# ELI: UK User perspective

High-power interactions, high-field science and secondary sources

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ELI Consultation of
UK User community,
London, 10 June 2018

# ELI: different user categories

- **Experimental users**

  Directly using the laser sources (Interaction physics, plasma physics, secondary source development …)

Involved in design/commissioning/ first light experiments/collaborations
ELI Beamlines: QUB, Strathclyde
ELI NP: York, QUB, Strathclyde, IC
ELI ALPS: Strathclyde, IC

Users/PI through competitive access

- **Beamline users :** Employing secondary sources for multidisciplinary experiments/testing
  Current users of accelerators/ light sources
  Academic/clinical/ industrial users

# UK High-power laser users: Current scenario

Strength in :

- Particle acceleration (ions, electrons, positrons, neutrons)
- X-ray generation (betatron, HHG)
- Laboratory astrophysics
- High-field science
- High Energy Density Physics/Warm Dense Matter
- Applications of laser-driven radiation (e.g. biology, medical imaging, material properties). ……

HPL provision:

**STFC Central Laser Facility:**
VULCAN
(PW, 500 J, 500 fs)
GEMINI
( 2 x 400 TW, 15 J, 40 fs)

**Local systems :**
SCAPA (Strathclyde): 350 TW, 25 fs, beamlines…
TARANIS, CERBERUS ( 50-100 TW, sub-ps)

**International access :**
EU (LASERLAB): LULI2000, PHELIX, PALS, etc…
Other access programs : NIF, LLE,..
Collaborative access : JKaren (J), Hercules, ATF (US)

# ELI - high power laser provision

eli beamlines

L3 HAPLS:
1 PW, 30 fs, 10 Hz

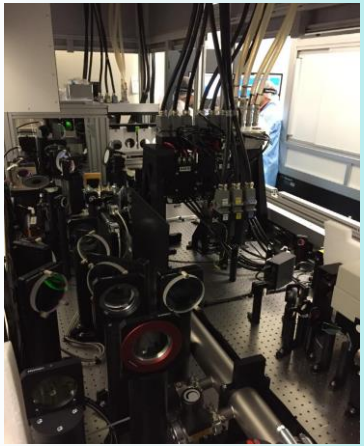
L4 : 10 PW, 130 fs, 2 kJ
(PW output,
ns uncompressed output)

eli Nuclear Physics

HPLS: 2 x 10 PW, 20 fs,
1 shot per minute
Other outputs:
100 TW, 10 Hz
1 PW, 1 HZ

eli attosecond

HF PW:
10 Hz, 2 PW, 17 fs

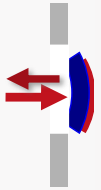


# Particle acceleration : *ions*

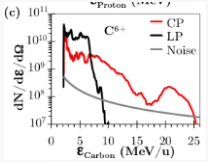
A-SAIL
ADVANCED STRATEGIES FOR ACCELERATING IONS WITH LASERS

## GEMINI

400 TW, 40 fs
I~ 5 $10^{20}$ W/cm$^2$

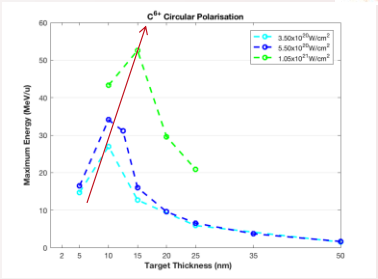


Emergence of Radiation Pressure Acceleration (up to 30 MeV/n C)



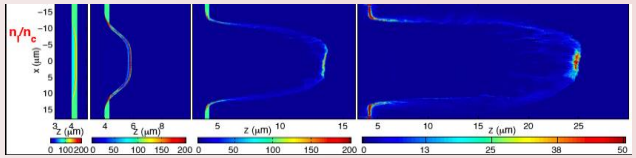

C. Scullion et al, PRL (2017)

## PW, 10s fs




Scaling towards 100 MeV/n

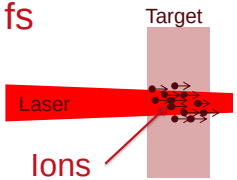
## 10 PW, 10s fs, I > $10^{22}$ W/cm$^2$

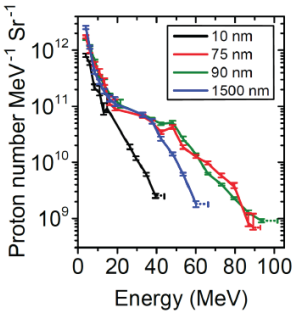



100s MeV to GeV/n acceleration

## VULCAN

PW, 500 fs



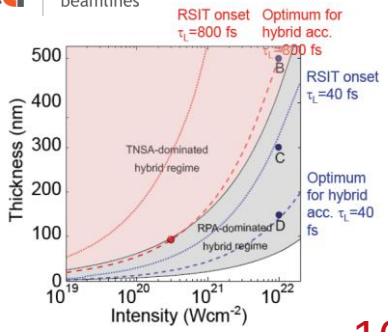



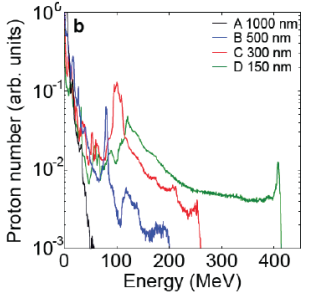

Hybrid regimes
Near 100 MeV protons in a relativistic transparency regime

A. Higginson *et al*, Nature Comm (2018)

## L4: multi-PW, 150s fs

beamlines



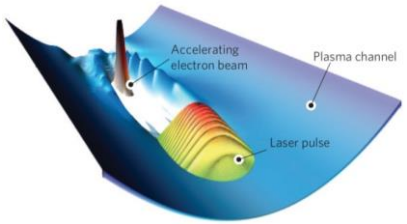



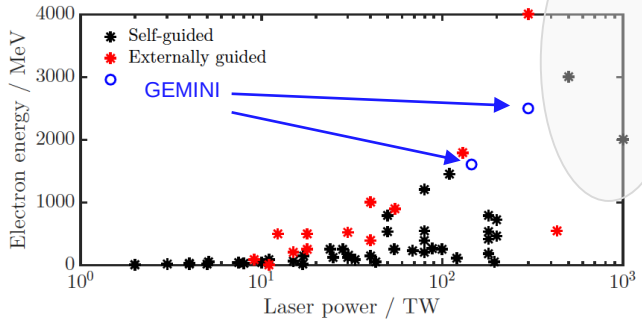

100s MeV at $10^{22}$ W/cm$^2$

# Particle acceleration: *electrons*

Strong UK activity
centered around GEMINI

*IC, Oxford,QUB*
*Strathclyde*




HAPLS, PW, 10 HZ
World-leading capabilities
(5 -10 GeV bunches)

Multi PW

Multi-GeV acceleration in gas cell
with f/40 focusing (IC + collaborators)

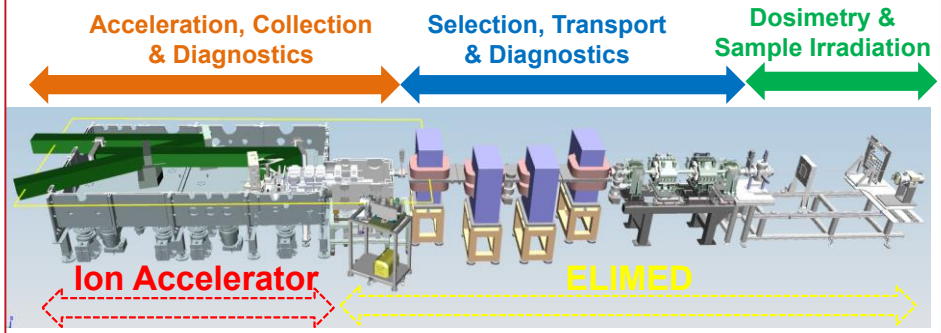
**10- 100 GeV**, with very long focusing, low density extended plasmas

Strong expertise/leadership in
guiding/injection/staging techniques

Generation of fs, KA multi- GeV **positron beams**
(e.g. $e^-$ - $e^+$ colliders, high energy astrophysics..)

# Beamline approach for applications

## ELIMAIA. - proton beamline

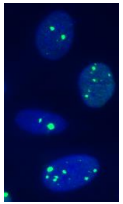



Well controlled , characterized proton beam output at up to 60 MeV

## HELL

electron beamline

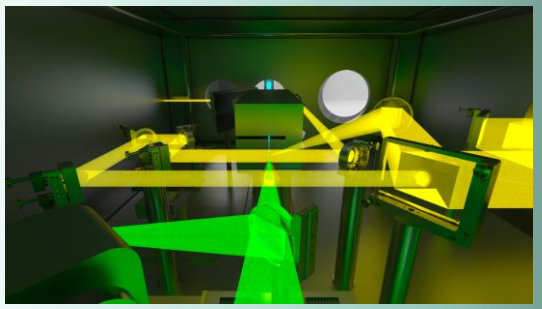
fs bunches for irradiation studies (100s MeV)



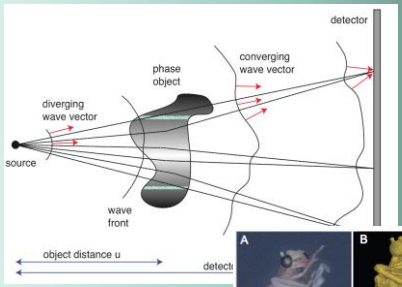
Opportunities for pulsed radiobiology, radiolisis, material irradiation studies,… (ultra-high dose rates, ns bunches)

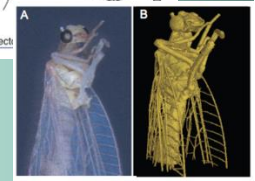
Strong activities in the UK

## Betatron/Compton beamline



Tomographic imaging with high resolution



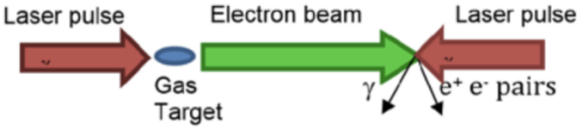




Phase-contrast imaging

# High-field science – QED studies

Dynamics of relativistic electrons in strong fields

QED critical field, $F_{cr} \sim 10^{18}$ V/m ($I \sim 10^{29}$ W/cm$^2$)

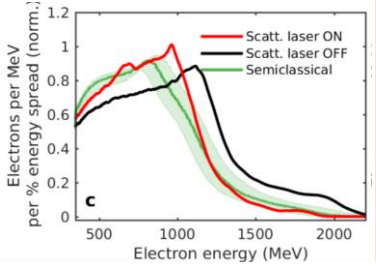



$$\chi = (1 - cos\theta)\gamma_e F_L / F_{cr}$$

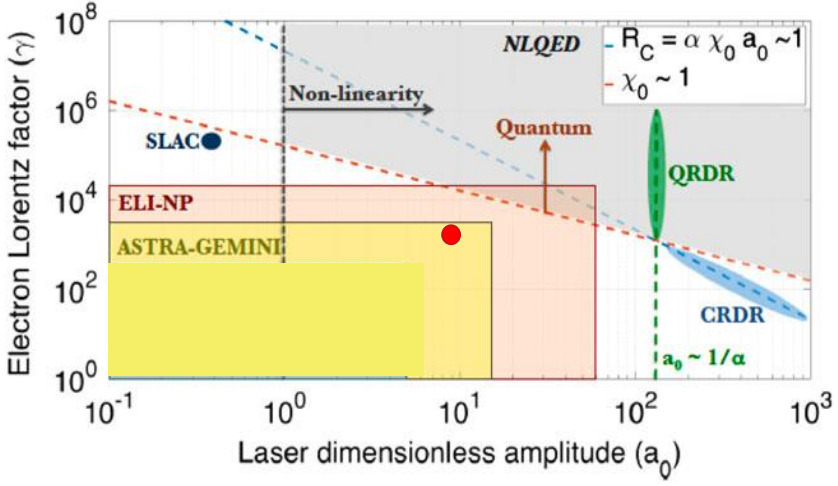
Signatures:
- Radiation reaction
- pair production
- Gamma flashes

Recent GEMINI results (IC, York, Strathclyde, QUB) have shown **radiation reaction** effects at $\chi \sim 0.25$

J.Cole *et al*, PRX (2018)
K Poder *et al*, PRX (2018)

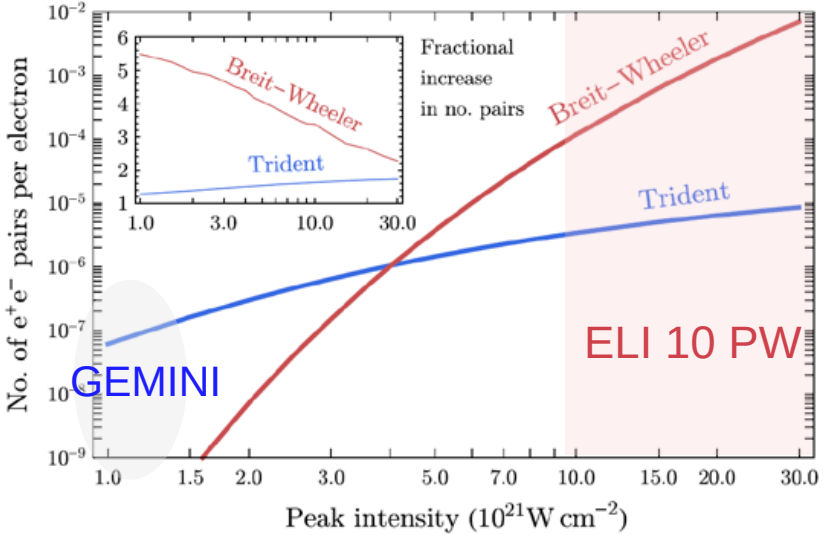



Extension to $\chi > 1$ on ELI-NP (2 x 10 PW) ELI Beamlines (HELL+L4) (10 GeV electron vs multi-PW laser pulse)

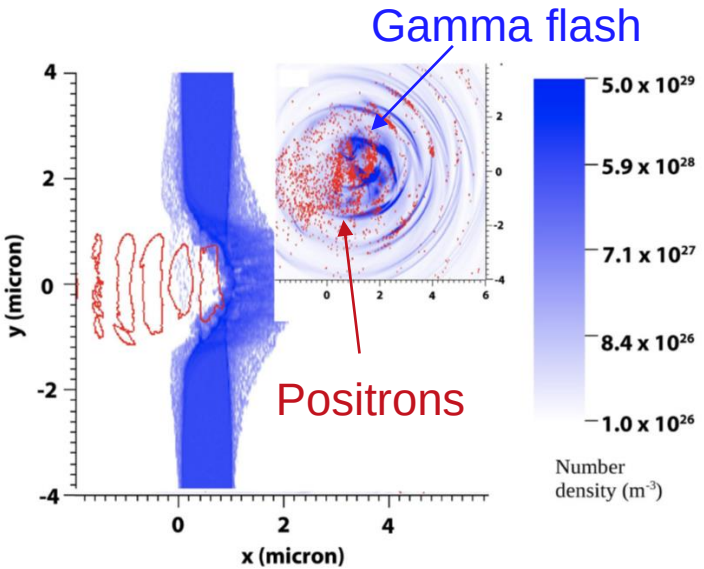


# High-field science – QED studies

Other key signature: **$e^+$- $e^-$ pair production**




1 GeV electrons colliding with a laser pulse
(from T. Blackburn et al, PRL (2012))



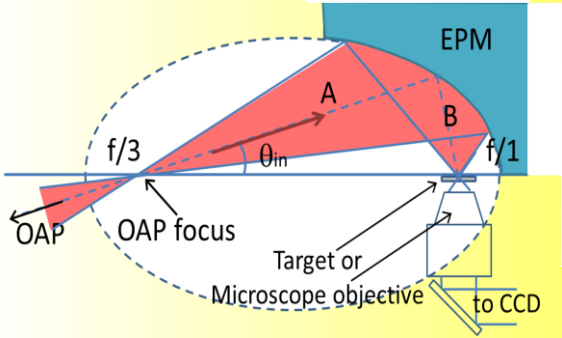

Solid interactions at I ~ $10^{23}$ W/cm$^2$
(from C. P. Ridgers et al, PRL (2014))

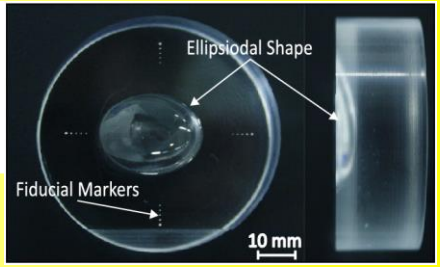
+ many other opportunities
(photon-photon colliders, vacuum birefringence, etc.)

# Opportunities for UK-developed technology

## Focusing plasma mirrors to increase intensities

Increasing laser intensity by de-magnifying the focal spot by a factor of 3 to 5



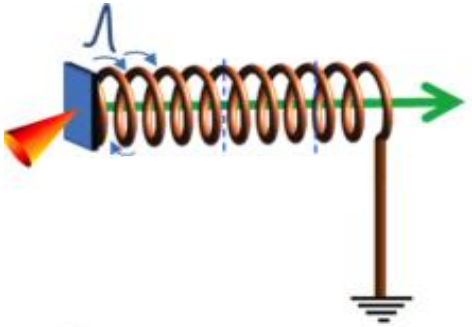



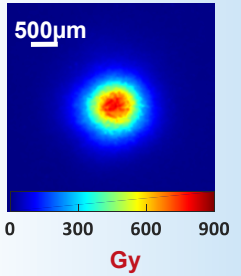

Technique developed on VULCAN PW

R. Wilson *et al*, PoP (2016)

Ongoing collaboration between Strathclyde, CLF and ELI Beamlines in relation to 10 PW L4 focusing.

## Target design for proton beam collimation






Dose profile at 6 cm, 45 MeV

QUB/ELI Beamlines collaboration on compact beamline design

S. Kar *et al*, Nature Comm (2016)

# ELI – opportunities for UK users conclusions

Capitalizing on current UK strength and leadership by:

- Advancing current CLF-based research to new regimes
- Test fundamental theory emerging at higher intensities/power
- Developing applicative opportunities via PW-driven beamlines
- Developing/exploiting technological advances

These are **essential** steps for the long term health and stability of the UK's HPL user community

**Examples:**

Particle acceleration
X-ray sources
Beamline applications
High-field science
Technology

**…but also**

High harmonics
Neutron, positrons, muons
WDM/lab astro/ HEDP