accu
2023

KEYNOTE:
C++ HORIZONS

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C++20 is in the field

- Modules
- Coroutines
- Concepts
- Ranges

C++23 is coming!

- More ranges
- Formatted output
- `mdspan`
- `expected`
- `import std`
- Deducing `this`

On The Horizon For

On The Horizon For C++

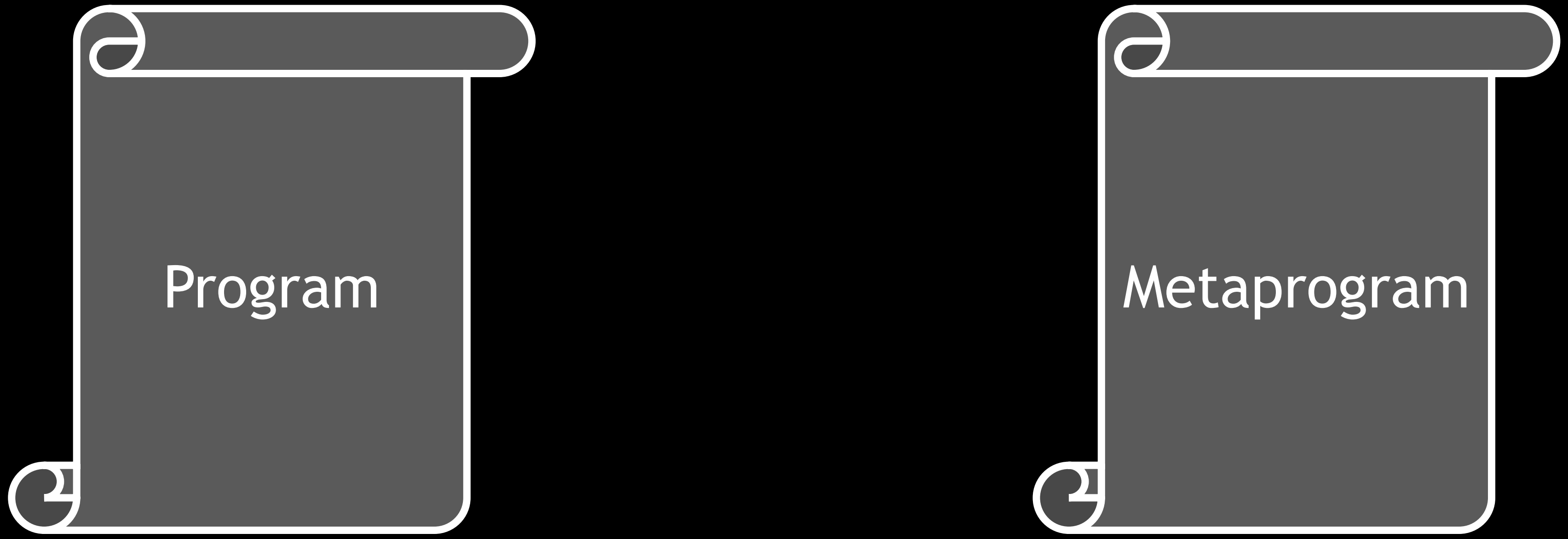
- Reflection

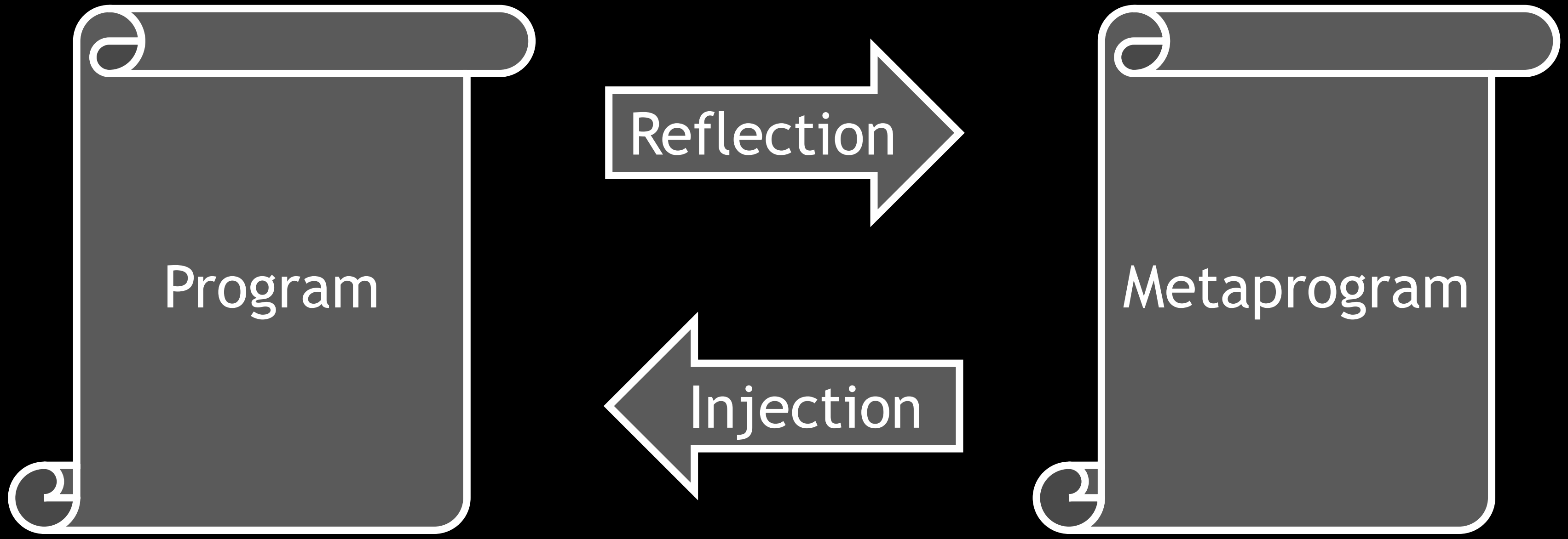
On The Horizon For C++

- Reflection
- Pattern Matching

On The Horizon For C++

- Reflection
- Pattern Matching
- Senders


Program
Metaprogram


Program
Reflection
Injection
Metaprogram

```
template <typename T> requires is_enum_v<T>
constexpr string to_string(T value) {
  template for (constexpr meta::info e : meta::members_of(^T))
    if ([:e:] == value)
      return meta::name_of(e);
  return "<unnamed>";
}
```

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template <typename T> requires is_enum_v<T>
constexpr string to_string(T value) {
  template for (constexpr meta::info e : meta::members_of(^T))
    if ([:e:] == value)
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}
```

^*name-or-postfix-expr*

The reify operator.
entity -> reflection

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constexpr string to_string(T value) {
  template for (constexpr meta::info e : meta::members_of(^T))
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      return me
  return "<unna
}
```

std::meta::info is the type for reflection objects.

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}
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Reflections can be manipulated and transformed like any C++ objects.

```
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constexpr string to_string(T value) {
  template for (constexpr meta::info e : meta::members_of(^T))
    if ([:e:] == value)
                     me_of(e);
```

template for

Compile-time expansion.

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}
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[:*reflection*:]

The splice operator.
reflection -> entity

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  return "<unnamed>";
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```
template <typename Hasher, typename T>
constexpr void hash_append(Hasher& hasher, T const& t) {
  constexpr meta::info data_members =
    meta::members_of(^T, meta::is_nonstatic_data_member);
  template for (constexpr meta::info member : data_members)
    hash_append(hasher, t.[:member:]);
}
```

```
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template <typename T> requires is_class<T>
struct traced {
  private: T payload_;
  template for (constexpr auto e : member_functions_of(^T))
    [:protection_of(e):]: [:attributes_of(e):]
    [:return_of(e):] [#e#]
    (...[:parameter_types_of(e):] ...[#parameters_of(e)#]...)
    [:qualifiers_of(e):]
    {
      print("Calling {}::{}\n", name_of(^T), name_of(e));
      return payload_.[:e:](forward<[:parameter_types_of(e):]>(
        ...[#parameter_names_of(e)#]...
      ));
    }
};
```

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template <typename T> requires is_class<T>
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    {
                              , name_of(^T), name_of(e));
                              rward<[:parameter_types_of(e):]>(
                              f(e)#]...

    }
};
```

[#*reflection*#]

The identifier splice operator.
reflection -> identifier

```cpp
template <typename T> requires is_class<T>
struct traced {
  private: T payload_;
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                          , name_of(^T), name_of(e));
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    }
};
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...[:*reflection*:]
...[#*reflection*#]

Splice pack expansion
reflection -> pack

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```

```
struct color {
  uint8_t red;
  uint8_t green;
  uint8_t blue;
};

std::vector<color> image(…);

for (auto& [r, g, b] : image)
  r /= 2;
```

```
struct color {
  std::vector<uint8_t> red;
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};

color image(…);

for (auto& r : image.red)
  r /= 2;
```

```
struct color {
  uint8_t red;
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std::vector<color> image(…);

for (auto& [r, g, b] : image)
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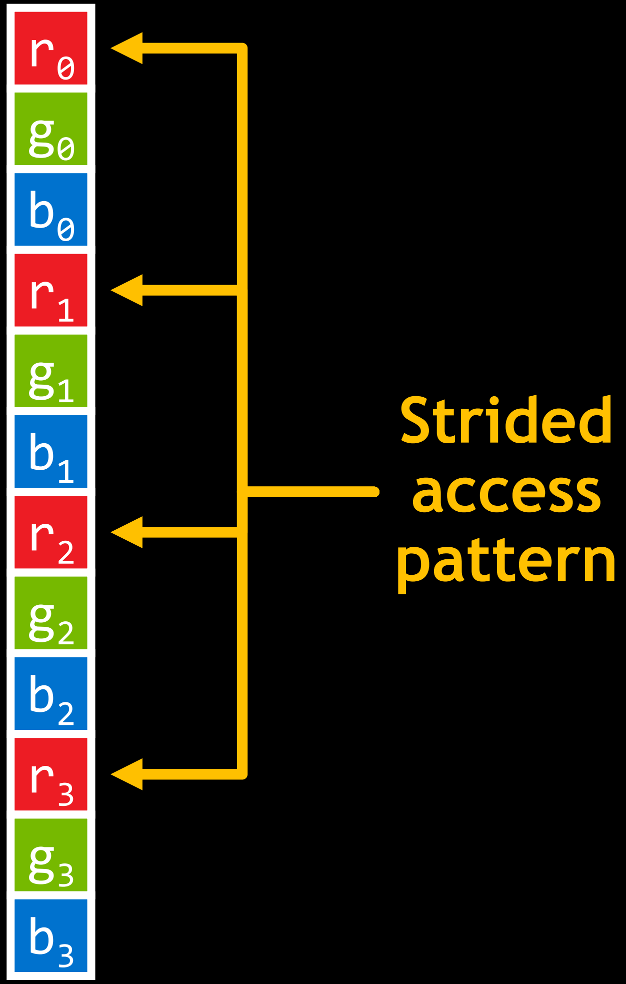

```
template <typename T>
struct soa {
  constexpr meta::info data_members =
    meta::members_of(^T, meta::is_nonstatic_data_member);

  vector<...[:meta::type_of(data_members):]> ...[#data_members#]...;

  soa(ranges::forward_range<T>&& aos) {
    template for (constexpr meta::info member : data_members) {
      [#member#].resize(ranges::size(aos));
      ranges::transform(aos, [#member#].begin(),
        [] (auto&& v) { return v.[:member:]; });
    }
  }

  auto operator[](size_t i) { return tie(...[#data_members#][i]...); }
};
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      ranges::transform(aos, [#member#].begin(),
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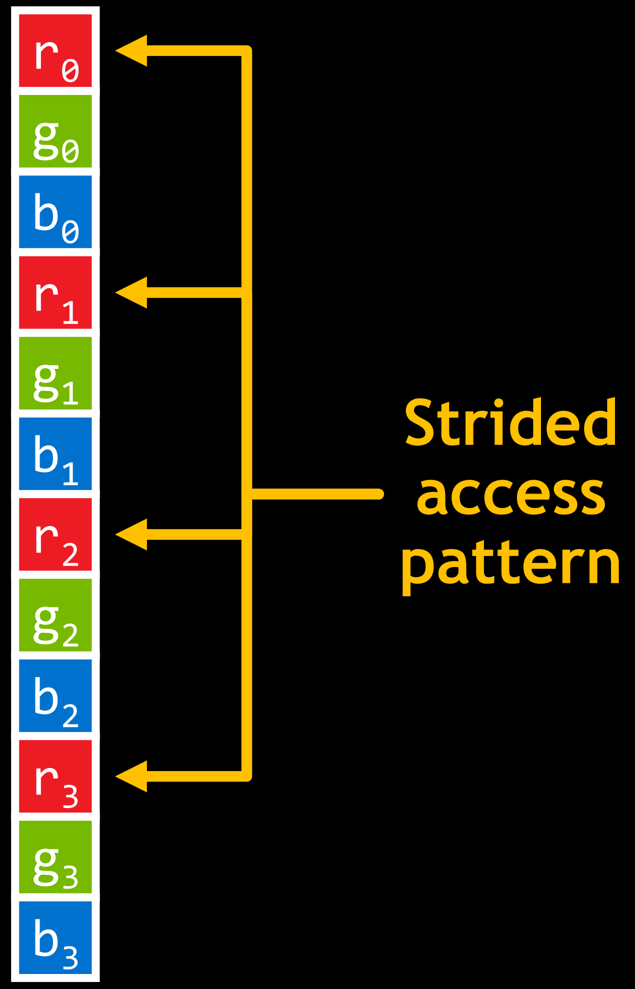
```

```
struct color {
  uint8_t red;
  uint8_t green;
  uint8_t blue;
};

std::vector<color> image(…);

for (auto& [r, g, b] : image)
  r /= 2;
```



```
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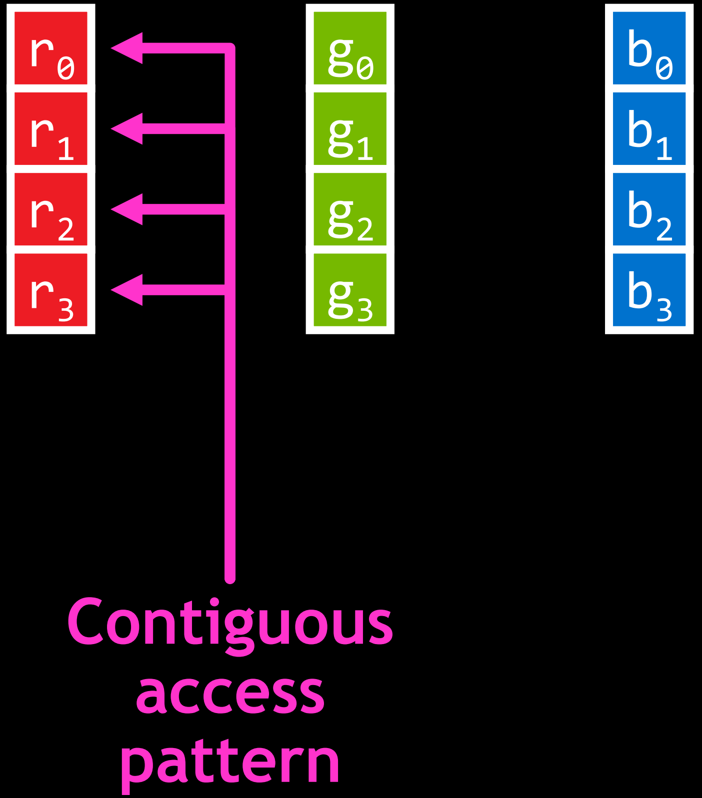

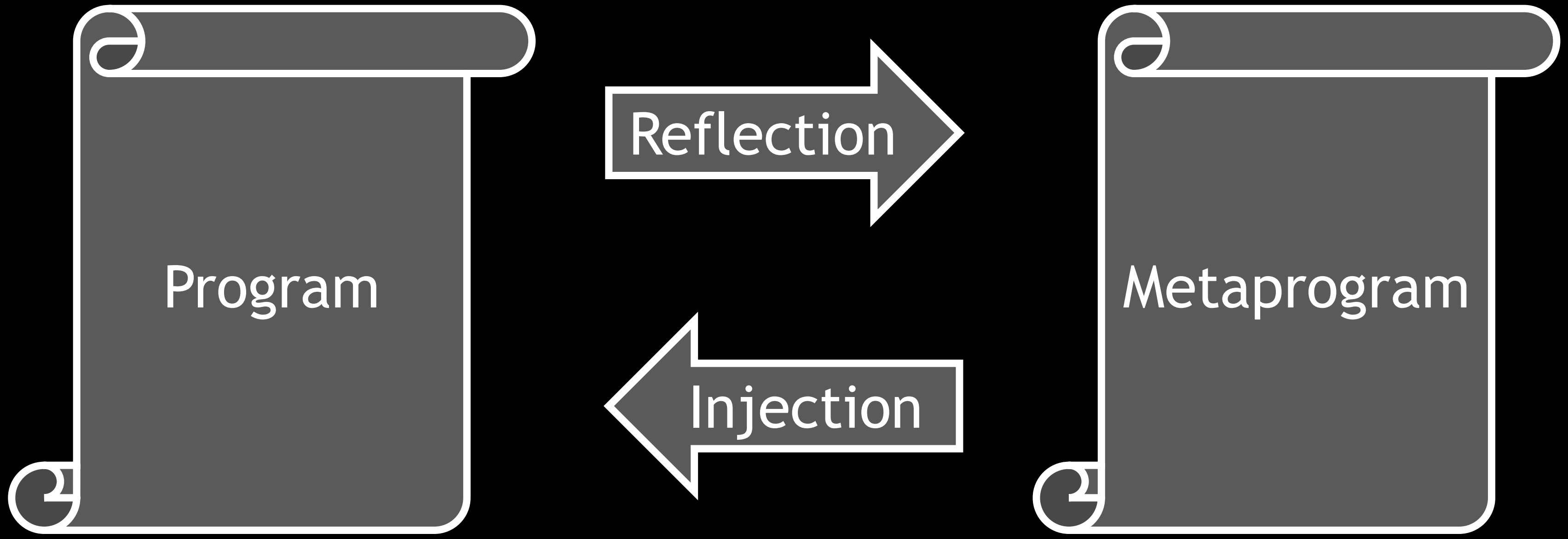
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Selection in C++

`switch`: Operates on a single integral value. Often too limited.

`inspect`: Matches values against patterns; binds variables on success.

`if`: Operates on arbitrary Boolean expressions. Often too complex.

```
switch (i) {
  case 0:  print("got zero"); break;
  case 1:  print("got one"); break;
  default: print("don't care");
}
```

```
inspect (i) {
  0  => { print("got zero"); }
  1  => { print("got one"); }
  __ => { print("don't care"); }
};
```

`inspect (`*expr*`) { … }`

Expression, not a statement.

```
switch (i) {
  case 0:  print("got zero"); break;
  case 1:  print("got one"); break;
  default: print("don't care");
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inspect (i) {
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```

pattern => *statement*

There's a variety of different patterns available.

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switch (i) {
  case 0:  print("got zero"); break;
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  0  => { print("got zero"); }
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```

inspect stops at the first match, not the best match.

Constant patterns.

```
switch (i) {
  case 0:  print("got zero"); break;
  case 1:  print("got one"); break;
  default: print("don't care");
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```

```
inspect (i) {
  0  => { print("got zero"); }
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};
```

Wildcard pattern.

```
switch (i) {
  case 0:  print("got zero"); break;
  case 1:  print("got one"); break;
  default: print("don't care");
}
```

```
inspect (i) {
  0  => { print("got zero"); }
  1  => { print("got one"); }
  __ => { print("don't care"); }
};
```

```
if (s == "foo") {
  print("got foo“);
} else if (s == "bar") {
  print("got bar");
} else {
  print("don't care");
}
```

```
inspect (x) {
  "foo" => { print("got foo"); }
  "bar" => { print("got bar"); }
  __    => { print("don't care"); }
};
```

Constant patterns aren’t limited to integrals or enums!

```
unsigned fibonacci(unsigned n) {
  return inspect (n) {
    0 => 0;
    1 => 1;
    e if (e > 47) => { throw overflow_error("too large"); }
    a => fibonacci(a - 1) + fibonacci(a - 2);
};
```

```
unsigned fibonacci(unsigned n) {
  return inspect (n) {
    0 => 0;
    1 => 1;
    e if (e > 47) => { throw overflow_error("too large"); }
    a => fibonacci(a - 1) + fibonacci(a - 2);
};
```

Identifier patterns bind the value to a name.

```
unsigned fibonacci(unsigned n) {
  re
  (
```

Pattern guards can perform complex tests that cannot be performed within the *pattern*.

```
    e if (e > 47) => { throw overflow_error("too large"); }
    a => fibonacci(a - 1) + fibonacci(a - 2);
};
```

```
auto&& [x, y, z] = p;
if (x == 0 && y == 0 && z == 0) {
  print("on origin");
} else if (x == 0) {
  print("on y-axis");
} else if (y == 0) {
  print("on x-axis");
} else if (z == 0) {
  print("on z-axis");
} else {
  print("{}, {}, {}", x, y, z);
}
```

```
inspect (p) {
  [0, 0] => { print("on origin"); }
  [0, y] => { print("on y-axis"); }
  [x, 0] => { print("on x-axis"); }
  [x, y] => { print("{}, {}, {}", x, y, z); }
};
```

[*pattern*, *pattern*, …] => …

Compound patterns can be used to decompose objects.

```
struct visitor {
  void operator()(int i) const {
    print("got int: {}", i);
  }
  void operator()(float f) const {
    print("got float: {}", f);
  }
};

visit(visitor{}, v);
```

```
inspect (v) {
  <int>   i => { print("got int: {}", i); }
  <float> f => { print("got float: {}", f); };
}
```

<type> pattern => …

Alternative patterns match different types.

```
struct phone_number_extractor {
  optional<array<string_view, 3>>
  try_extract(string_view sv) const;
};
inline constexpr phone_number_extractor phone_number;
```

```
struct email_extractor {
  optional<array<string_view, 2>>
  try_extract(string_view sv) const;
};
inline constexpr email_extractor email;

inspect (s) {
  (phone_number?) ["212", __, __]   => { print("got a New York phone number"); }
  (email?)        [address, domain] => { print("got an email"); }
};
```

(expr?) pattern => …

Extractor patterns allow you to customize matching and decomposition.

```
struct phone_number_extractor {
  optional<array<string_view, 3>>
  try_extract(string_view sv) const {
    auto s = views::split(sv, "-");
    if (ranges::size(s) != 3) return nullopt;
    for (auto&& c: s) if (ranges::find_if_not(c, isdigit)) return nullopt;
    return {begin(s), begin(s) + 1, begin(s) + 2};
  }
};
inline constexpr phone_number_extractor phone_number;

struct email_extractor {
  optional<array<string_view, 2>>
  try_extract(string_view sv) const;
};
inline constexpr email_extractor email;

inspect (s) {
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  std::string out;
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Selection in C++

`switch`: Operates on a single integral value. Often too limited.

`inspect`: Matches values against patterns; binds variables on success.

`if`: Operates on arbitrary Boolean expressions. Often too complex.

Today, C++ has:

- No standard model for asynchrony.
- No standard way to express where things should execute.

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The solution is coming soon:

Senders

Schedulers are handles to execution contexts.

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Senders represent asynchronous work.

Schedulers are handles to execution contexts.

Senders represent asynchronous work.

Receivers process asynchronous signals.

```
ex::scheduler auto sch = thread_pool.scheduler();

ex::sender auto begin = ex::schedule(sch);
ex::sender auto hi    = ex::then(begin, [] { return 13; });
ex::sender auto add   = ex::then(hi, [] (int a) { return a + 42; });

auto [i] = this_thread::sync_wait(add).value();
```

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ex::scheduler auto sch = thread_pool.scheduler();

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auto [i] = this_thread::sync_wait(add).value();
```

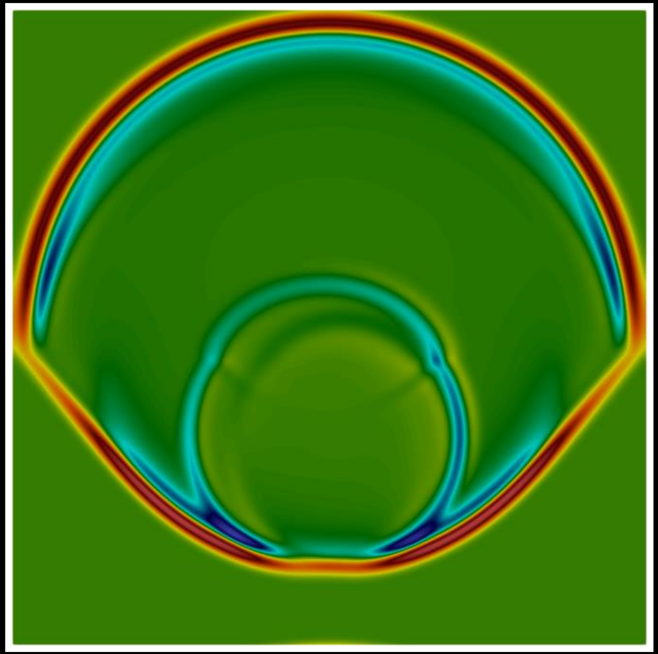
```
std::vector<std::string_view> v{…};

ex::sender auto s = ex::transfer_just(gpu_stream_scheduler{}, v)
                  | sort_async
                  | unique_async
                  | ex::transfer(thread_pool.scheduler())
                  | for_each_async([] (std::string_view e)
                                   { std::print(file, "{}\n", e); });

this_thread::sync_wait(s);
```

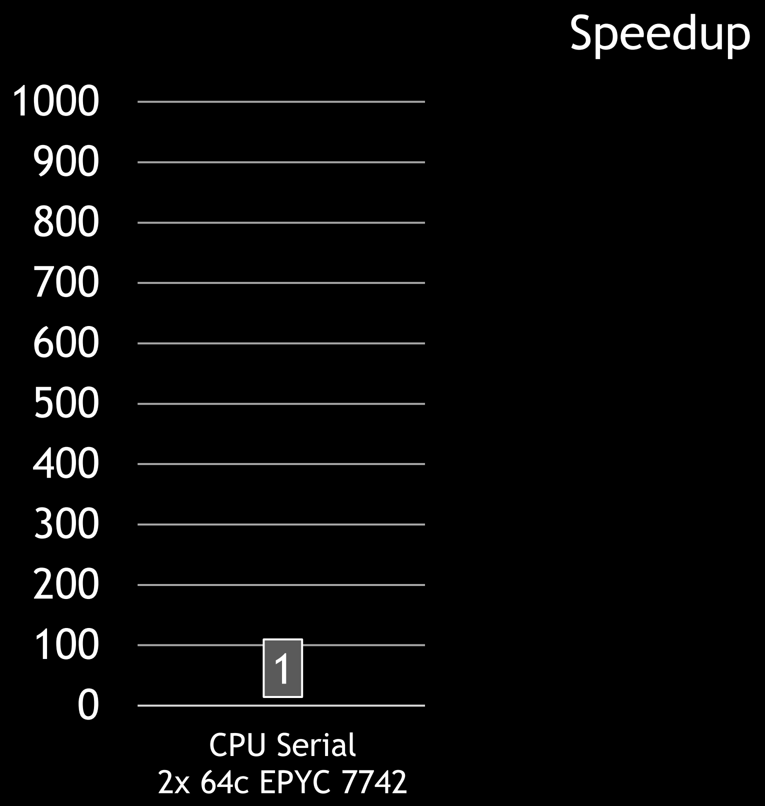
Maxwell's Equations

```
sender auto maxwell_eqs(scheduler auto &compute,
                        grid_accessor A, …) {
  return repeat_n(n_outer_iterations,
           repeat_n(n_inner_iterations,
               schedule(compute)
             | bulk(G.cells, update_h(G))
             | halo_exchange(G, hx, hy)
             | bulk(G.cells, update_e(time, dt, G))
             | halo_exchange(G, hx, hy))
           | transfer(cpu_serial_scheduler)
           | then(output_results))
         );
}
```



Maxwell's Equations

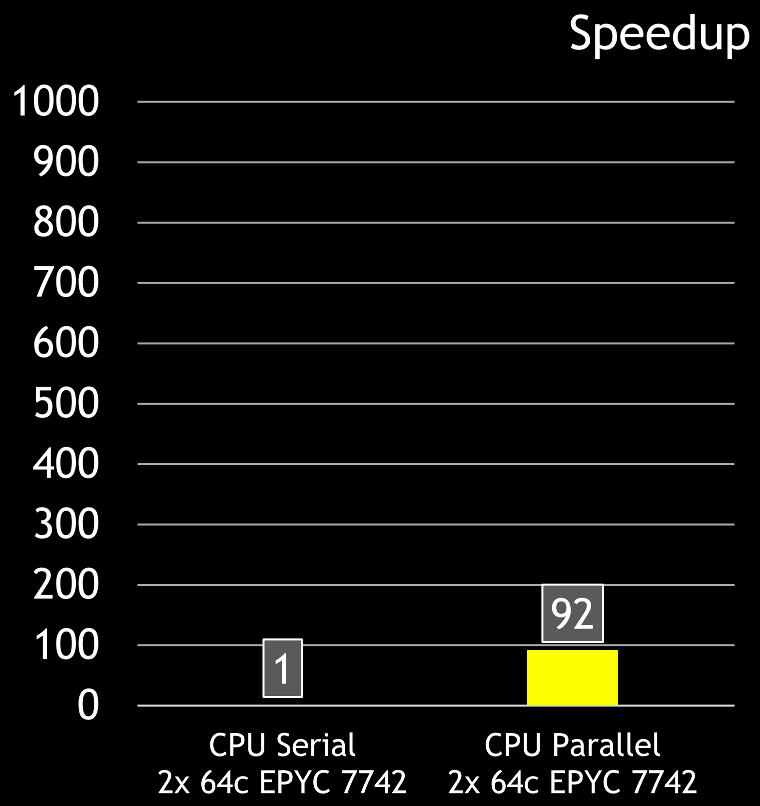
Change one line of code and scale from a single CPU thread…




```
sync_wait(maxwell_eqs(cpu_serial_scheduler), …);
```

Maxwell's Equations

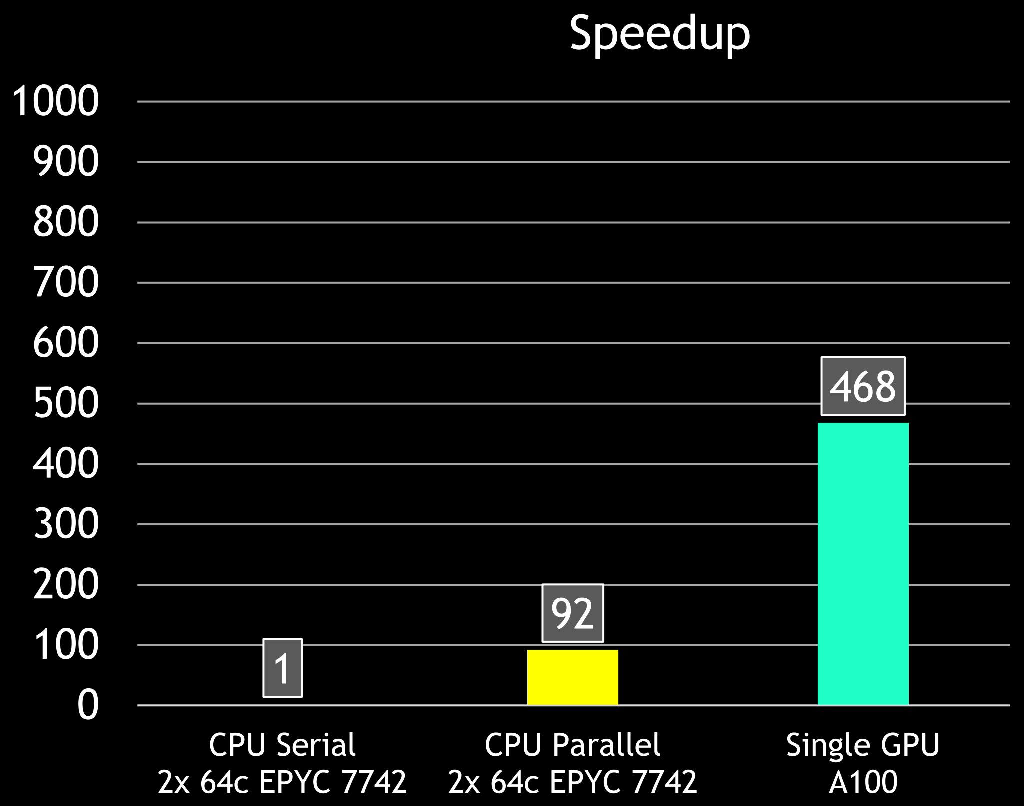
Change one line of code and scale from a single CPU thread up to multiple CPU threads…




```
sync_wait(maxwell_eqs(cpu_parallel_scheduler), …);
```

Maxwell's Equations

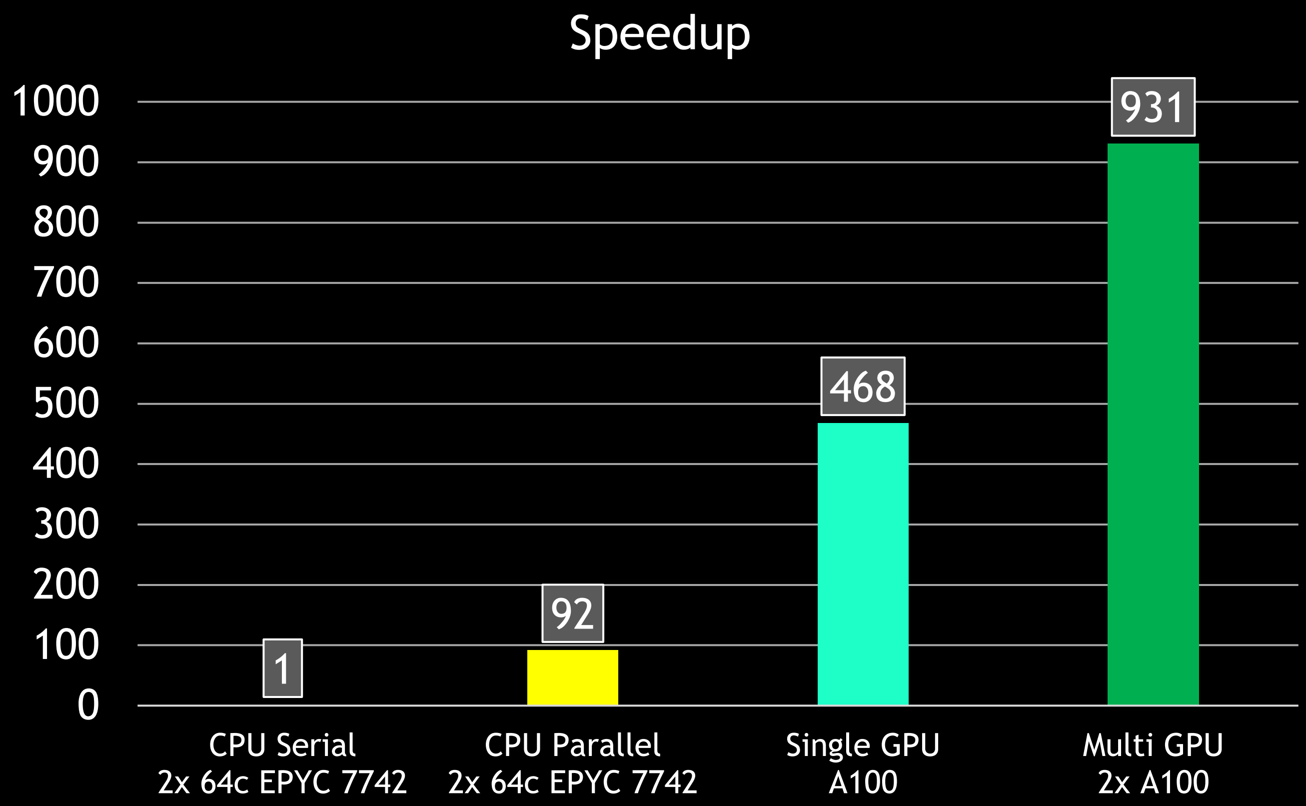
Change one line of code and scale from a single CPU thread up to a GPU…




```
sync_wait(maxwell_eqs(single_gpu_scheduler), …);
```

Maxwell's Equations

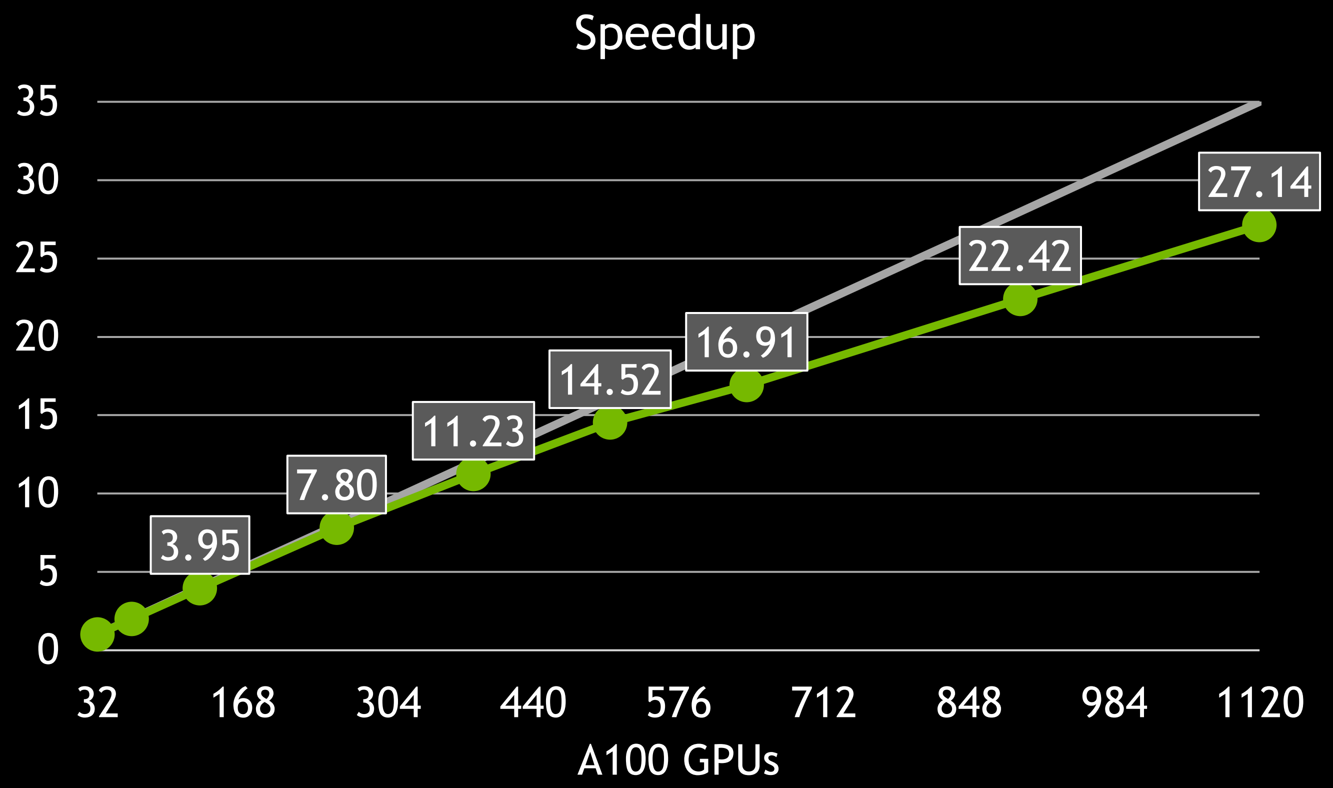
Change one line of code and scale from a single CPU thread up to multiple GPUs…




```
sync_wait(maxwell_eqs(multi_gpu_scheduler), …);
```

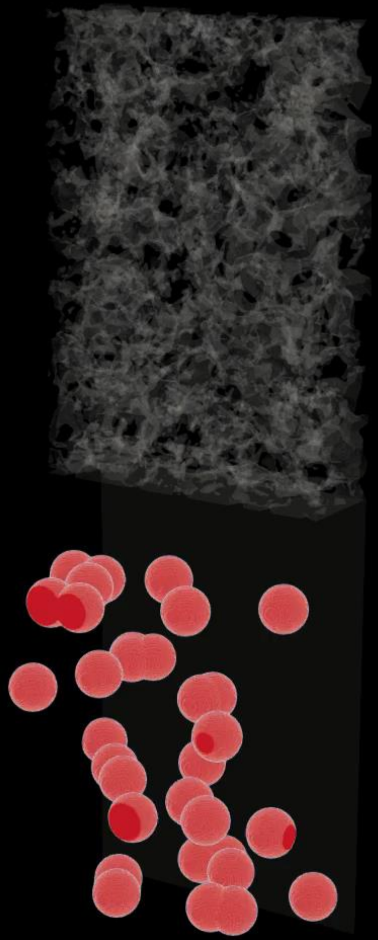
Maxwell's Equations

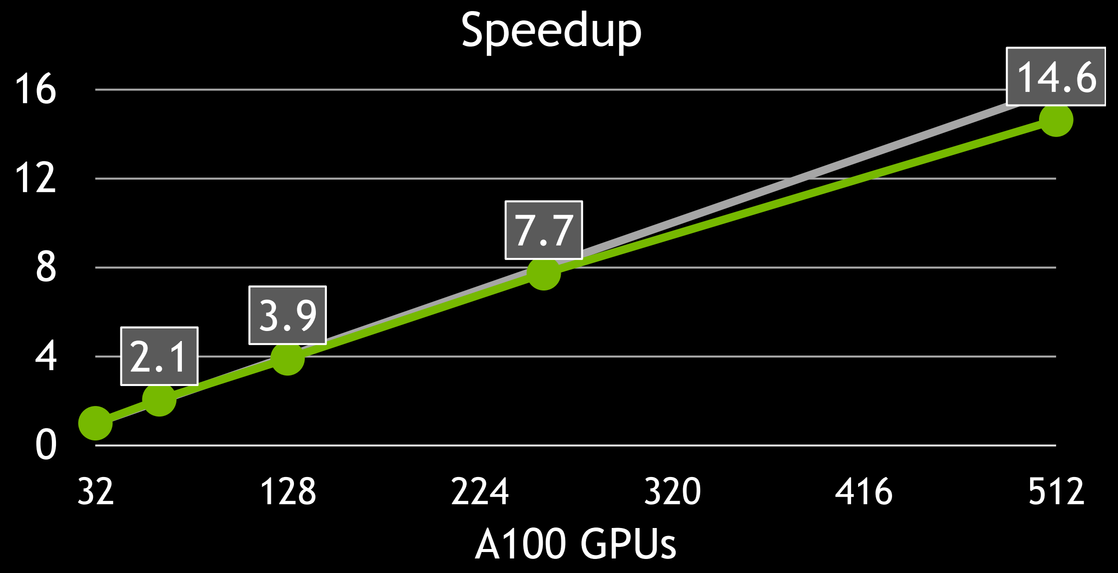
Change one line of code and scale from a single CPU thread up to a cluster of GPUs!




```
sync_wait(maxwell_eqs(multi_node_gpu_scheduler), …);
```

Palabos Carbon Sequestration





- Palabos is a framework for parallel computational fluid dynamics simulations using the Lattice-Boltzmann method.
- Code for multi-component flow through a porous media ported to C++ Senders and Receivers.
- Application: simulating carbon sequestration in sandstone.

Jonas Latt (University of Geneva), Christian Huber (Brown University)
Georgy Evtushenko (NVIDIA), Gonzalo Brito (NVIDIA)

```
struct dynamic_buffer {
  unique_ptr<byte[]> data;
  size_t size;
};

sender_of<set_value_t(dynamic_buffer)> auto async_read_array(auto handle) {
  return just(dynamic_buffer{})
       | let_value([handle] (dynamic_buffer& buf) {
           return just(as_writeable_bytes(span(&buf.size, 1))
                | async_read(handle)
                | then([&buf] (size_t bytes_read) {
                    assert(bytes_read == sizeof(buf.size));
                    buf.data = make_unique<byte[]>(buf.size);
                    return span(buf.data.get(), buf.size);
                  })
                | async_read(handle)
                | then([&buf] (size_t bytes_read) {
                    assert(bytes_read == buf.size);
                    return move(buf);
                  });
         });
}
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```

```
inline constexpr sender_adaptor auto
async::inclusive_scan = [] (…) -> ex::sender auto {
  …
}
```

```
inline constexpr sender_adaptor auto
async::inclusive_scan = [] (ex::sender auto last, auto init, std::size_t tile_count) -> ex::sender auto {
  …
}
```

```
inline constexpr sender_adaptor auto
async::inclusive_scan = [] (ex::sender auto last, auto init, std::size_t tile_count) -> ex::sender auto {
  return last
       | ex::then([=] (stdr::random_access_range auto input) {
                    …
                  })
  …
}
```

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inline constexpr sender_adaptor auto
async::inclusive_scan = [] (ex::sender auto last, auto init, std::size_t tile_count) -> ex::sender auto {
  return last
       | ex::then([=] (stdr::random_access_range auto input) {
                      std::vector<stdr::range_value_t<decltype(input)>> partials(tile_count + 1);
                      partials[0] = init;
                      return send_values(input, std::move(partials));
                    })
  …
}
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       | ex::bulk(tile_count,
                   [=] (std::size_t i, auto input, auto partials) {
                     …
                   })
  …
}
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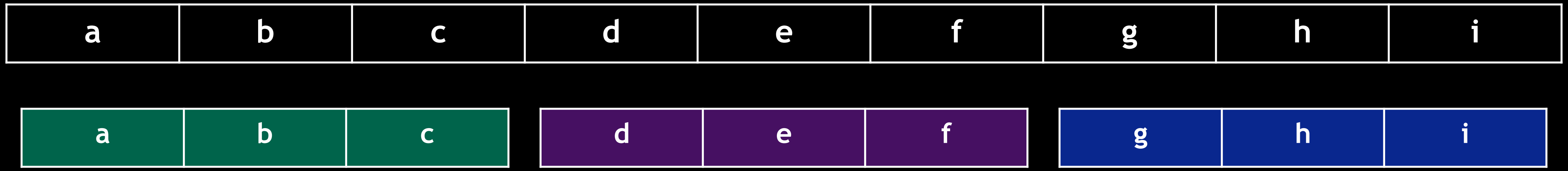
                   return send_values(input, std::move(partials));
                 })
       | ex::bulk(tile_count,
                 [=] (std::size_t i, auto input, auto partials) {
                   auto tile_size  = (input.size() + tile_count - 1) / tile_count;
                   auto start      = i * tile_size;
                   auto end        = std::min(input.size(), (i + 1) * tile_size);
                   …
                 })
  …
}
```


a b c d e f g h i
a b c
d e f
g h i

a	b	c	d	e	f	g	h	i

a	ab	abc

`std::inclusive_scan`

d	de	def

`std::inclusive_scan`

g	gh	ghi

`std::inclusive_scan`

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inline constexpr sender_adaptor auto
async::inclusive_scan = [] (ex::sender auto last, auto init, std::size_t tile_count) -> ex::sender auto {
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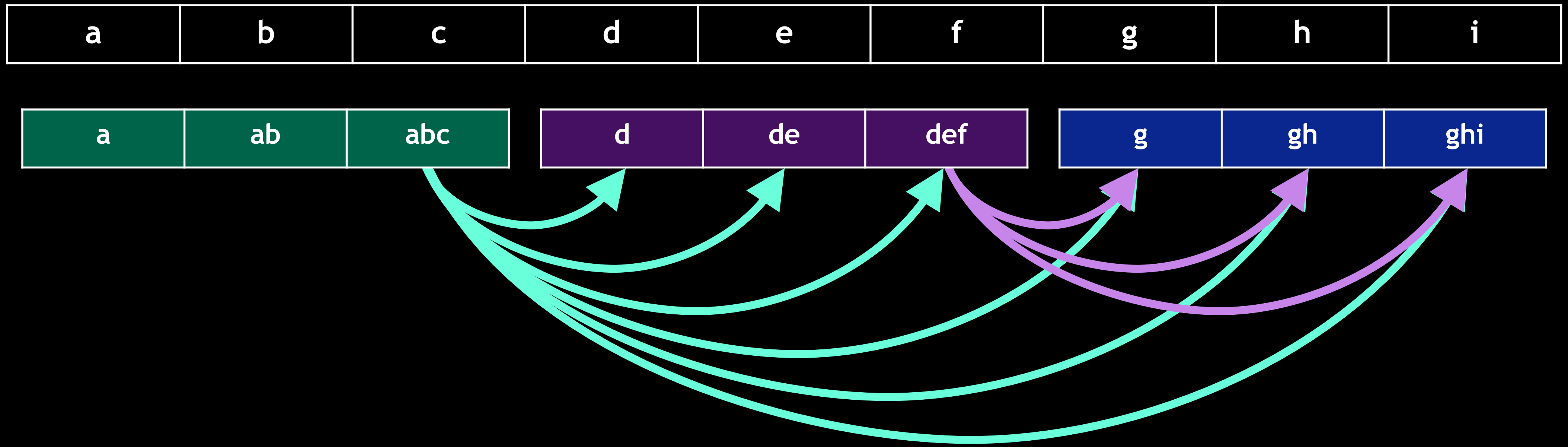
                  return send_values(input, std::move(partials));
                })
       | ex::bulk(tile_count,
                [=] (std::size_t i, auto input, auto partials) {
                  auto tile_size  = (input.size() + tile_count - 1) / tile_count;
                  auto start      = i * tile_size;
                  auto end        = std::min(input.size(), (i + 1) * tile_size);
                  …                    std::inclusive_scan(begin(input) + start,
                                                           begin(input) + end,
                                                           begin(input) + start);

                })
  …
}
```


a
b
c
d
e
f
g
h
i
a
ab
abc
d
de
def
g
gh
ghi

```
inline constexpr sender_adaptor auto
async::inclusive_scan = [] (ex::sender auto last, auto init, std::size_t tile_count) -> ex::sender auto {
  return last
       | ex::then([=] (stdr::random_access_range auto input) {
                    std::vector<stdr::range_value_t<decltype(input)>> partials(tile_count + 1);
                    partials[0] = init;
                    return send_values(input, std::move(partials));
                  })
       | ex::bulk(tile_count,
                  [=] (std::size_t i, auto input, auto partials) {
                    auto tile_size  = (input.size() + tile_count - 1) / tile_count;
                    auto start      = i * tile_size;
                    auto end        = std::min(input.size(), (i + 1) * tile_size);
                    …               = *--std::inclusive_scan(begin(input) + start,
                                                             begin(input) + end,
                                                             begin(input) + start);

                  })
  …
}
```

```
inline constexpr sender_adaptor auto
async::inclusive_scan = [] (ex::sender auto last, auto init, std::size_t tile_count) -> ex::sender auto {
  return last
      | ex::then([=] (stdr::random_access_range auto input) {
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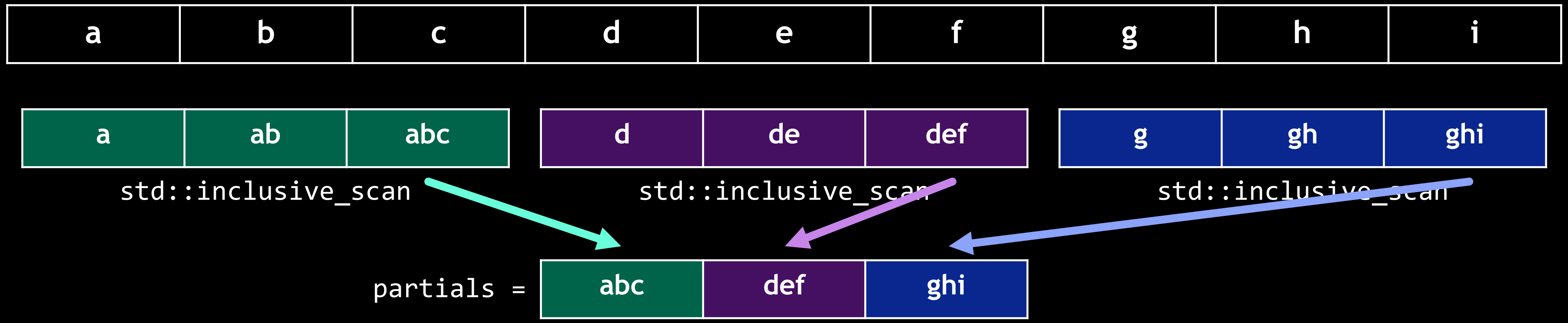
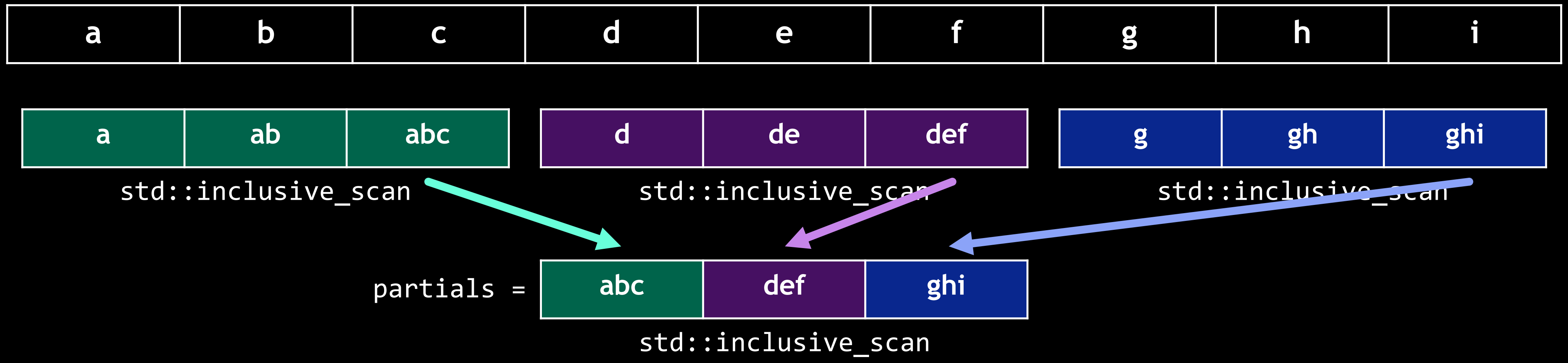
                   partials[0] = init;
                   return send_values(input, std::move(partials));
                 })
      | ex::bulk(tile_count,
                 [=] (std::size_t i, auto input, auto partials) {
                   auto tile_size  = (input.size() + tile_count - 1) / tile_count;
                   auto start      = i * tile_size;
                   auto end        = std::min(input.size(), (i + 1) * tile_size);
                   partials[i + 1] = *--std::inclusive_scan(begin(input) + start,
                                                            begin(input) + end,
                                                            begin(input) + start);
                 })
  …
}
```


a
b
c
d
e
f
g
h
i
a
ab
abc
d
de
def
g
gh
ghi
std::inclusive_scan
std::inclusive_scan
std::inclusive_scan
partials =
abc
def
ghi


a
b
c
d
e
f
g
h
i
a
ab
abc
d
de
def
g
gh
ghi
std::inclusive_scan
std::inclusive_scan
std::inclusive_scan
partials =
abc
def
ghi
std::inclusive_scan

```
inline constexpr sender_adaptor auto
async::inclusive_scan = [] (ex::sender auto last, auto init, std::size_t tile_count) -> ex::sender auto {
  return last
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                     std::vector<stdr::range_value_t<decltype(input)>> partials(tile_count + 1);
                     partials[0] = init;
                     return send_values(input, std::move(partials));
                   })
       | ex::bulk(tile_count,
                   [=] (std::size_t i, auto input, auto partials) {
                     auto tile_size  = (input.size() + tile_count - 1) / tile_count;
                     auto start      = i * tile_size;
                     auto end        = std::min(input.size(), (i + 1) * tile_size);
                     partials[i + 1] = *--std::inclusive_scan(begin(input) + start,
                                                              begin(input) + end,
                                                              begin(input) + start);
                   })
       | ex::then([] (auto input, auto partials) {
                     std::inclusive_scan(begin(partials), end(partials), begin(partials));
                     …
                   })
  …
}
```

```
inline constexpr sender_adaptor auto
async::inclusive_scan = [] (ex::sender auto last, auto init, std::size_t tile_count) -> ex::sender auto {
  return last
       | ex::then([=] (stdr::random_access_range auto input) {
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                  partials[0] = init;
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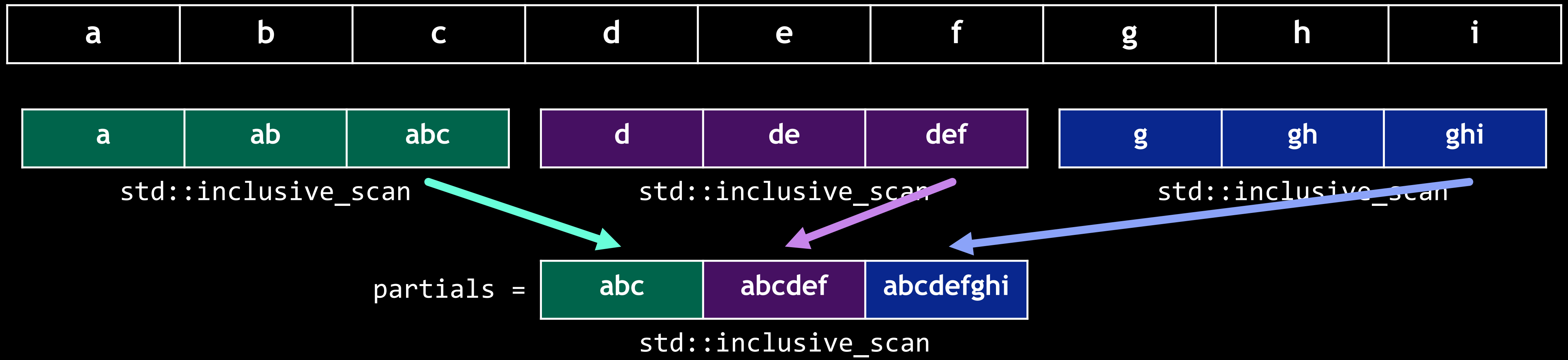
                })
       | ex::bulk(tile_count,
                [=] (std::size_t i, auto input, auto partials) {
                  auto tile_size  = (input.size() + tile_count - 1) / tile_count;
                  auto start      = i * tile_size;
                  auto end        = std::min(input.size(), (i + 1) * tile_size);
                  partials[i + 1] = *--std::inclusive_scan(begin(input) + start,
                                                           begin(input) + end,
                                                           begin(input) + start);
                })
       | ex::then([] (auto input, auto partials) {
                  std::inclusive_scan(begin(partials), end(partials), begin(partials));
                  return send_values(input, std::move(partials));
                })
  …
}
```


a
b
c
d
e
f
g
h
i
a
ab
abc
d
de
def
g
gh
ghi
std::inclusive_scan
std::inclusive_scan
std::inclusive_scan
partials =
abc
abcdef
abcdefghi
std::inclusive_scan

```
inline constexpr sender_adaptor auto
async::inclusive_scan = [] (ex::sender auto last, auto init, std::size_t tile_count) -> ex::sender auto {
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                    partials[0] = init;
                    return send_values(input, std::move(partials));
                  })
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                  [=] (std::size_t i, auto input, auto partials) {
                    auto tile_size  = (input.size() + tile_count - 1) / tile_count;
                    auto start      = i * tile_size;
                    auto end        = std::min(input.size(), (i + 1) * tile_size);
                    partials[i + 1] = *--std::inclusive_scan(begin(input) + start,
                                                             begin(input) + end,
                                                             begin(input) + start);
                  })
       | ex::then([] (auto input, auto partials) {
                    std::inclusive_scan(begin(partials), end(partials), begin(partials));
                    return send_values(input, std::move(partials));
                  })
       | ex::bulk(tile_count,
                  [=] (std::size_t i, auto input, auto partials) {
                    …
                  })
  …
}
```

```
inline constexpr sender_adaptor auto
async::inclusive_scan = [] (ex::sender auto last, auto init, std::size_t tile_count) -> ex::sender auto {
  return last
       | ex::then([=] (stdr::random_access_range auto input) {
                    std::vector<stdr::range_value_t<decltype(input)>> partials(tile_count + 1);
                    partials[0] = init;
                    return send_values(input, std::move(partials));
                  })
       | ex::bulk(tile_count,
                  [=] (std::size_t i, auto input, auto partials) {
                    auto tile_size  = (input.size() + tile_count - 1) / tile_count;
                    auto start      = i * tile_size;
                    auto end        = std::min(input.size(), (i + 1) * tile_size);
                    partials[i + 1] = *--std::inclusive_scan(begin(input) + start,
                                                             begin(input) + end,
                                                             begin(input) + start);
                  })
       | ex::then([] (auto input, auto partials) {
                    std::inclusive_scan(begin(partials), end(partials), begin(partials));
                    return send_values(input, std::move(partials));
                  })
       | ex::bulk(tile_count,
                  [=] (std::size_t i, auto input, auto partials) {
                    auto tile_size = (input.size() + tile_count - 1) / tile_count;
                    auto start     = i * tile_size;
                    auto end       = std::min(input.size(), (i + 1) * tile_size);
                    …
                  })
  …
}
```

```
inline constexpr sender_adaptor auto
async::inclusive_scan = [] (ex::sender auto last, auto init, std::size_t tile_count) -> ex::sender auto {
  return last
      | ex::then([=] (stdr::random_access_range auto input) {
                  std::vector<stdr::range_value_t<decltype(input)>> partials(tile_count + 1);
                  partials[0] = init;
                  return send_values(input, std::move(partials));
                })
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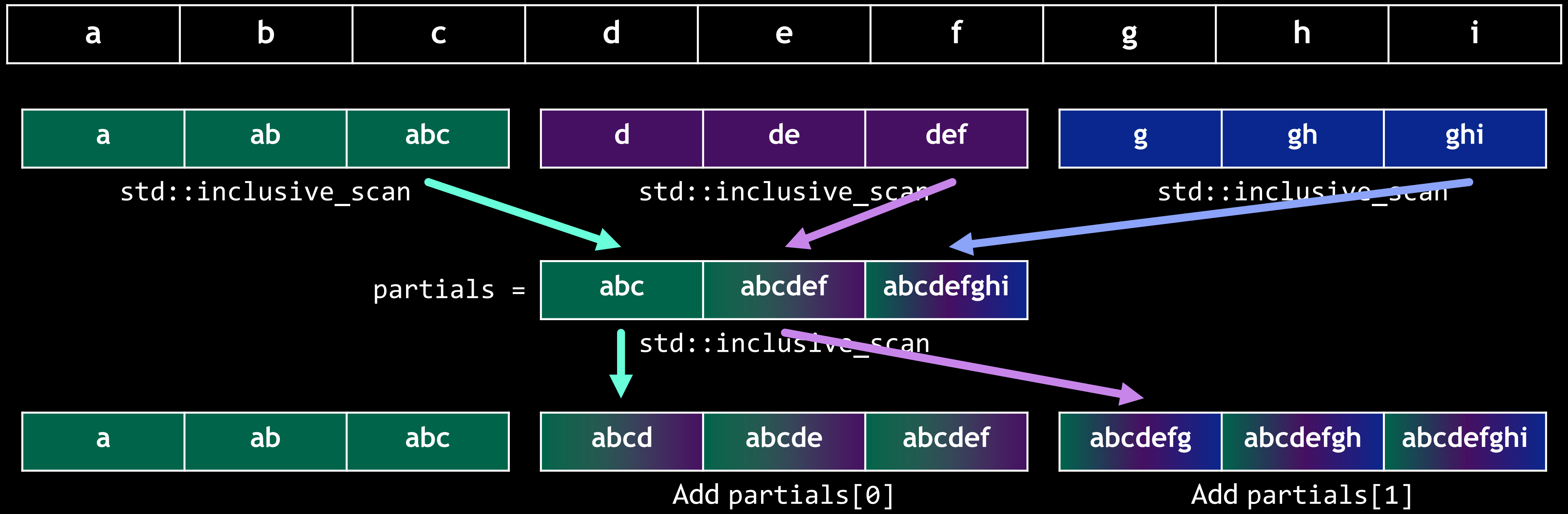
                  auto tile_size  = (input.size() + tile_count - 1) / tile_count;
                  auto start      = i * tile_size;
                  auto end        = std::min(input.size(), (i + 1) * tile_size);
                  partials[i + 1] = *--std::inclusive_scan(begin(input) + start,
                                                           begin(input) + end,
                                                           begin(input) + start);
                })
      | ex::then([] (auto input, auto partials) {
                  std::inclusive_scan(begin(partials), end(partials), begin(partials));
                  return send_values(input, std::move(partials));
                })
      | ex::bulk(tile_count,
                [=] (std::size_t i, auto input, auto partials) {
                  auto tile_size = (input.size() + tile_count - 1) / tile_count;
                  auto start     = i * tile_size;
                  auto end       = std::min(input.size(), (i + 1) * tile_size);
                  std::for_each(begin(input) + start, begin(input) + end,
                                [&] (auto& e) { e = partials[i] + e; });
                })
  …
}
```


a
b
c
d
e
f
g
h
i
a
ab
abc
std::inclusive_scan
d
de
def
std::inclusive_scan
g
gh
ghi
std::inclusive_scan
partials =
abc
abcdef
abcdefghi
std::inclusive_scan
a
ab
abc
abcd
abcde
abcdef
Add partials[0]
abcdefg
abcdefgh
abcdefghi
Add partials[1]

```
inline constexpr sender_adaptor auto
async::inclusive_scan = [] (ex::sender auto last, auto init, std::size_t tile_count) -> ex::sender auto {
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                    partials[0] = init;
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                  })
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                    partials[i + 1] = *--std::inclusive_scan(begin(input) + start,
                                                             begin(input) + end,
                                                             begin(input) + start);
                  })
       | ex::then([] (auto input, auto partials) {
                    std::inclusive_scan(begin(partials), end(partials), begin(partials));
                    return send_values(input, std::move(partials));
                  })
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                    auto start     = i * tile_size;
                    auto end       = std::min(input.size(), (i + 1) * tile_size);
                    std::for_each(begin(input) + start, begin(input) + end,
                                  [&] (auto& e) { e = partials[i] + e; });
                  })
       | ex::then([=] (auto input, auto partials) { return input; });
}
```

```
inline constexpr sender_adaptor auto
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                  })
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                    partials[i + 1] = *--std::inclusive_scan(begin(input) + start,
                                                             begin(input) + end,
                                                             begin(input) + start);
                  })
       | ex::then([] (auto input, auto partials) {
                    std::inclusive_scan(begin(partials), end(partials), begin(partials));
                    return send_values(input, std::move(partials));
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                    std::for_each(begin(input) + start, begin(input) + end,
                                  [&] (auto& e) { e = partials[i] + e; });
                  })
       | ex::then([=] (auto input, auto partials) { return input; });
}
```

On The Horizon For C++

- Reflection
- Pattern Matching
- Senders

accu 2023

KEYNOTE:
C++ HORIZONS

BRYCE ADELSTEIN LELBACH

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