(a) Produce Photon Beams by Accelerating Charges

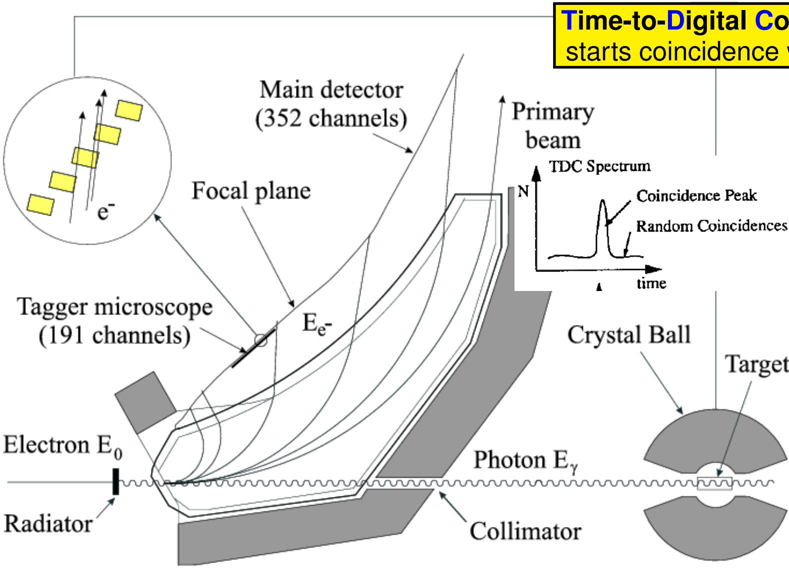
Tagged Photon Facility: “Glasgow Tagger” (A2@MAMI)

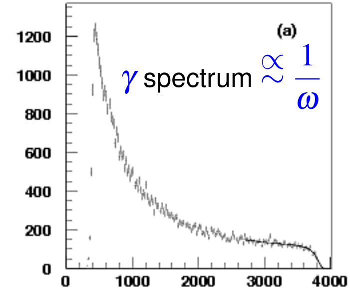
upgrade under way: **see Downie**

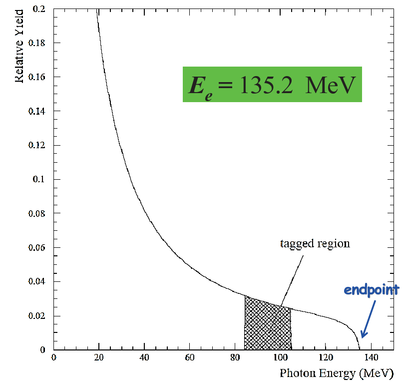
e^- on diamond (polarised γ at MAMI) or foil (unpolarised) $\Longrightarrow$ continuous **Bremsstrahlung** spectrum

Tagging: detect momentum of deflected electron event-by-event $\Longrightarrow$ photon energy $\omega = E_0 - E'_e$

Time-to-Digital Converter starts coincidence window







Event-selector is excellent trigger to reduce background for small-rate experiments (Compton: nanobarn$\widehat{=}\frac{\text{events}}{\text{hour}}$).

(b) Synchrotron Radiation

[Edyn RadSys pp. 37ff, Edyn HW]

accelerated charges radiate $\Longrightarrow$ ultra-relativistic energy loss of single particle per orbit on circle:

$$-\Delta E = \frac{4\pi Z^2 \alpha}{3} \frac{1}{R} \left(\frac{E}{m}\right)^4$$

Larmor's formula (relativistic)

HW: Very narrowly peaked in direction of $\vec{v}$, *not* of acceleration!

LEP-II (electron-positron, same tunnel as LHC): $E = 85\text{GeV}$ $\Longrightarrow$ 2% energy loss

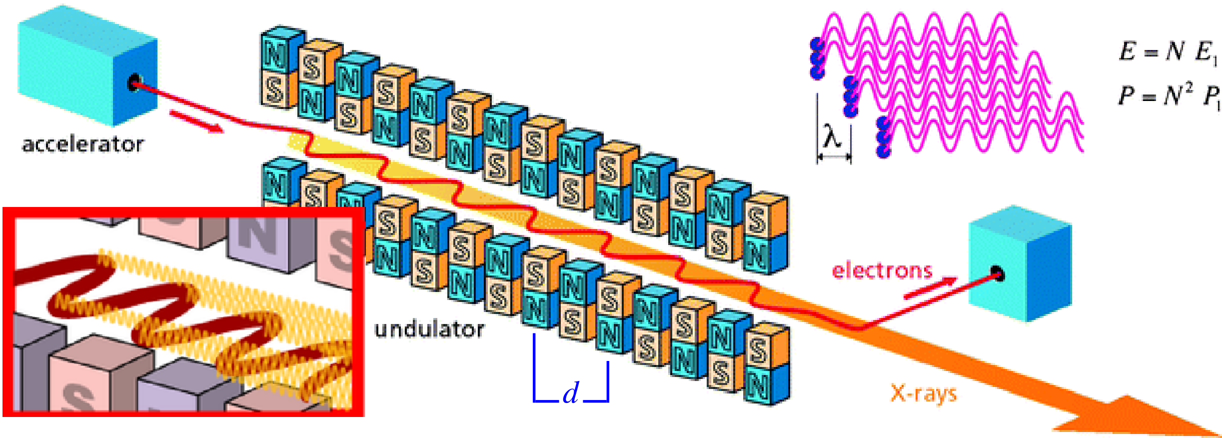
Compensate by increasing R??: 4th power vs 1st power $\Longrightarrow$ $$$!

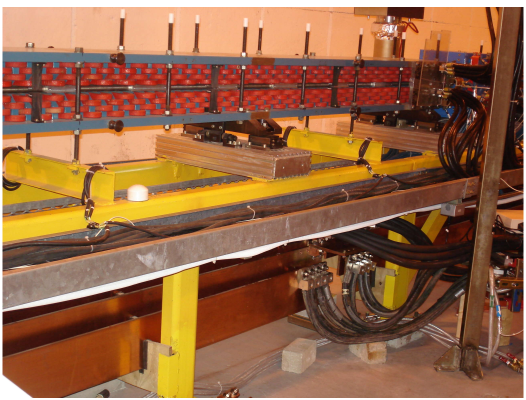
at same energy, radiation loss for proton smaller by

$$\left(\frac{m_e}{M_p}\right)^4 \approx \left(\frac{1}{1800}\right)^4 \approx 10^{-13}$$

$\Longrightarrow$ LHC-proton energy up to $14\ \text{TeV}$ (limit is strength of mag. holding field for same orbit!)

(c) 3rd Generation Synchrotron & Free Electron Laser





Undulators, period d: e^- wiggles $\Longrightarrow$ emits radiation

Lasing: e^- in bunches, tuning $\Longrightarrow$ **induced emission**

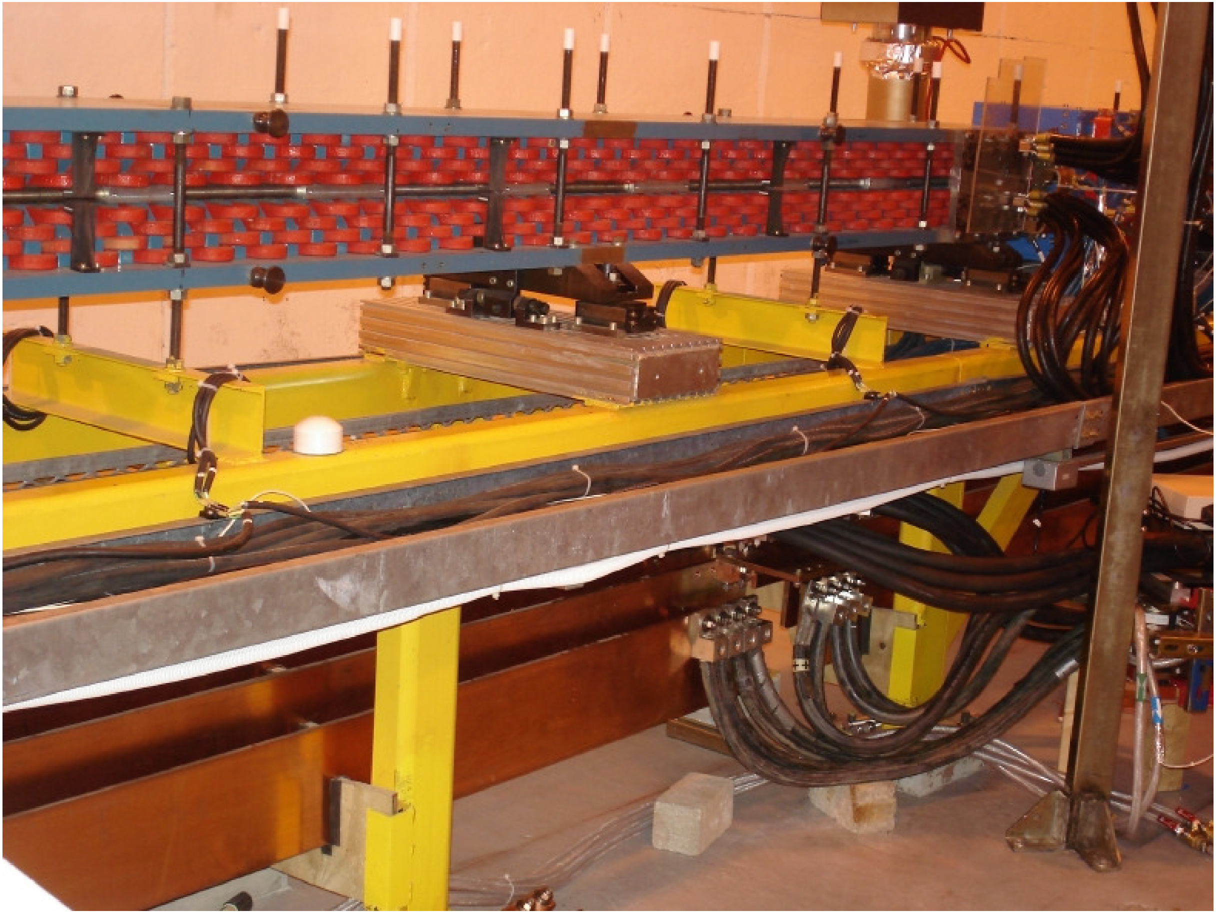
Lorentz contraction: wavelength $\frac{d}{\gamma}$ in e^- rest frame

"Radiation Always Forward" (HW): emit photon along e^-

Relativistic Doppler Effect into lab frame: $\lambda = \frac{1}{\gamma}\left(\frac{d}{\gamma}\right)$

Example: electrons at $1\mathrm{GeV} \Longrightarrow \gamma = \frac{E}{m} \approx 2000$:

$$\omega \approx \frac{2\pi\,(\gamma \sim 2000)^2}{d \sim 0.3\mathrm{m}} \approx [1\ldots10]\mathrm{eV}\text{: visible light, UV}$$



FEL $+$ Mirror $=$ Compton Backscattering Facility   Feldman, Downie (hg PAC)

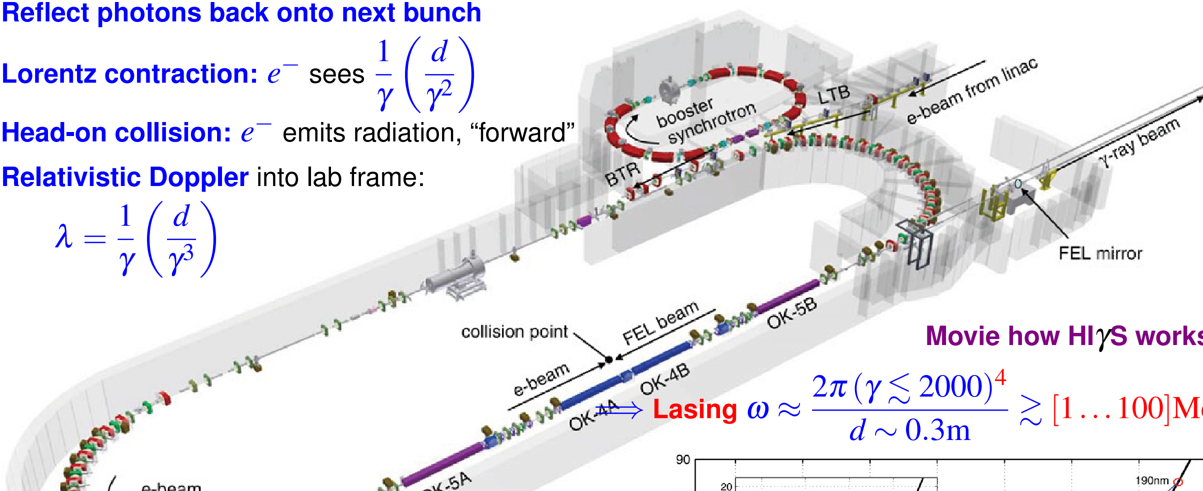
Reflect photons back onto next bunch

Lorentz contraction: e^- sees $\frac{1}{\gamma}\left(\frac{d}{\gamma^2}\right)$

Head-on collision: e^- emits radiation, "forward"

Relativistic Doppler into lab frame:

$$\lambda = \frac{1}{\gamma}\left(\frac{d}{\gamma^3}\right)$$



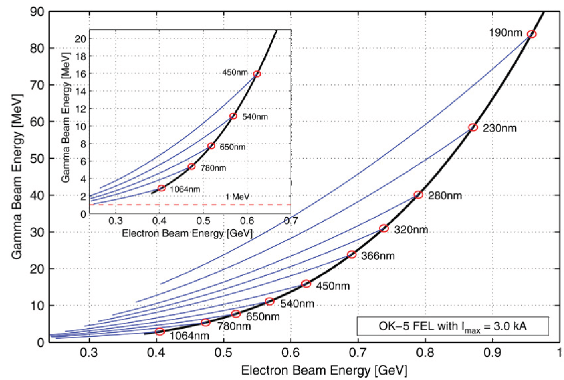
Movie how HIγS works

$\Longrightarrow$ **Lasing** $\omega \approx \frac{2\pi\,(\gamma \lesssim 2000)^4}{d \sim 0.3\text{m}} \gtrsim [1\ldots100]\text{MeV}$

High Intensity γ-Ray Facility HIγS, Duke U. (NC)

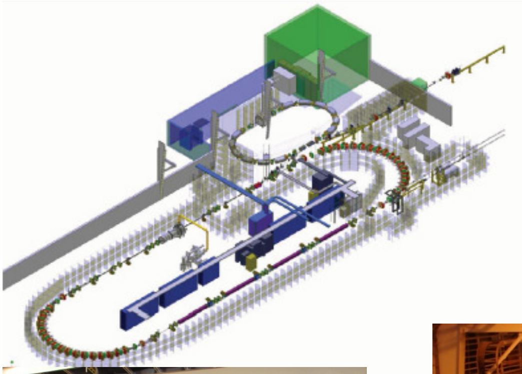
$E < 100\text{MeV}$ tunable, $\Delta E \lesssim 5\%$ quasi-monochromatic

$10^7\,\frac{\gamma}{s}$: **most brilliant laser**, 100% circ. or lin. polarisation



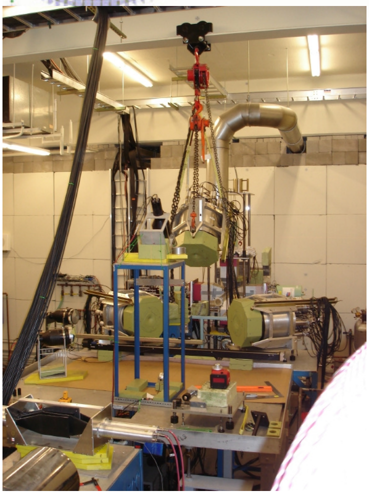
e^- energy, FEL (mirror) wavelength, γ energy

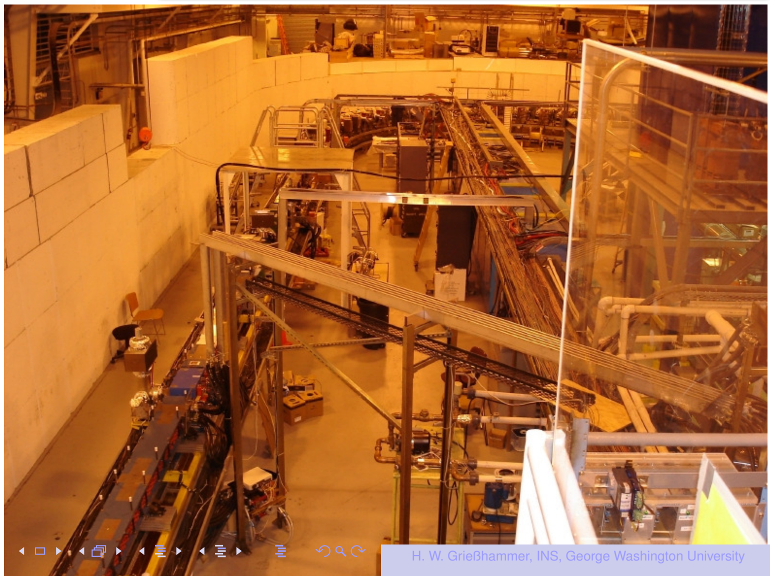
(d) High Intensity γ-Ray Facility HIγS, Duke U. (NC)

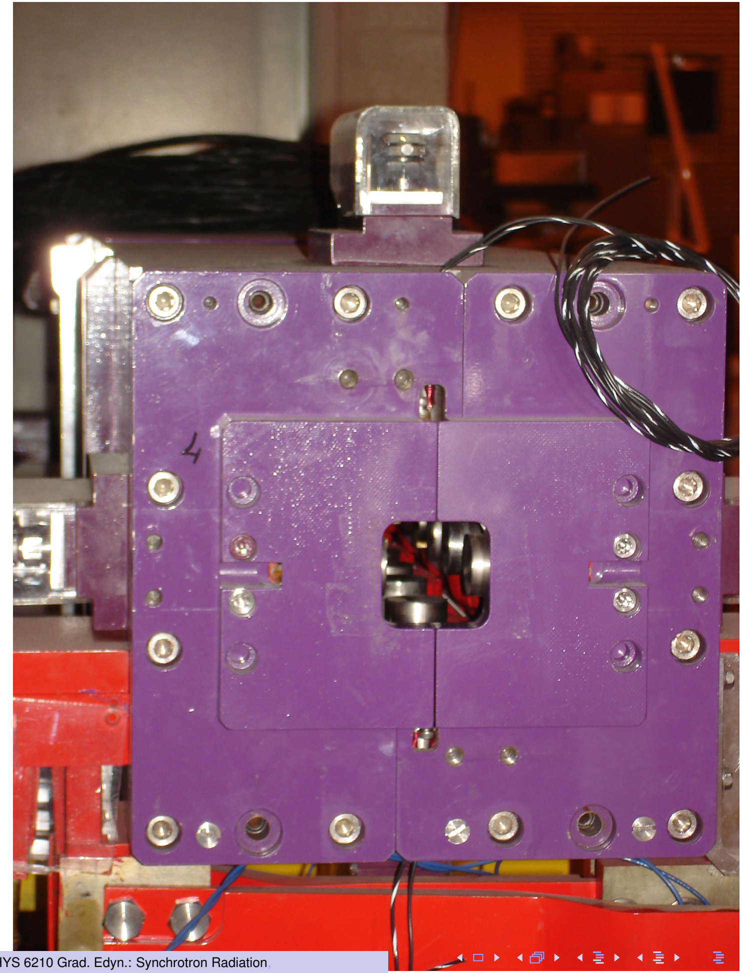


The Duke Storage Ring

Parameters	Value
Ring Circumference	107.46 m
Operating Energy	0.24 to 1.2 GeV
Energy Acceptance	+/- 3.5%
Revolution Frequency	2.7898 MHz
Bunch Length (RMS)	30 - 120 ps
Maximum Single-Bunch Current	50 mA (0.6 GeV) 95 mA with lasing
Typical Two-Bunch Current	60-80 mA (limited by FEL mirror)







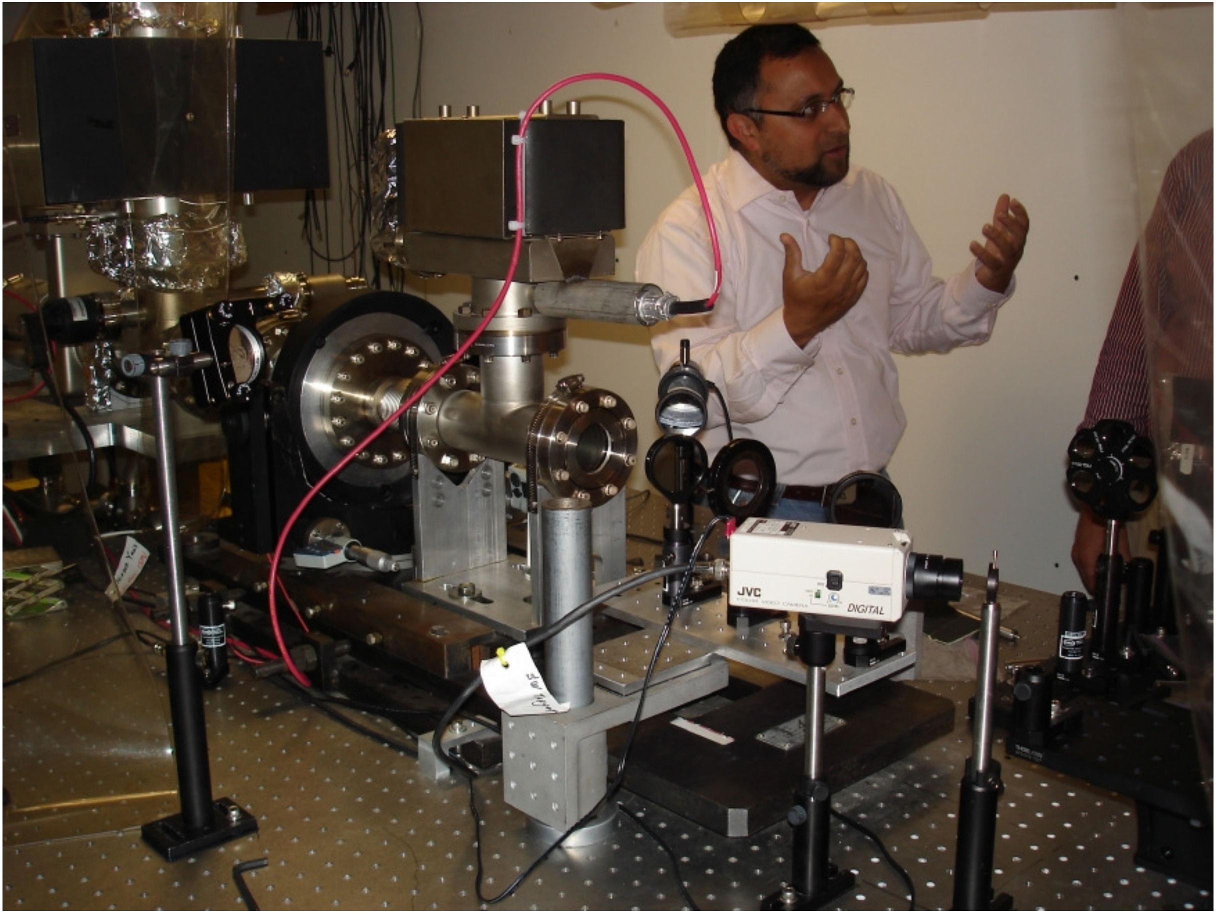
Movie: Pondermotive Force

Movie: Locking Phases

Movie: Lasing to eV

Movie how HIγS works:

Lasing to MeV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