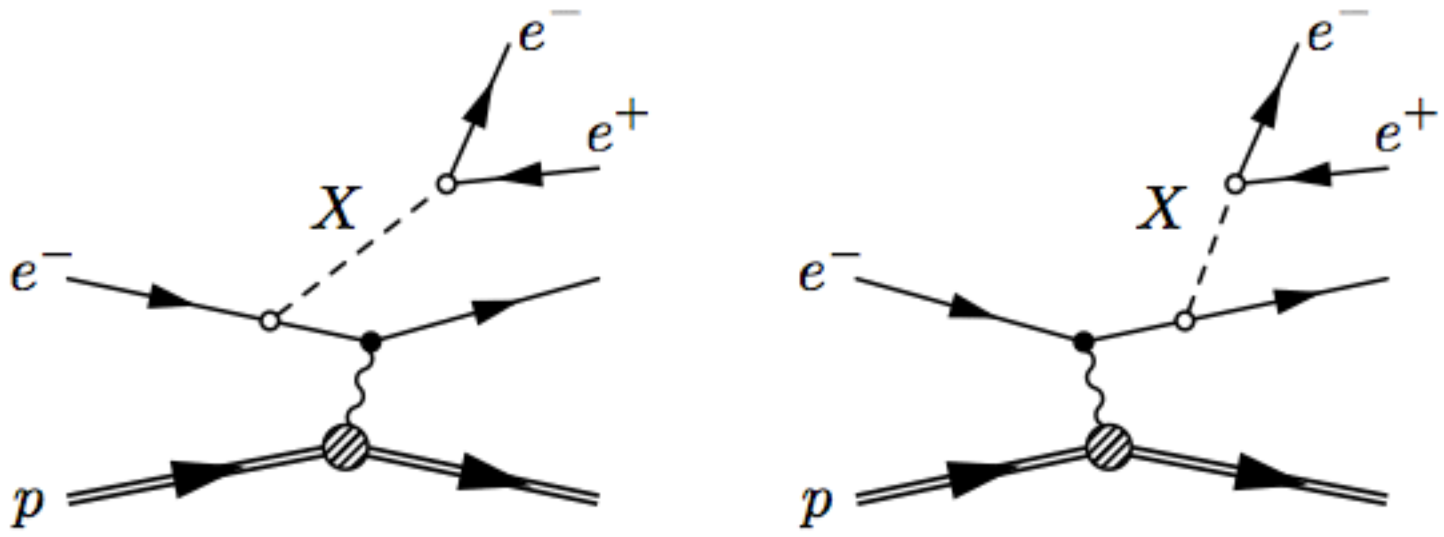
Internal Targets at the Intensity Frontier

The view from DARKLIGHT

Ross Corliss, MIT

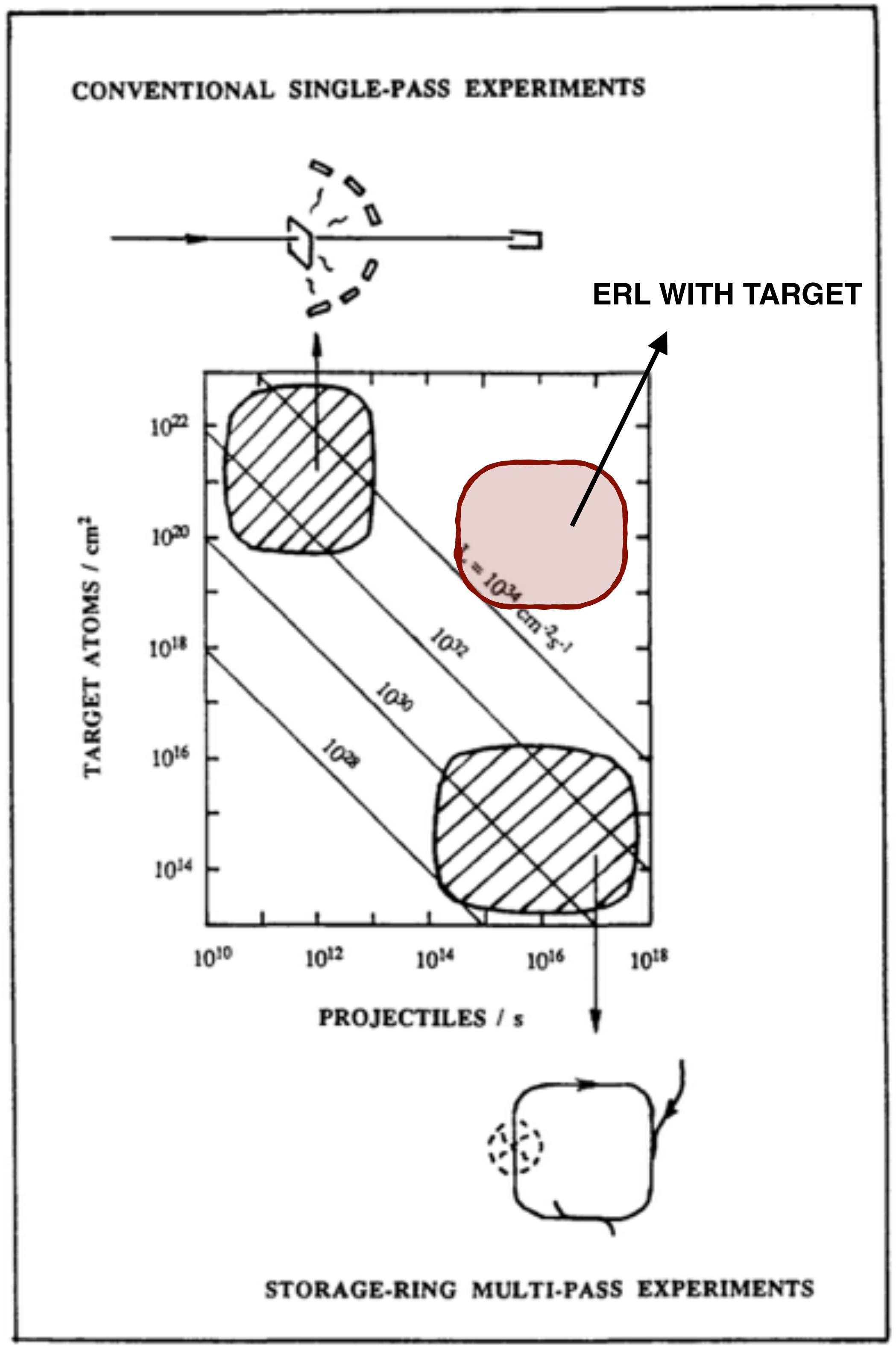
DarkLight Disclaimer

- This talk is from the perspective of someone who works on the DarkLight experiment (J. Balewski,Thursday)
- Hunt for dark photon (X) underneath large, irreducible SM background



- 100 MeV e- beam to stay under pion threshold.
- To do it fast, need high luminosity: dense target, intense beam.

Quick-Sell For Energy Recovery Linacs



C. Ekström

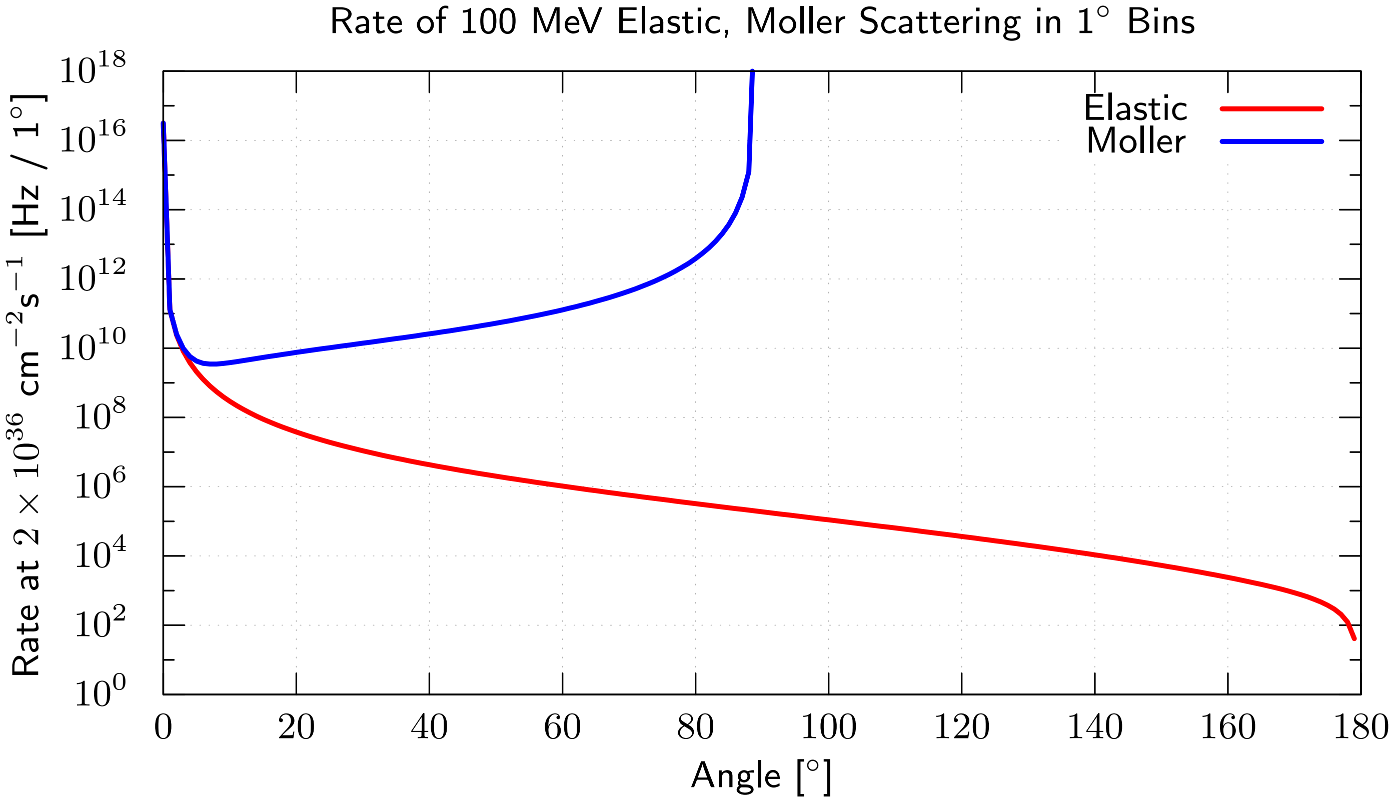
- External target - low current, no emittance limit
- Storage ring - higher current, low emittance limit
- ERL - higher current, higher emittance allowed

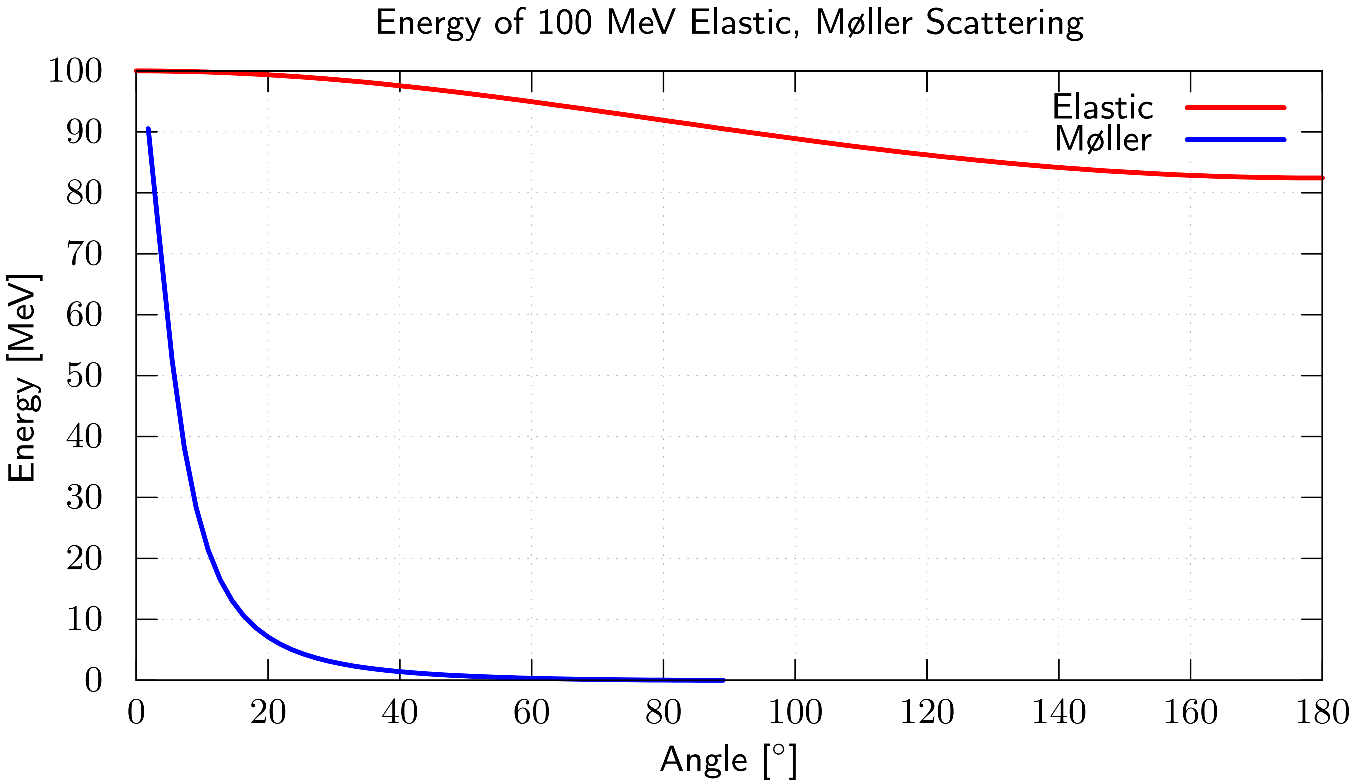
Outline

- Motivation for High Luminosity
- Standard Model Rates
- Detector Concerns
- Beam Concerns
- Possible Targets

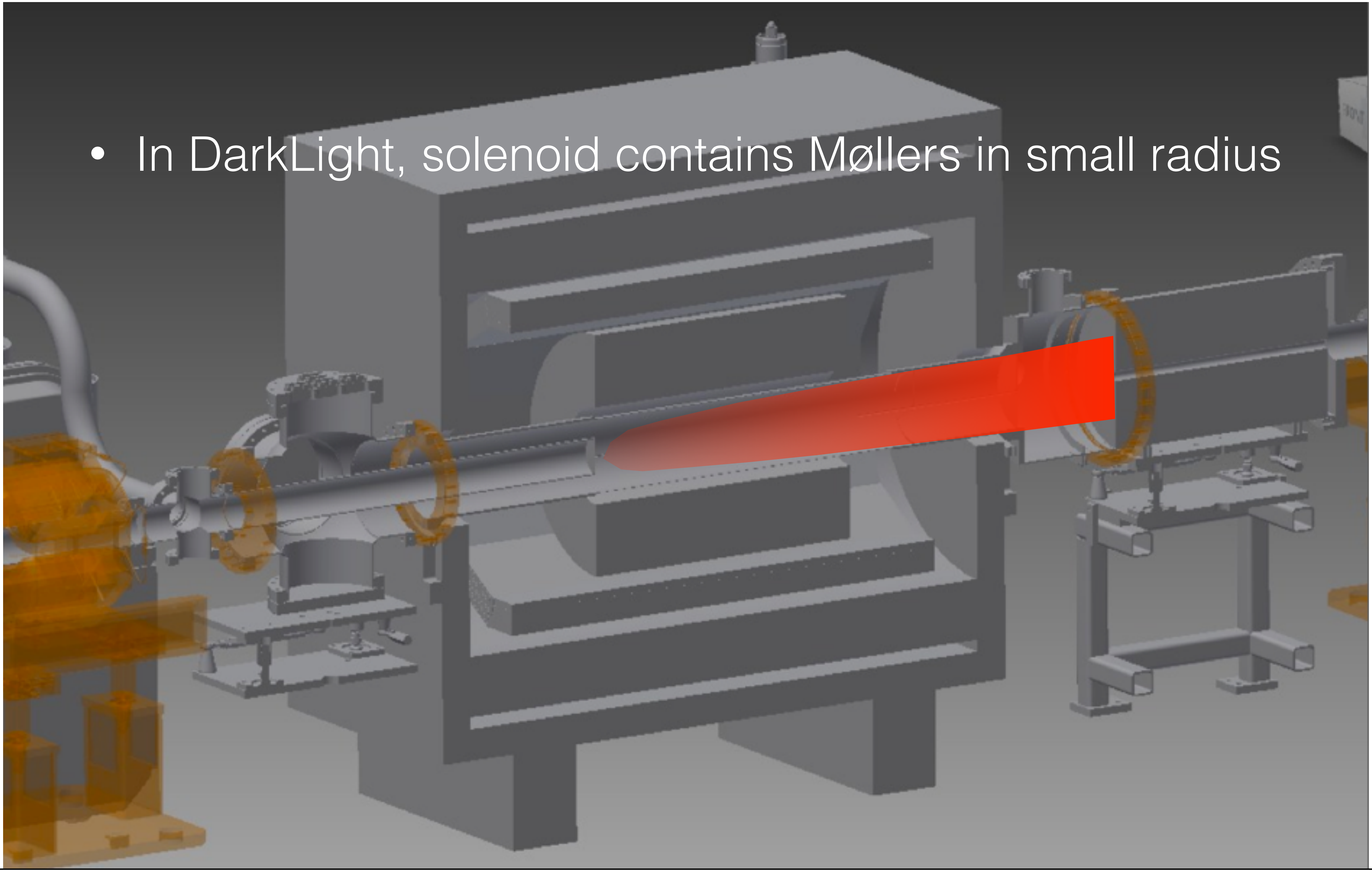
Standard Model Environment

- Luminosity= 2x10^{36} cm^{-2}s^{-1} (beam intensity=6x10^{16} e- s^{-1} target thickness=3x10^{19}cm^{-2})
- Total Møller rate 2-5^{o} ~ 30 GHz (E<100 MeV)
- Total Elastic rate 2-5^{o} ~ 30 GHz (E~100 MeV)


Rate of 100 MeV Elastic, Moller Scattering in 1° Bins

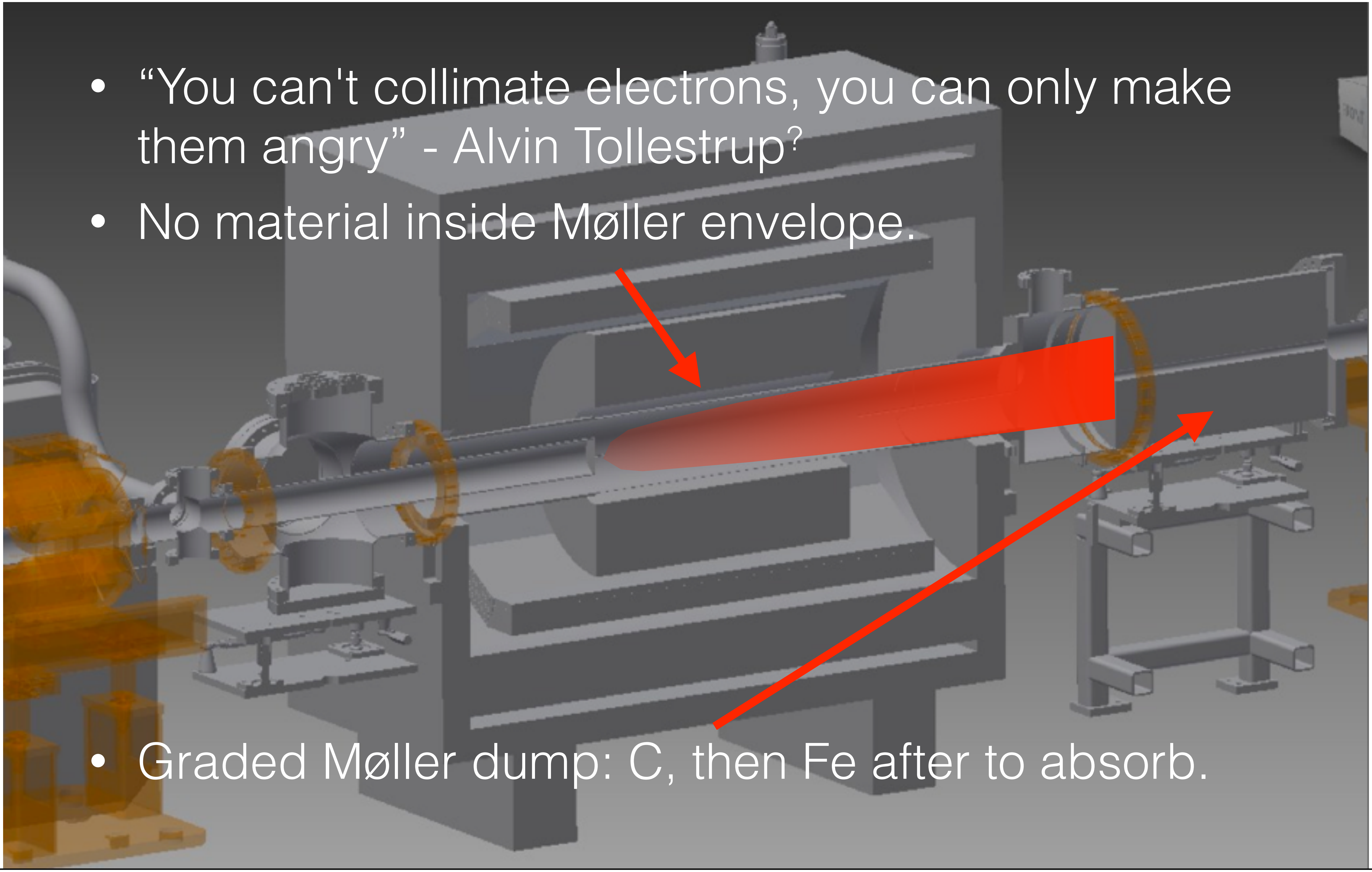

Energy of 100 MeV Elastic, Møller Scattering

Møller Envelope



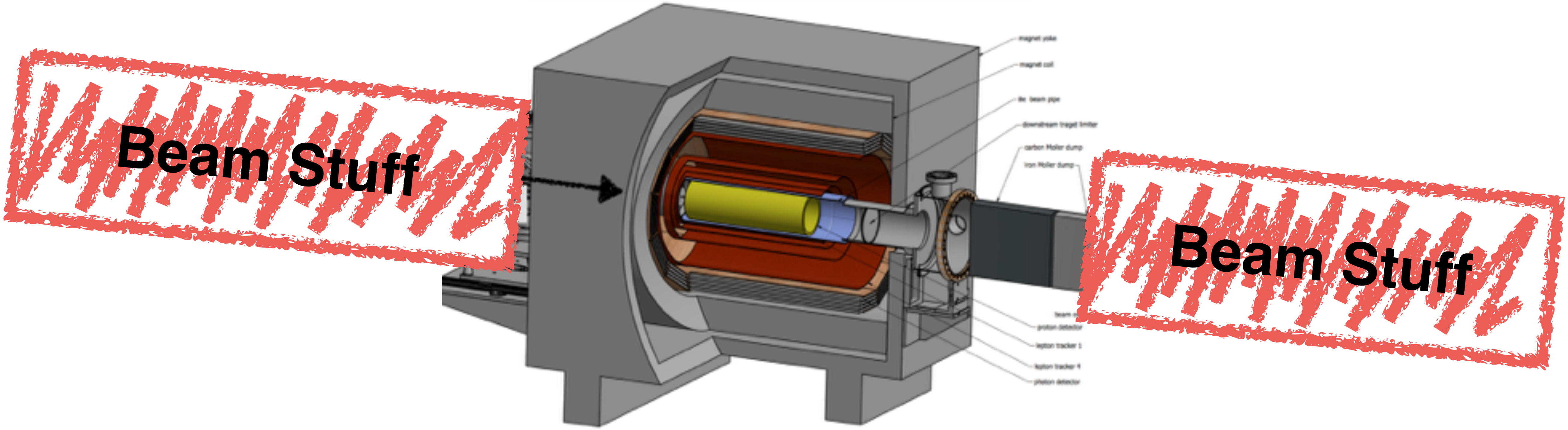
- In DarkLight, solenoid contains Møllers in small radius

Material Downstream



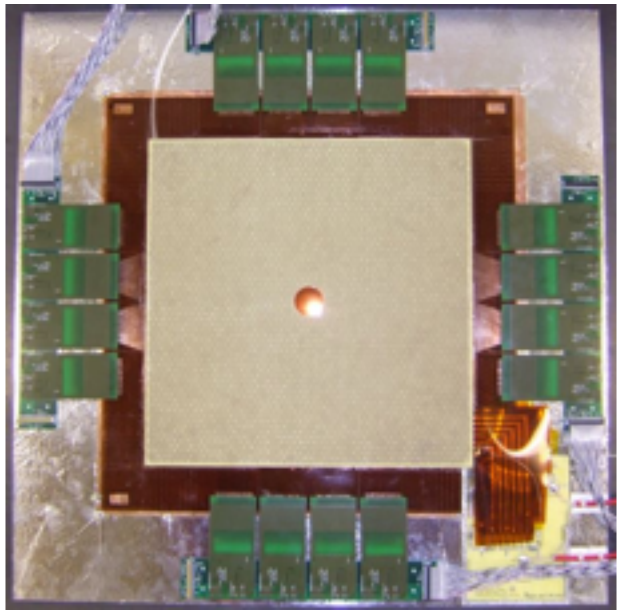
- “You can't collimate electrons, you can only make them angry” - Alvin Tollestrup?
- No material inside Møller envelope.
- Graded Møller dump: C, then Fe after to absorb.

Detector's Perspective



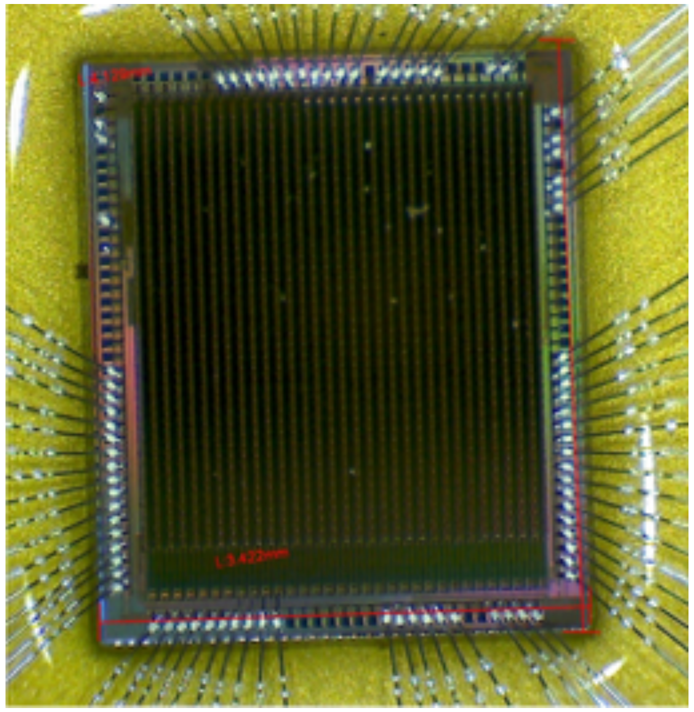
- Must handle very high, forward-peaking rate
- Multiple scattering complicates tracking and design
- Moller dump unevenly heated.

Some Rate-Tolerant Detectors

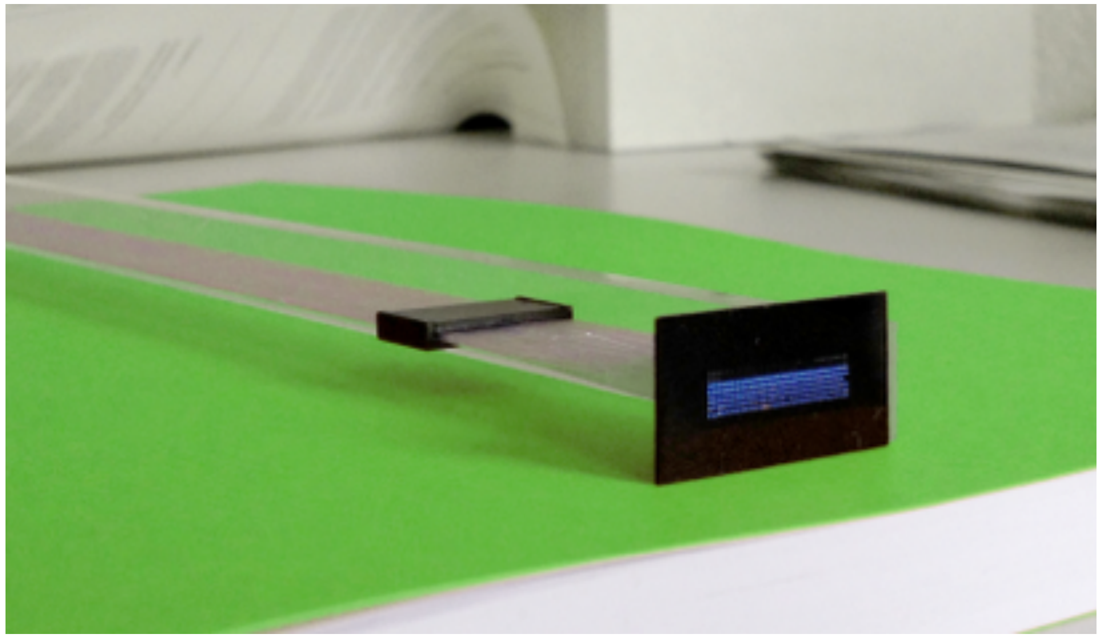


- GEMs (COMPASS)

- Micromegas (CLAS12)

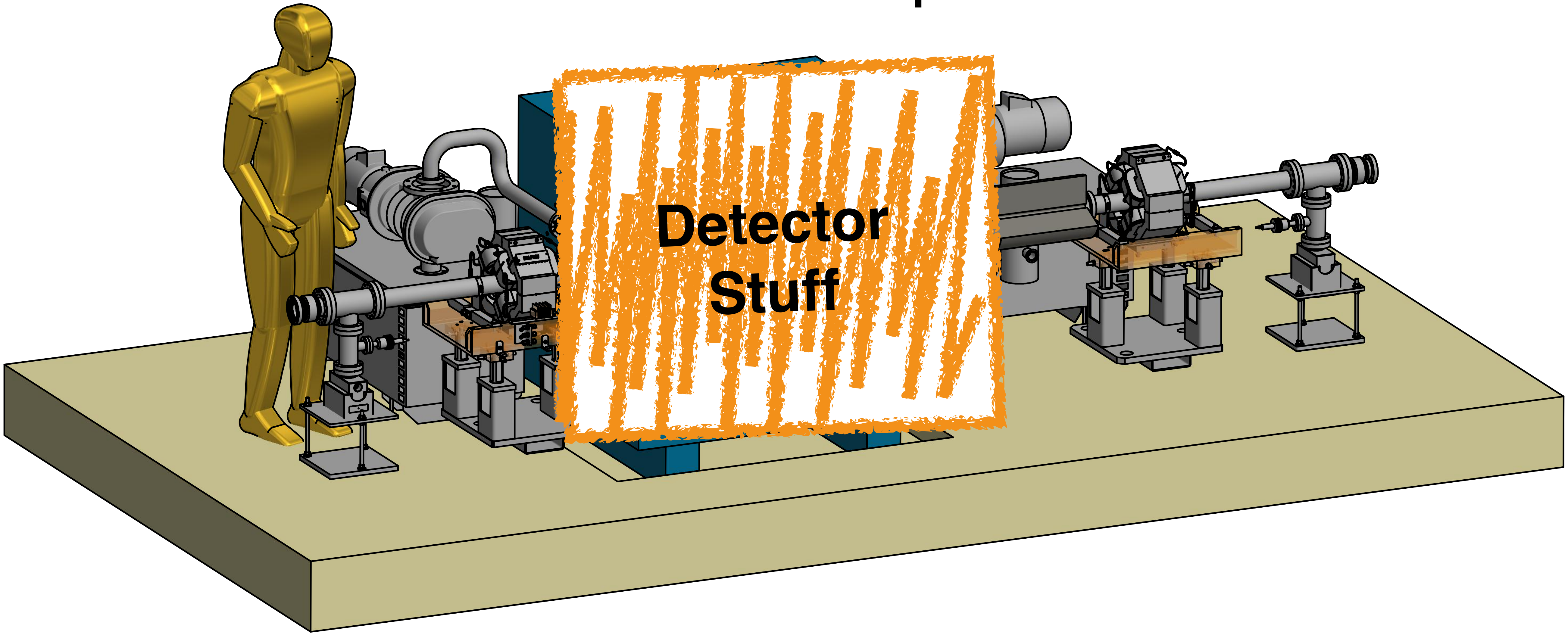


- HV-MAPS (Mu3e)



- Scintillating Fibers (Mu3e)

Beam's Perspective



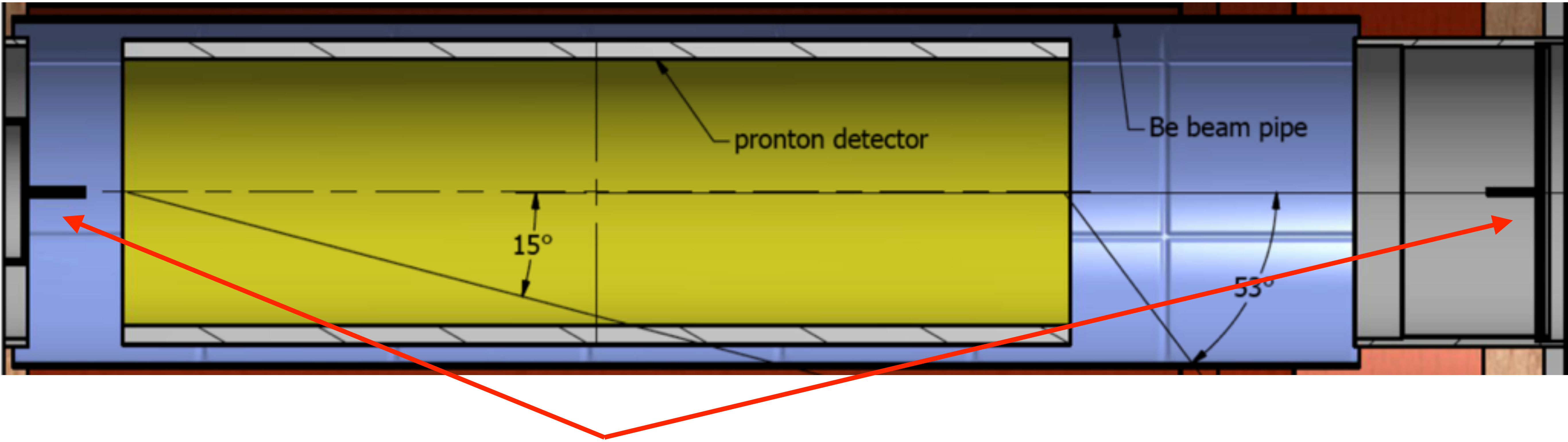
- Only areal density matters
- Energy loss in target doesn't affect phase at RF
- Beamline must remain low pressure
- Max. acceptable emittance unclear (DL beam tests, 2016)

Possible Targets

- Gas cell -- distributed target
- Gas jet -- pointlike
- Thin foil -- pointlike

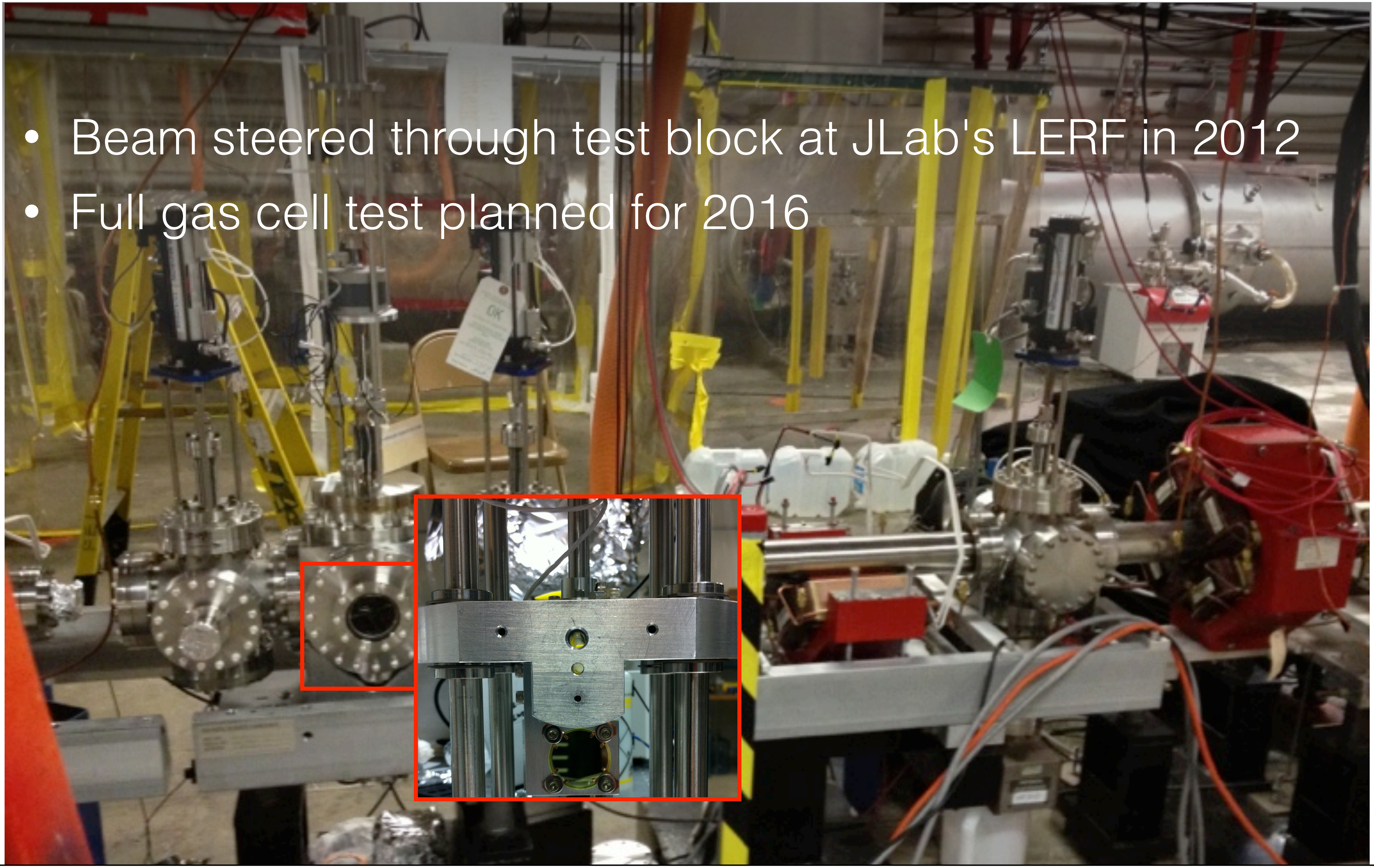
Gas Cell Concept

- Flow gas into windowless cell
- Contain with narrow flow limiters (tube or baffle)
- Pump aggressively to maintain vacuum



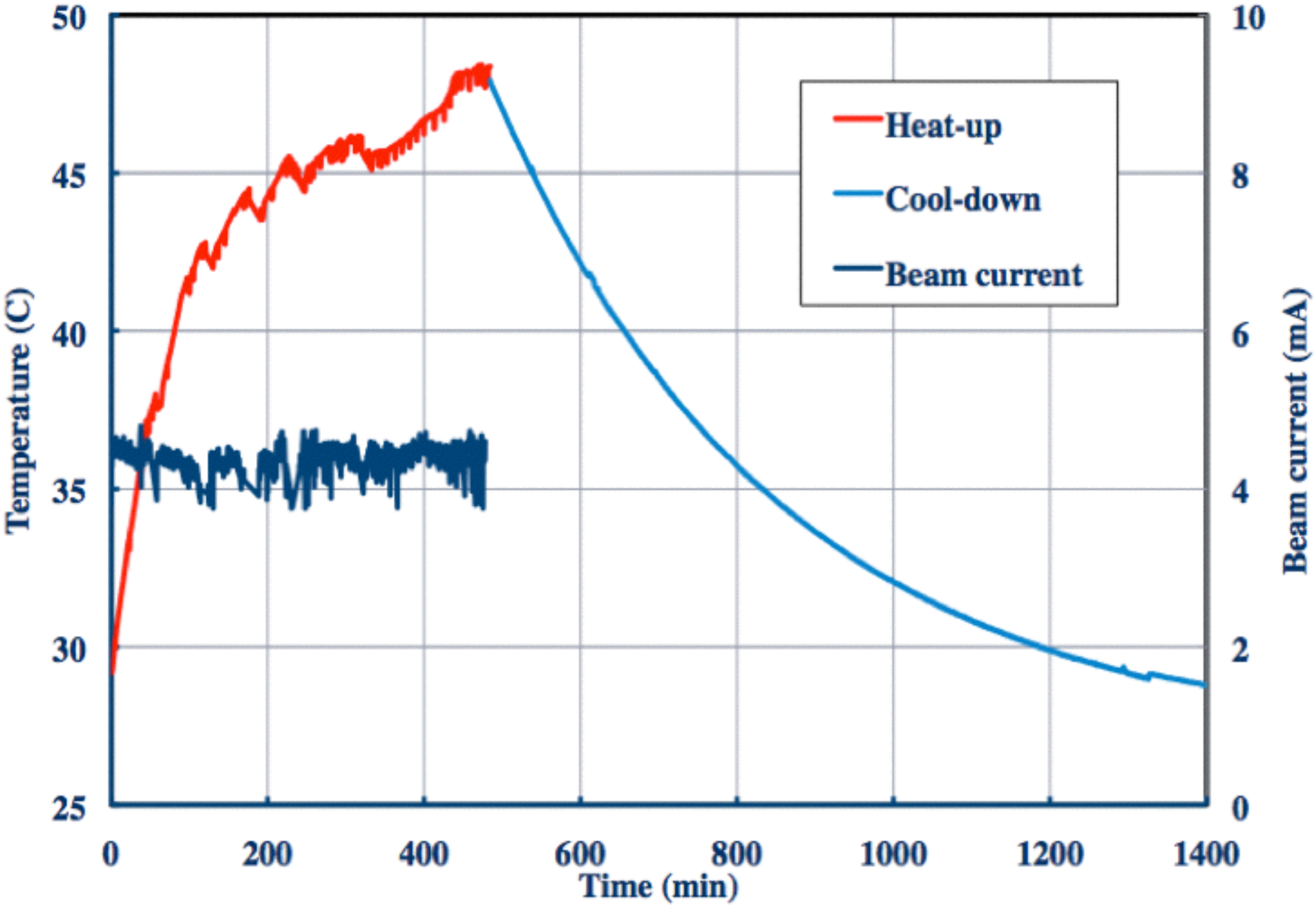
'coffee stirrer' flow limiters

Flow Limiter Study



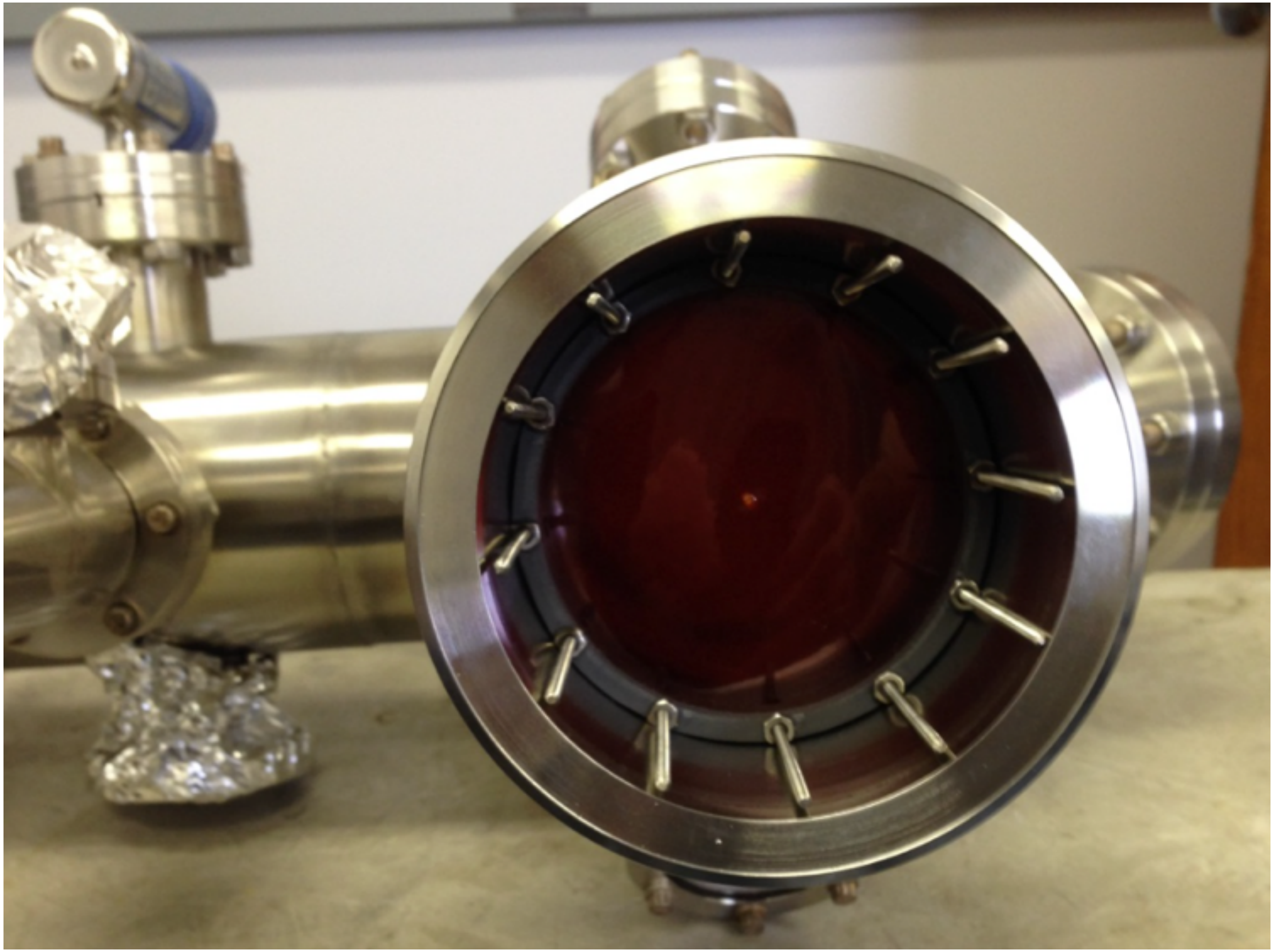
- Beam steered through test block at JLab's LERF in 2012
- Full gas cell test planned for 2016

Measuring Beam Losses



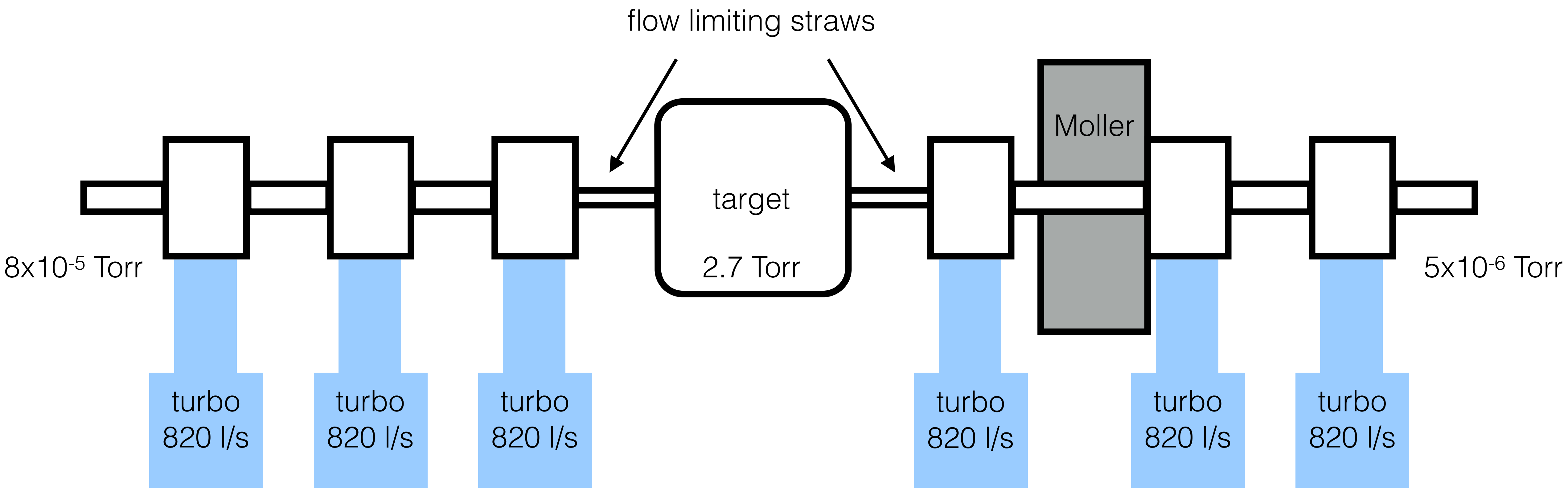
$$P_B = c_p m(dT/dt)_{block} + P_C$$

Baffle Prototype



- Flow model more complex, but simpler support

Gas Cell Pumping Scheme



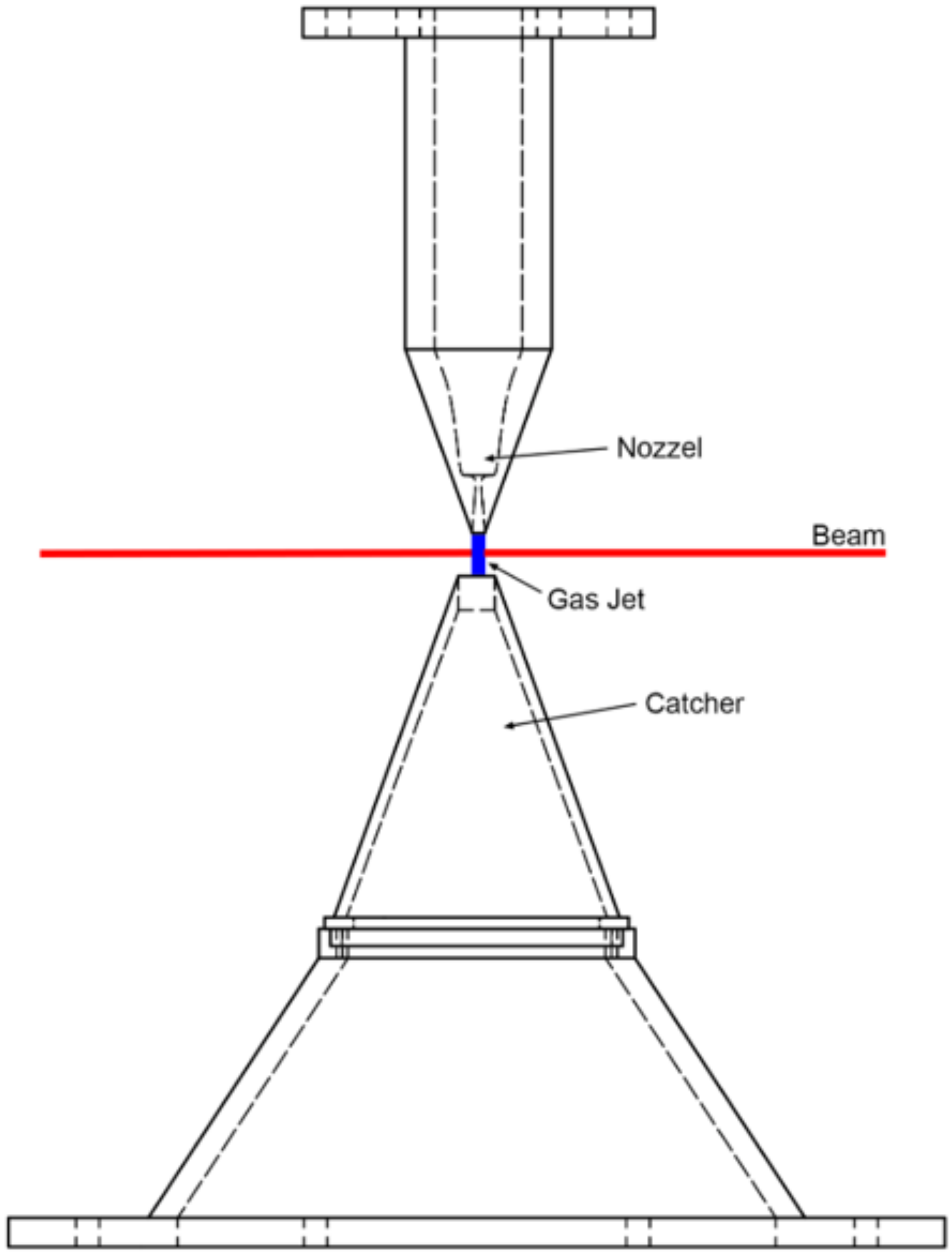
- Many tunable parameters

Gas Cell

- Engineering:
  - Little solid-angle obstruction
  - Difficult gas flow regime to model
  - Conductance limiters in Møller envelope
- Physics:
  - Distributed primary vertices
  - Acceptance uneven

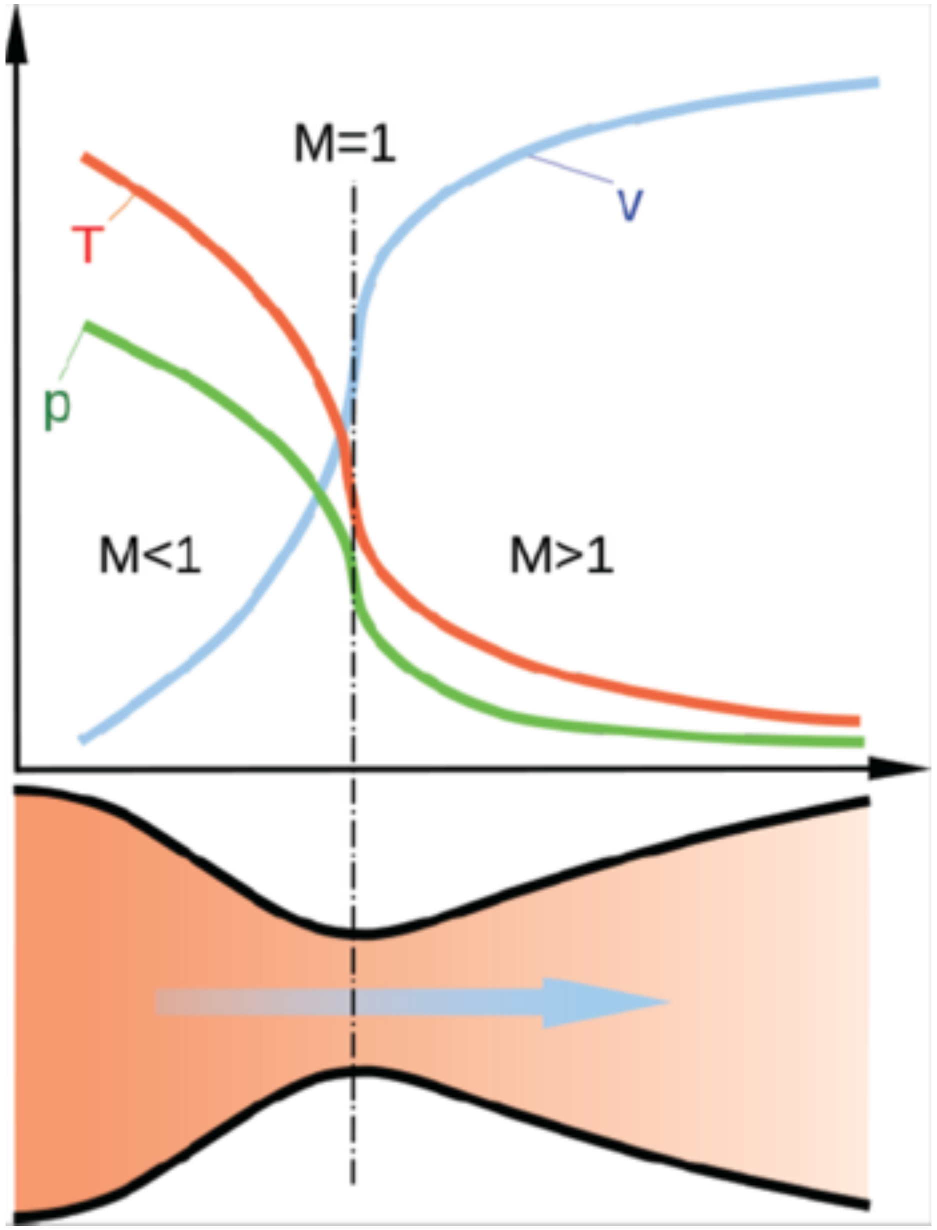
Gas Jet Concept

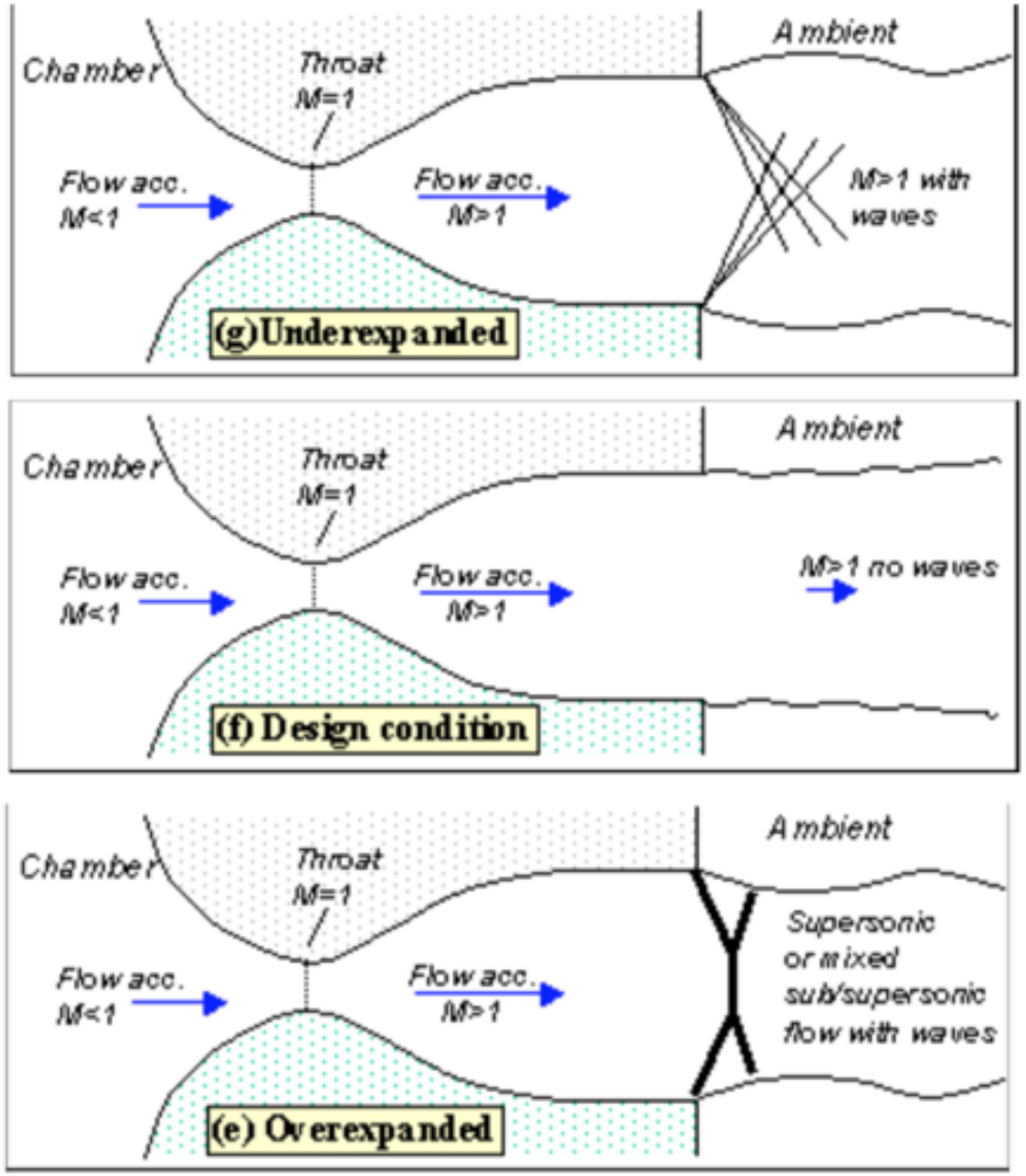
- Supersonic gas jet crosses beam path
- Majority of the jet is captured in receiver
- Very little gas leaks into beamline



Gas Jet Concept

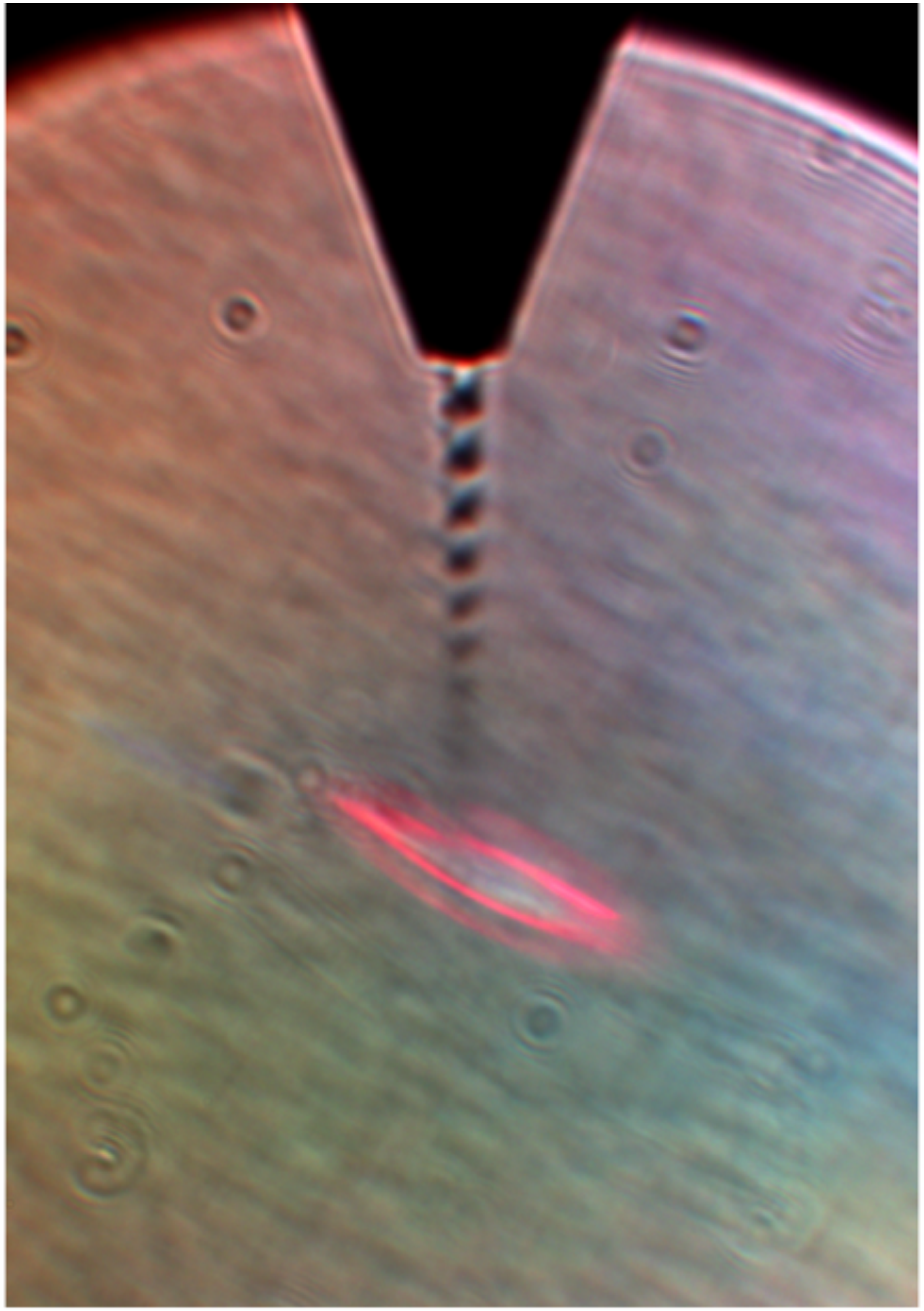
- Laval nozzle produces supersonic flow.
- Nozzle profile can be tuned for turbulence-free flow



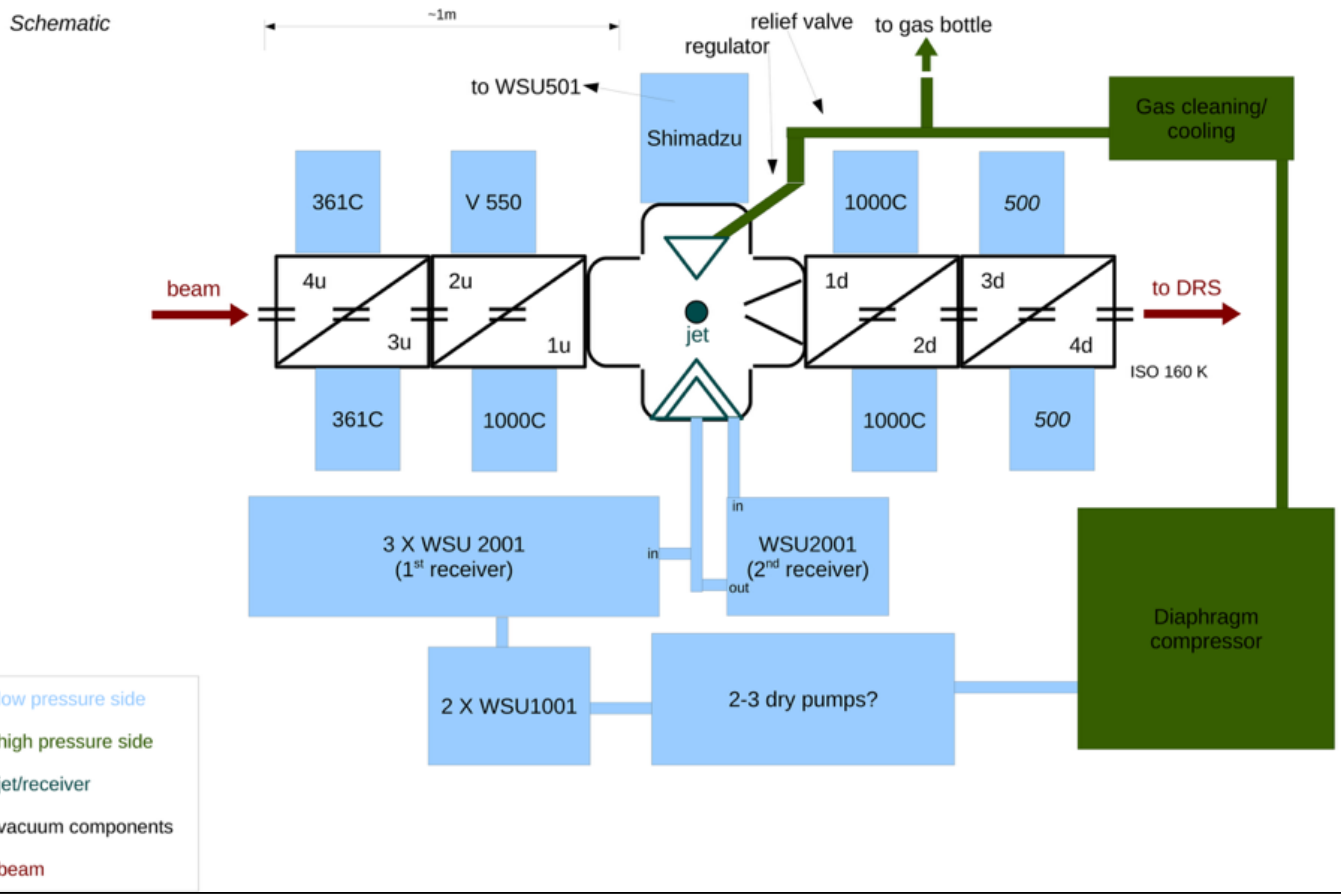


Gas Jet Status

- Many 10^{19} gas jets have been demonstrated
- MAGIX (Mainz)
  - Laser sintered nozzles aiming for 10^{19}
  - Sees first jet!
- JENSA (ORNL/MSU)
  - Sees 10^{18}-10^{19} in He and others



JENSA Pumping Scheme

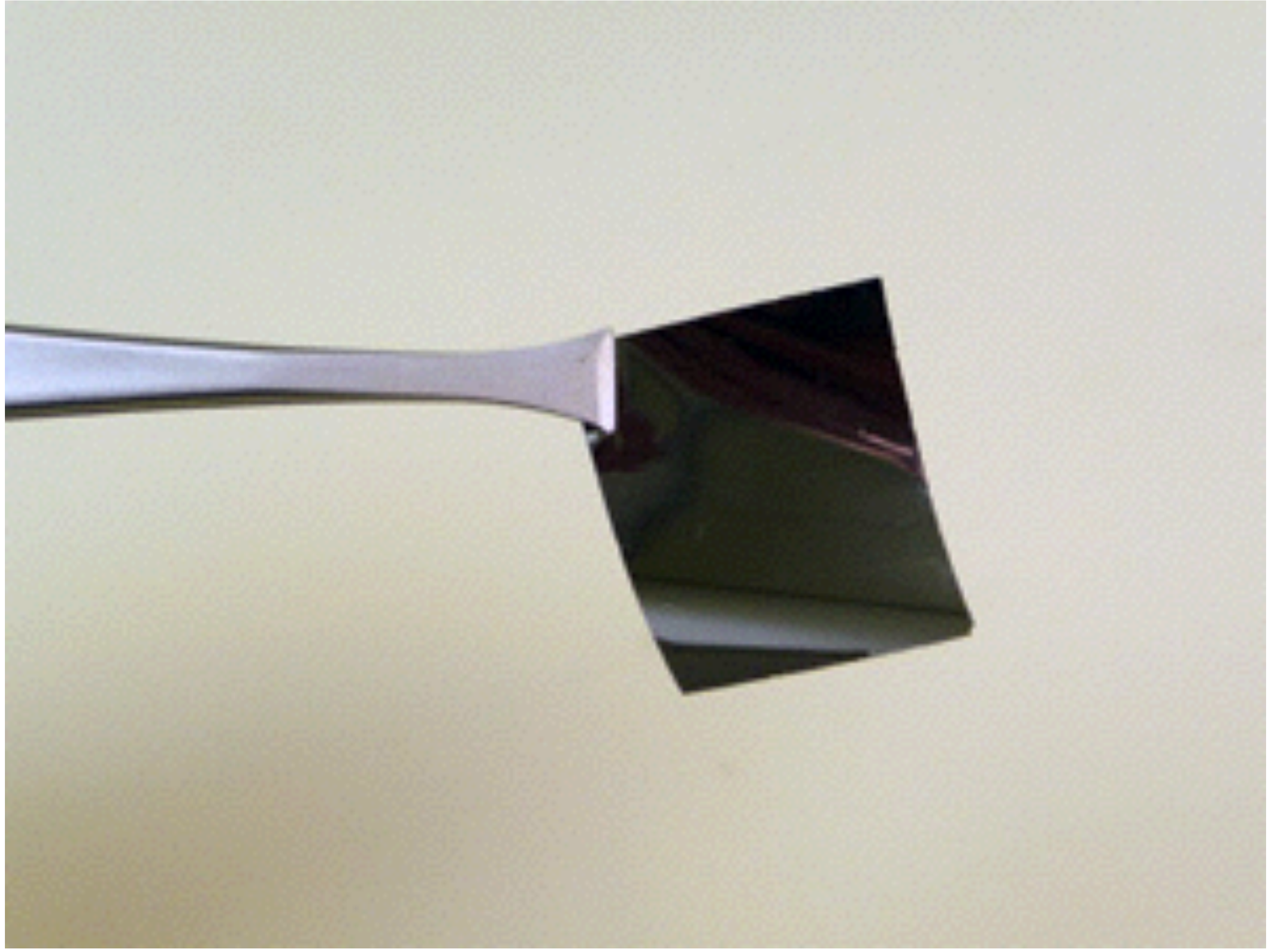


Gas Jet

- Engineering:
  - Some solid-angle obstruction
  - must pump on receiver
  - beamline pumping reduced
  - Many operating parameters to optimize
- Physics:
  - Single primary vertex

Thin Foil Concept

- Self-supporting, ≥0.5um foil of carbon nanoparticles.
- Used as stripper foils in accelerator settings



http://www.micromatter.com/dlc.php

Thin Foil

- Engineering
  - No pumping required
  - Thermal properties sufficient
  - Requires much lower beam intensity
- Physics
  - Very precise primary vertex
  - Limited choice of target species

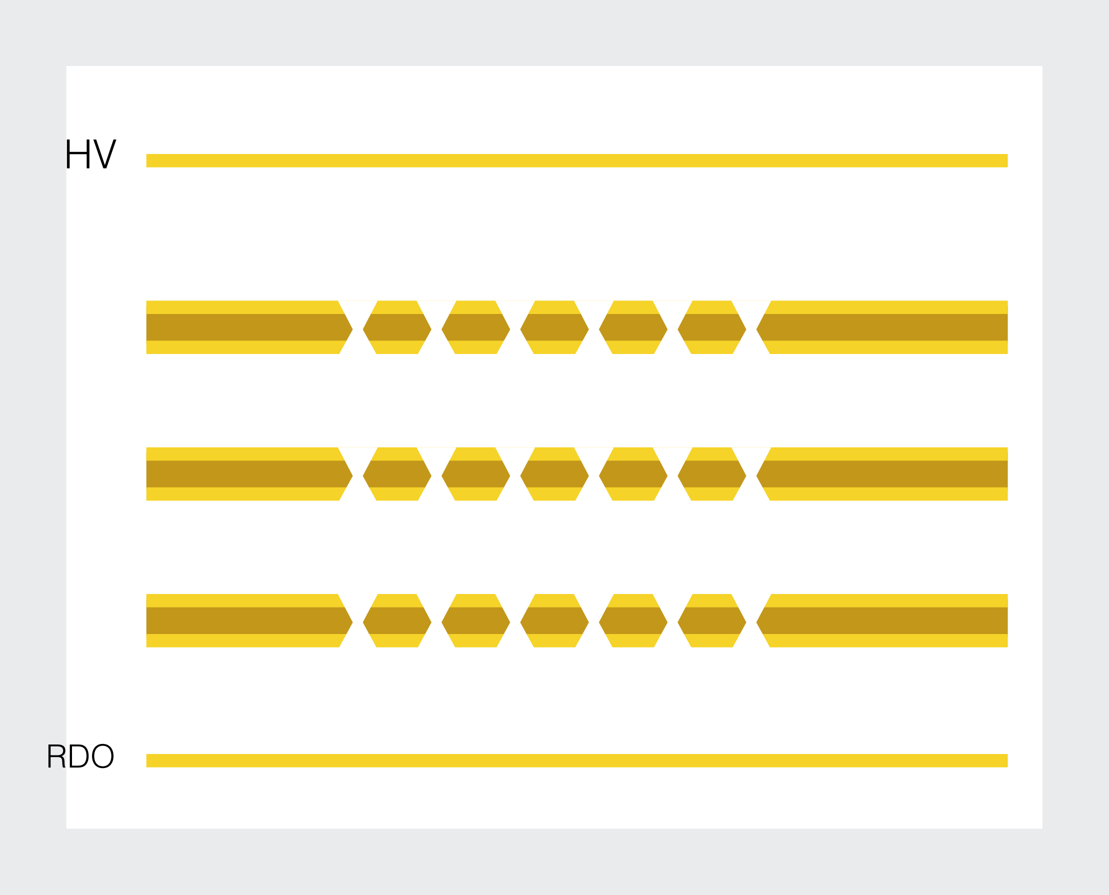
Outlook

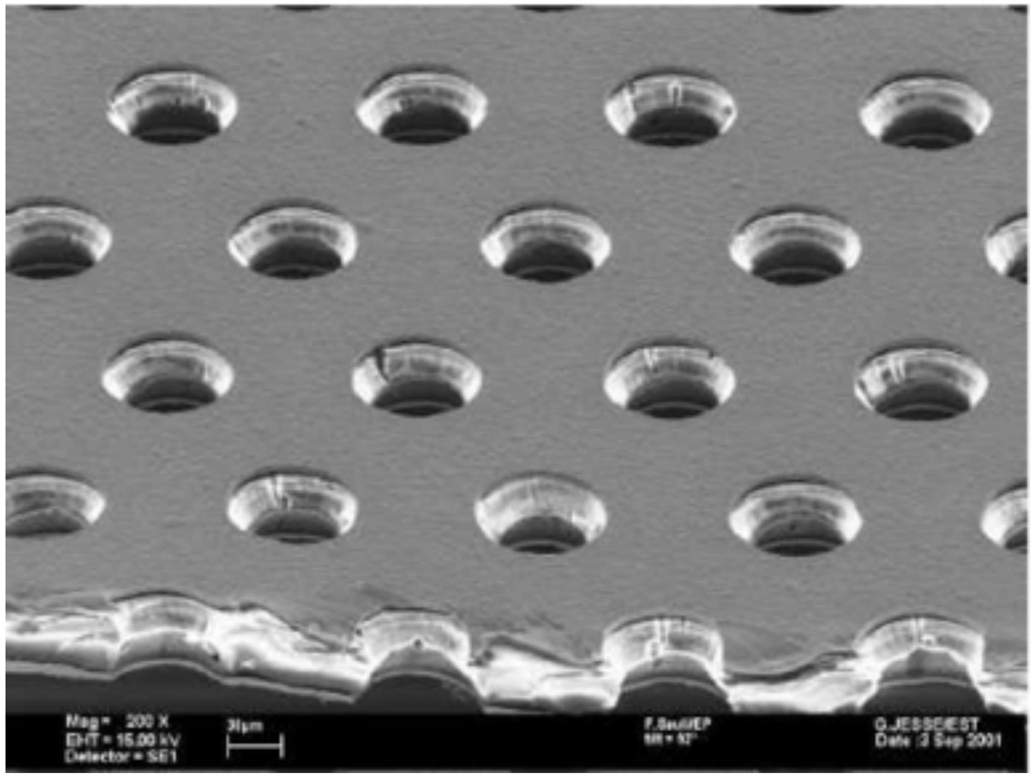
- Standard model effects dominate design
- Several detector technologies (Micromegas, GEMs, HVMAPS, scintillating fibers, and more).
- Several options for targets (Gas Cell, Gas Jet, Thin Film).
- Planned beam test (2016) will explore many of these options in real conditions.

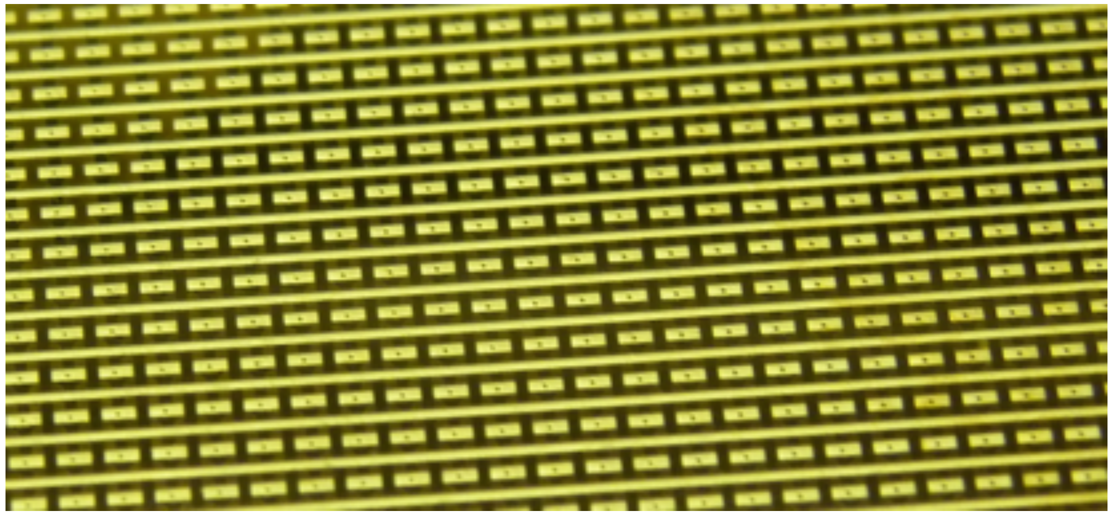
GEMs

Gas Electron Multiplier

- Three stages of gas amplification
- Simple lithography
- Complex assembly



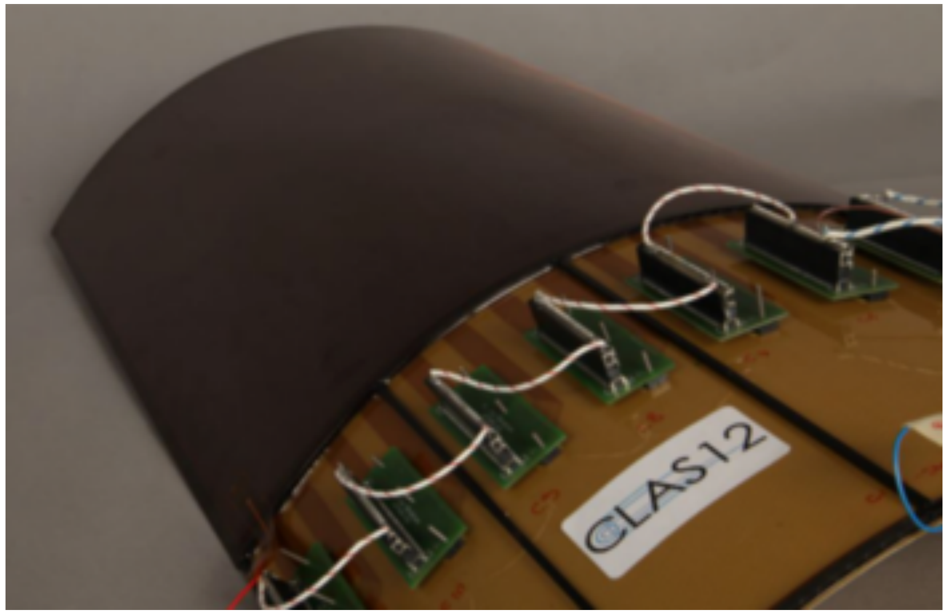


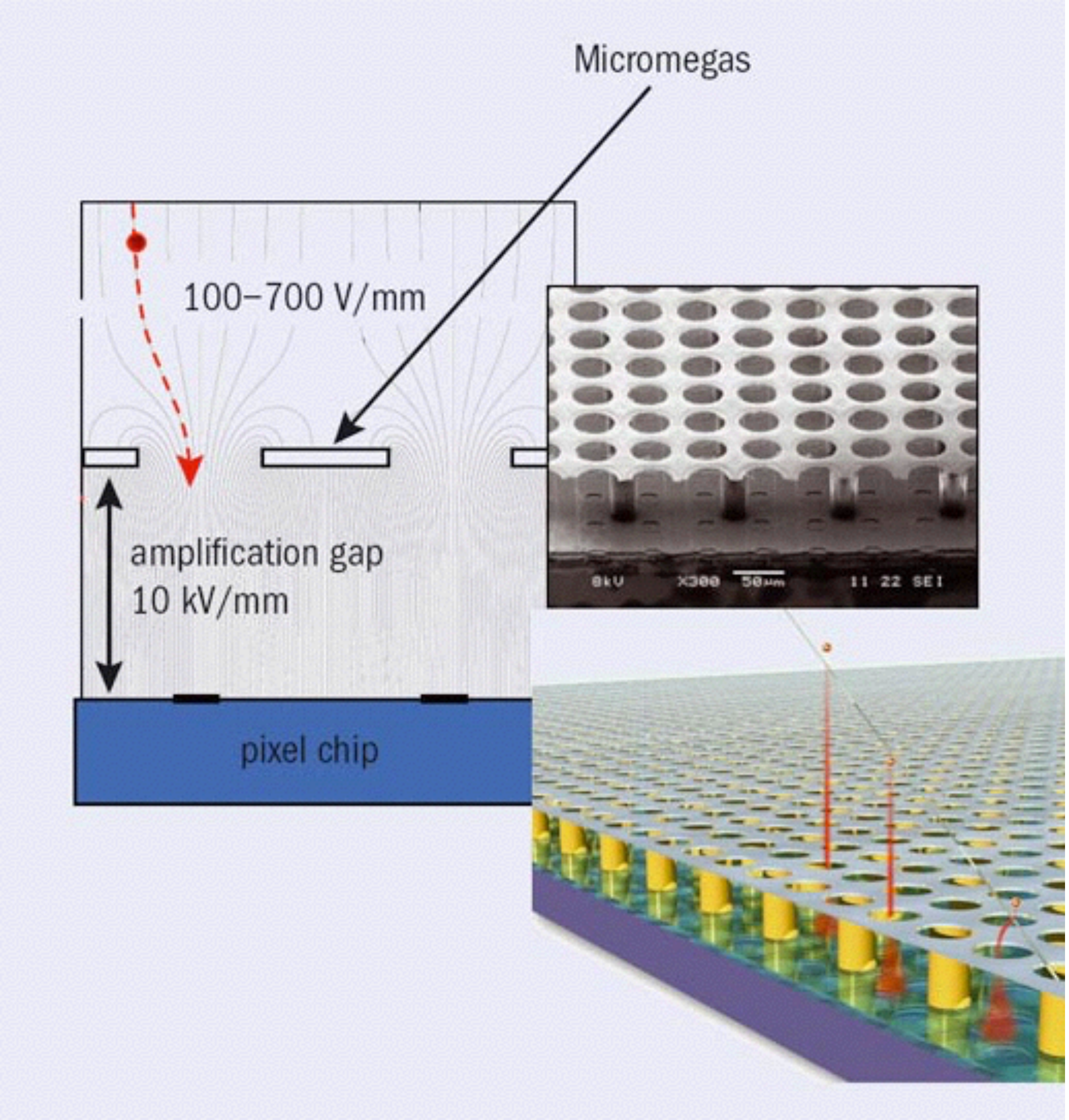


Micromegas

Micro-Mesh Gaseous Structure

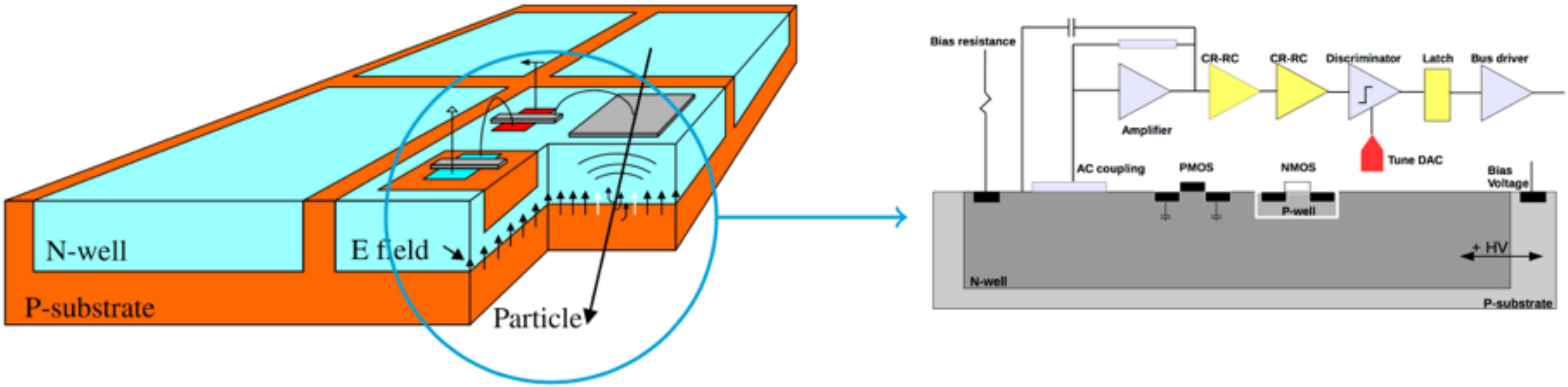
- Single-stage
- Complex lithography
- Curved detectors possible

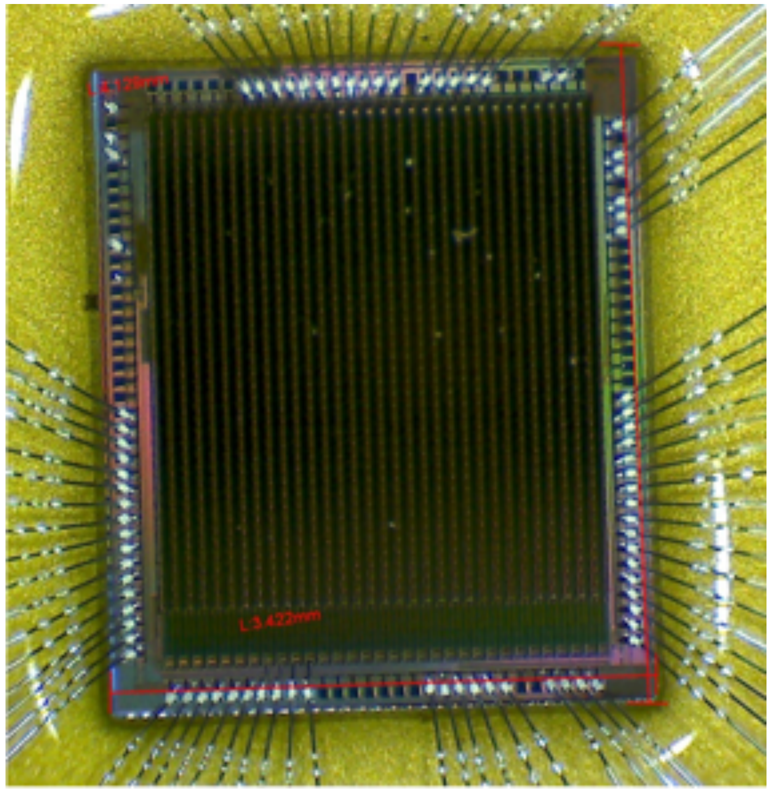




HV-MAPS

High Voltage - Monolithic Active Pixel Sensors

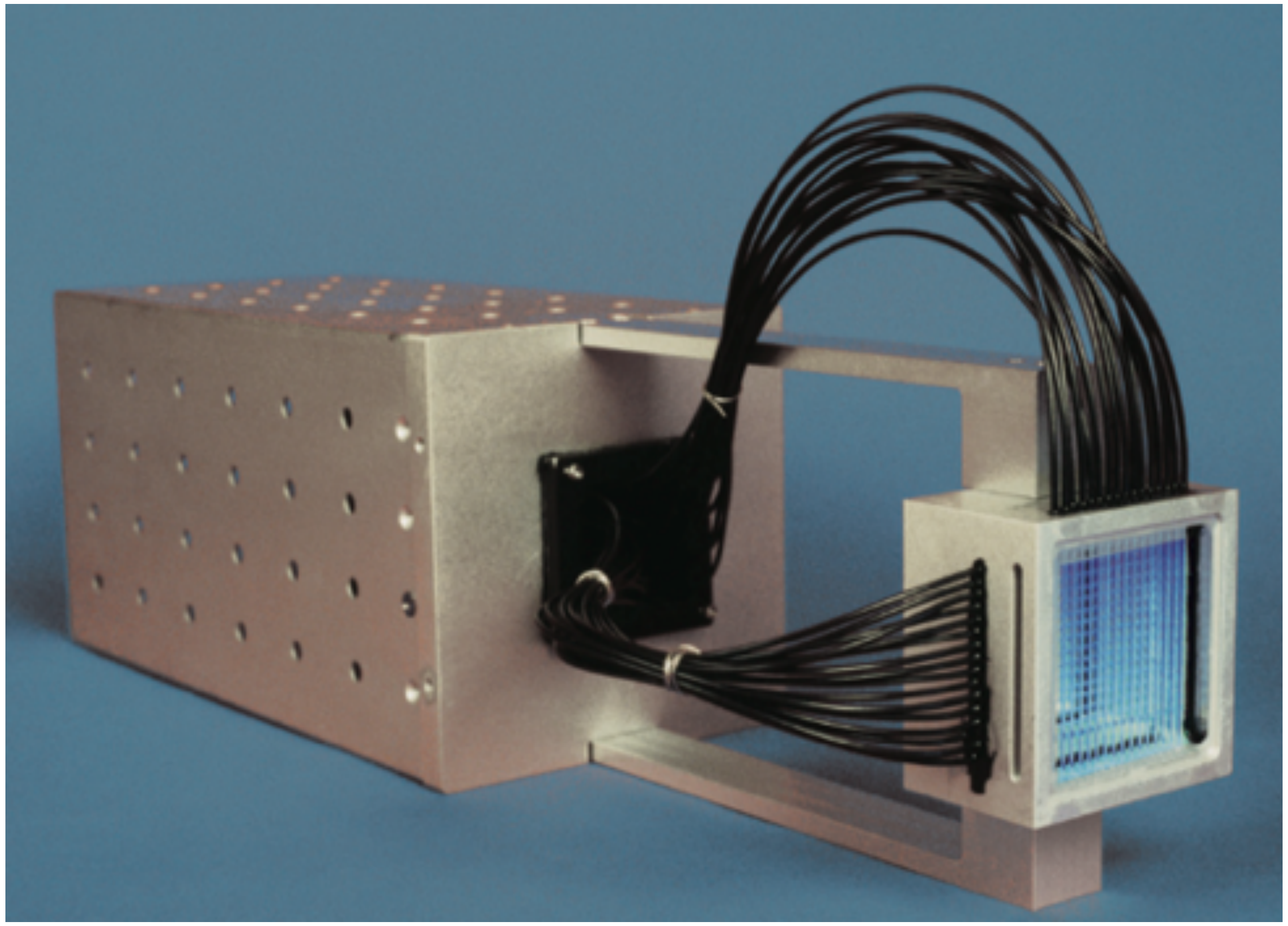


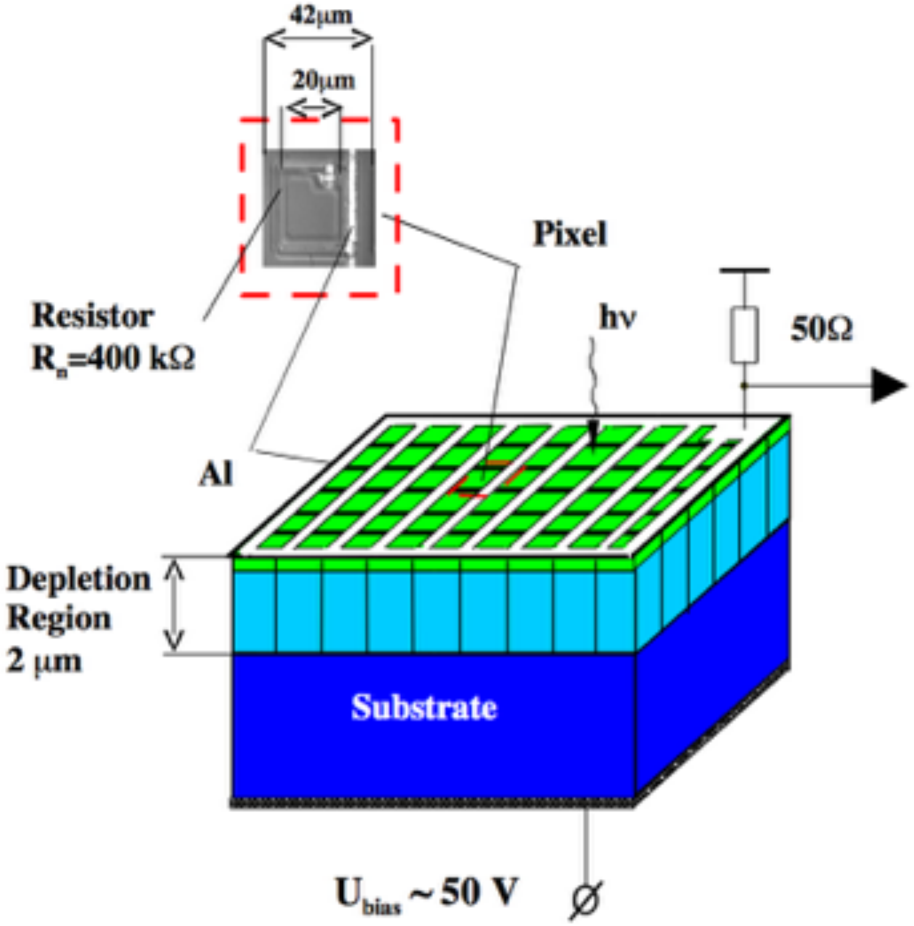


- Digital and analog components integrated into Si pixel material
- Thin
- Zero-suppression built in

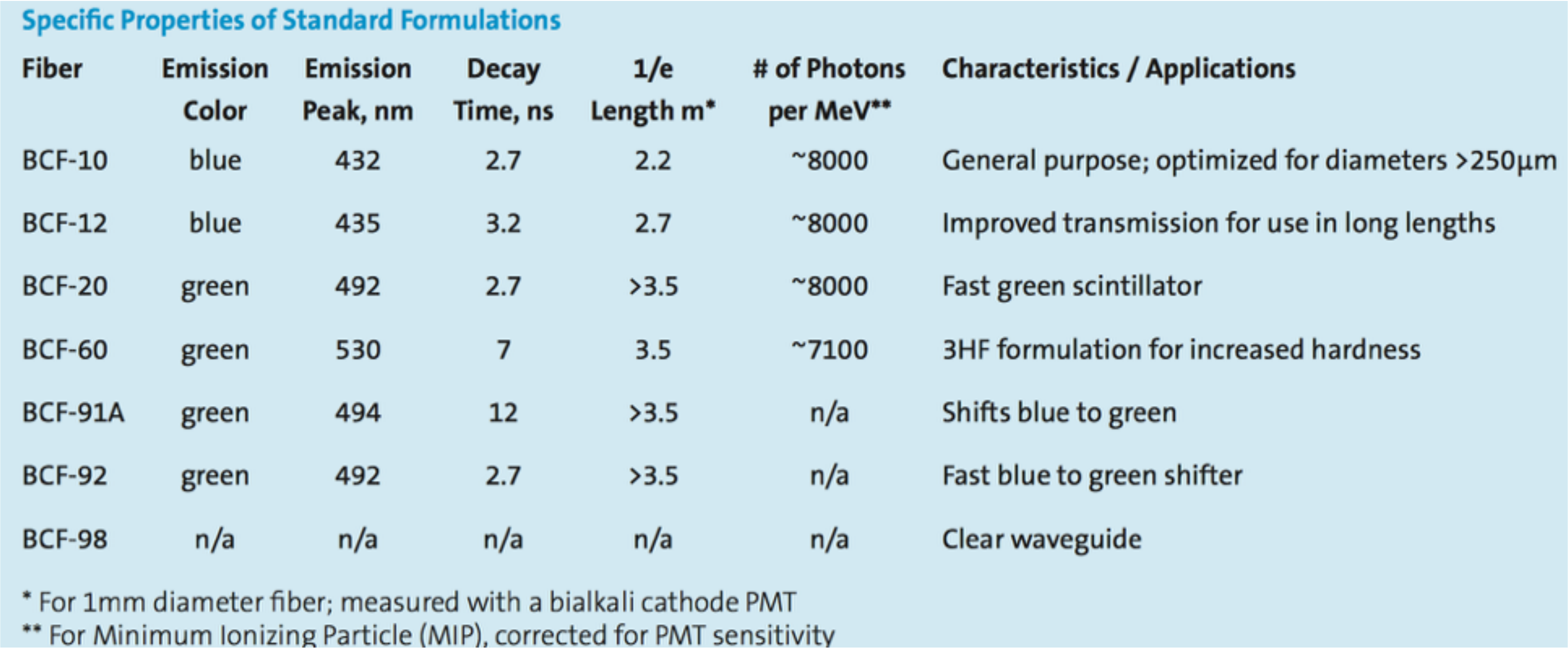
Scintillating Fibers

- Fast signal propagation
- Mass comparable to GEM stack
- Vacuum-compatible
- Mate to multi-anode PMTs or SiPMs





Scintillating Fibers



Specific Properties of Standard Formulations

Fiber	Emission Color	Emission Peak, nm	Decay Time, ns	1/e Length m*	# of Photons per MeV**	Characteristics / Applications
BCF-10	blue	432	2.7	2.2	~8000	General purpose; optimized for diameters >250µm
BCF-12	blue	435	3.2	2.7	~8000	Improved transmission for use in long lengths
BCF-20	green	492	2.7	>3.5	~8000	Fast green scintillator
BCF-60	green	530	7	3.5	~7100	3HF formulation for increased hardness
BCF-91A	green	494	12	>3.5	n/a	Shifts blue to green
BCF-92	green	492	2.7	>3.5	n/a	Fast blue to green shifter
BCF-98	n/a	n/a	n/a	n/a	n/a	Clear waveguide

* For 1mm diameter fiber; measured with a bialkali cathode PMT

** For Minimum Ionizing Particle (MIP), corrected for PMT sensitivity