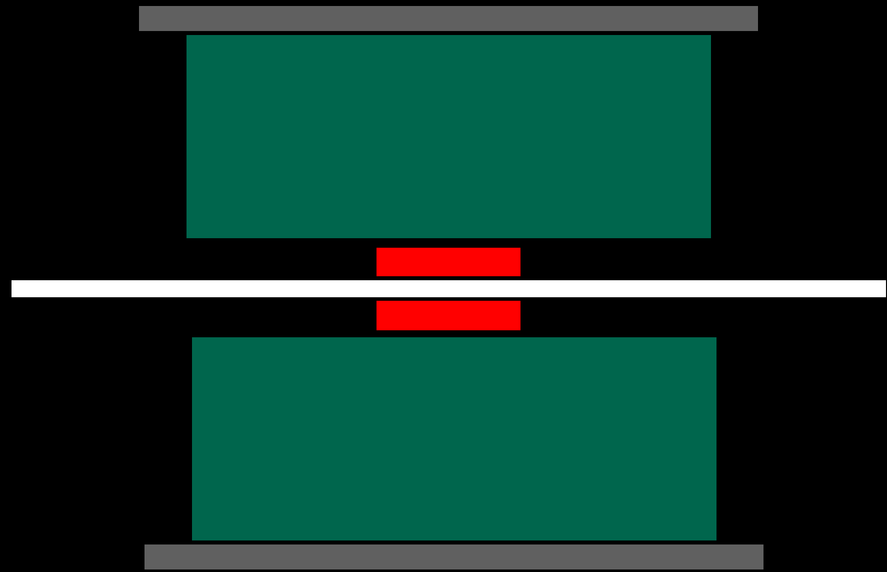

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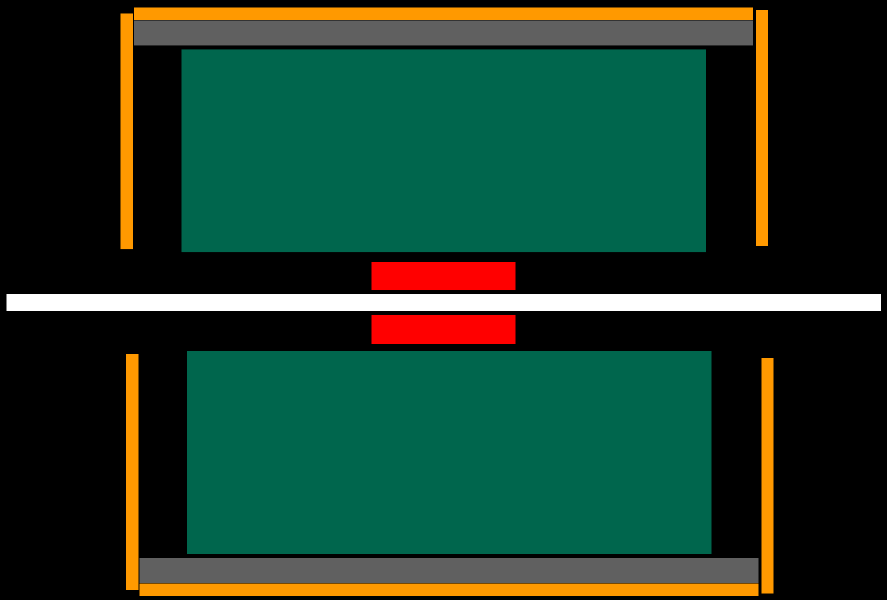

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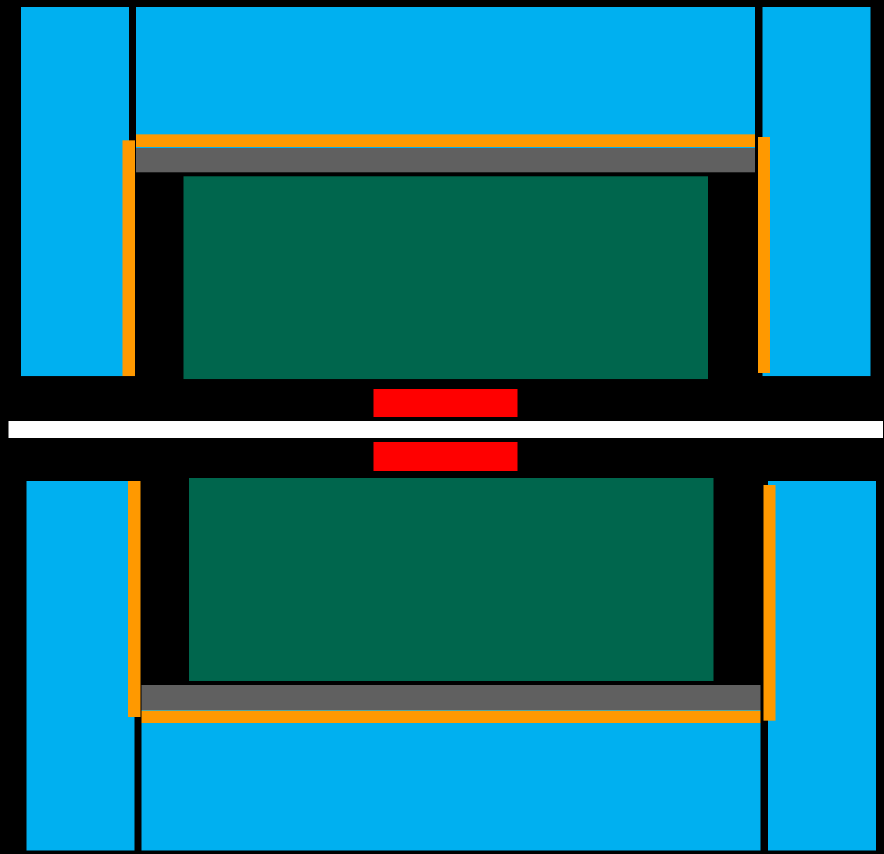

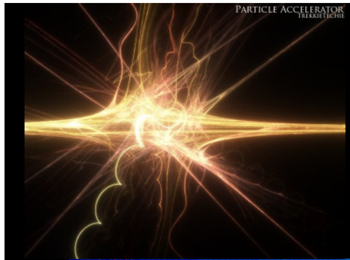

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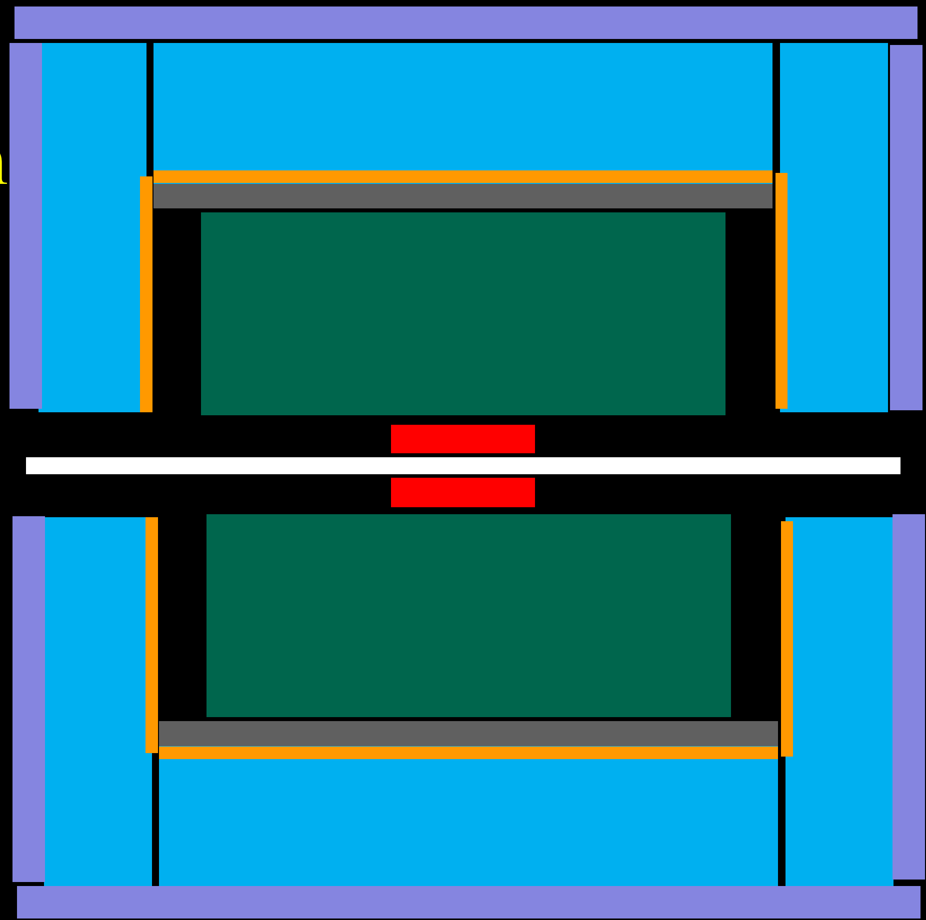

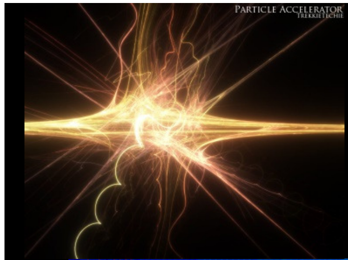

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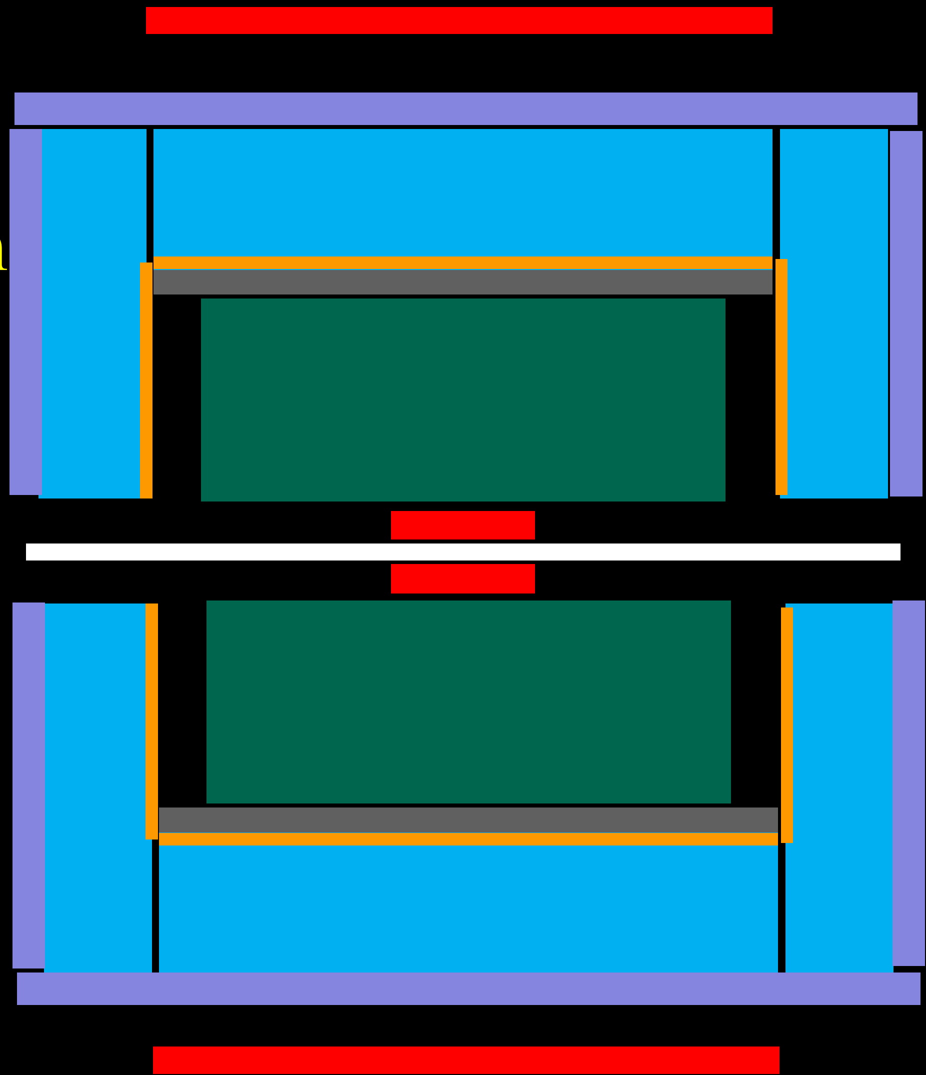
- VTX: 4-7 MAPS layers
- DCH: 4 m long, R 40-200 cm
- 2 T, R~2 m SC Coil
- Preshower (1-2 X_0)
- DR calorimeter (2 m/8 λ_{int})
- (yoke) muon chambers
  - (Dual solenoid ?)



Conclusions

- Proposed detector is:
  - Feasible with existing technology
    - More R&D can only improve
  - Performant in full range of energy and luminosity
    - Fast detector, can resolve beam crossing
  - Very low mass ~3-4% X_0 before solenoid
  - Low cost relative to ILD-like solutions
- Several optimizations needed → future simulation work
  - Pixel layers, preshower, calorimeter and muon system configuration
  - Need for more PID beyond DCH and Calorimeter?
- Major overlap with current FCC-ee baseline detector

Backup

BACKUP

Parameter for CEPC Partial Double Ring

（wangdou20161109-61km）

	Pre-CDR	*H-high lumi.*	*H-low power*	*W*	*Z*	*Z-5cell*
Energy (GeV)	120	120	120	80	45.5	45.5
Circumference (km)	54	61	61	61	61	61
SR loss/turn (GeV)	3.1	2.96	2.96	0.58	0.061	0.061
N_e/bunch (10^{11})	3.79	2.0	1.98	0.85	0.6	0.6
Bunch number	50	107	70	400	1100	700
SR power /beam (MW)	51.7	50	32.5	15.7	3.2	2.0
β_{IP} x/y (m)	0.8/0.0012	0.272/0.0013	0.275 /0.0013	0.16/0.001	0.12/0.001	0.12/0.001
Emittance x/y (nm)	6.12/0.018	2.05/0.0062	2.05 /0.0062	0.93/0.003	0.87/0.0046	0.87/0.0046
ξ_x/IP	0.118	0.041	0.042	0.0145	0.0098	0.0098
ξ_y/IP	0.083	0.11	0.11	0.084	0.073	0.073
V_{RF} (GV)	6.87	**3.48**	**3.51**	**0.7**	**0.12**	**0.12**
f_{RF} (MHz)	650	650	650	650	650	650
Nature σ_z (mm)	2.14	**2.7**	**2.7**	**3.23**	**3.9**	**3.9**
Total σ_z (mm)	2.65	2.95	2.9	3.35	4.0	4.0
HOM power/cavity (kw)	3.6	0.74	0.48	0.47	0.59	0.93
Energy acceptance (%)	2	2	2			
Energy acceptance by RF (%)	6	**2.3**	**2.4**	**1.3**	**1.1**	**1.1**
Life time due to beamstrahlung cal (minute)	47	37	37			
L_{max}/IP ($10^{34}cm^{-2}s^{-1}$)	2.04	3.1	2.01	3.5	3.44	2.2

R. Manqui: FCC physics workshop, Jan. 14, 2017

Parameters for CEPC Fully Partial Double Ring

（wangdou20161219-100km_1mmβy）

	Pre-CDR	H-high lumi.	H-low power	W	Z	
Energy (GeV)	120	120	120	80	45.5	45.5
Circumference (km)	54	100	100	100	100	100
SR loss/turn (GeV)	3.1	1.67	1.67	0.33	0.034	0.034
N_e/bunch (10^{11})	3.79	1.12	1.12	1.05	0.46	0.46
Bunch number	50	555	333	1000	16666	65716
SR power /beam (MW)	51.7	**50**	**30**	16.7	12.7	50
β_{IP} x/y (m)	0.8/0.0012	0.3/0.001	0.3/0.001	0.1 /0.001	0.12/0.001	0.12/0.001
Emittance x/y (nm)	6.12/0.018	1.01/0.0031	1.01/0.0031	2.68/0.008	0.93/0.0049	0.93/0.0049
ξ_x/ξ_y/IP	0.118/0.083	0.029	0.029	0.0082/0.055	0.0075/0.054	0.0075/0.054
RF Phase (degree)	153.0	0.083	0.083	149	160.8	160.8
V_{RF} (GV)	6.87	**2.0**	**2.0**	**0.63**	**0.11**	**0.11**
f_{RF} (MHz) (harmonic)	650	650	650	650 (217800)	650 (217800)	
Nature σ_z (mm)	2.14	**2.72**	**2.72**	**3.8**	**3.93**	**3.93**
Total σ_z (mm)	2.65	2.9	2.9	3.9	4.0	4.0
HOM power/cavity (kw)	3.6 (5cell)	0.75(2cell)	0.45(2cell)	1.0 (2cell)	1.6(1cell)	6.25(1cell)
Energy acceptance (%)	2	1.5	1.5			
Energy acceptance by RF (%)	6	1.8	1.8	1.5	1.1	1.1
Life time due to beamstrahlung_cal (minute)	47	52	52			
L_{max}/IP (10^{34}cm^{-2}s^{-1})	2.04	5.42	3.25	4.08	18.0	70.97

J. Gao: IAS Conference, HK, Jan. 23, 2017